defra
Department for Environment Food and Rural Affairs

Environment Agency

delivering benefits through science

Flood and Coastal Erosion Risk Management Research and Development Programme

Reservoir Safety Research and Development Strategy

Final Report

The British Dam Society

This page is intentionally left blank for double sided printing

Reservoir Safety Research and Development Strategy

Final Report

Notice

Document History

JOB NUMBER: 5042263/006			DOCUMENT REF: 5042263-006-DG-071-005.doc			
1	Draft Final for review by project team	MA		CB, MM, AH		06-05-08
2	Draft final for review by project team	MA	MM, WED	MM	AH	18-05-08
3	Draft final for review by client	MA	WED	AH	AH	29-05-08
4	Final for Client	MA	WED, MM	AH	AH	14-07-08
5	Draft Final for Industry Consultation	MA	WED, MM	AH	AH	05-08-08
6	Final Report	GB	GB	GB	IH	13-01-09
Revision	Purpose Description	Originated	Checked	Reviewed	Authorised	Date

Contents

Section Page

List of Tables

List of Figures

Appendices

List of Tables

List of Figures

1. Introduction

1.1 Background

The Reservoirs Act of 1930 was passed following two dam failures in Scotland and Wales in 1925. It has since been superseded by the Reservoirs Act 1975 which remains the primary instrument for reservoir safety in Great Britain. The 1975 Act provides the legal framework to ensure the safety of British reservoirs that hold at least 25,000 cubic metres of water impounded above natural ground level. Approximately 2,500 reservoirs are covered by the Act with some 88% being formed by embankment dams and the remainder comprising concrete or masonry dams or service reservoirs. In England and Wales, responsibility for enforcement of the Act was passed to the Environment Agency in 2004, while responsibility remains with the Scottish Executive and councils for Scotland.

Reservoir Safety Research and Development is delivered as part of the joint Defra/ Environment Agency Flood and Coastal Erosion Risk Management R&D programme. The programme of project work resulting from this strategy will be managed by the Environment Agency's Flood Risk Science Team. Ian Hope (EA Reservoir Safety Technical Manager) will be the Champion for Reservoir Safety R&D work. The Environment Agency will be assisted in delivering the reservoir safety work by the Institution of Civil Engineers Reservoir Safety Advisory Group, which draws on experience from government, industry and academia.

Atkins, in collaboration with HR Wallingford, Bristol University and Chris Binnie Consulting were commissioned by Defra to undertake work to determine the future research needs with respect to reservoir safety in the UK and also, possible sources of funding for future research. The purpose of this document is to report on the process by which the research strategy was developed and to present the reservoir safety research strategy, which includes a list of prioritised research projects for the next 5-15 years, additional sources of funding for projects and an indicative schedule of projects that can be completed with different levels of funding.

1.2 Objectives

The main objectives of the project are therefore to:

1. Identify the issues that will impact reservoir safety in the future.
2. Identify sources of funding including innovations for obtaining funding for future research projects.
3. Provide a prioritised schedule of research projects for the planning period being considered.

1.3 Guiding Principles

A number of guiding principles have been identified as key to the successful development of a research strategy. These are:

Principle 1 – Identify the drivers that will shape the future use, and hence safety, of reservoirs.
Principle 2 – Identify the likely impact of the drivers on reservoir safety.
Principle 3 – Establish the research baseline to avoid duplication of effort.
Principle 4 – Identify research that will address the issues arising from the drivers.
Principle 5 – Identify projects which provide tools, guidance or new scientific discovery deliverables of use to the profession.

1.4 Definition of Terms

Research : The term research is defined here as applied research aimed at scientific discovery, the review and interpretation of information and the development of methods and systems for the advancement of knowledge. Hence research as defined here includes scientific research which provides scientific information and theories for the explanation of the nature and properties of the world around us, and makes practical application possible as well as investigations involving the review and interpretation of existing

information. The products of research as defined here include, reports, tools, guides and new scientific discovery.

2. Drivers for Reservoir Safety

In order to develop an effective strategy for research supporting UK reservoir safety, it is first necessary to consider the drivers affecting reservoir design, maintenance and operation in the UK now, and in the future. Actual needs within the strategy may be grouped into theme areas such as supporting design, monitoring, emergency planning etc. Specific actions may then fall into categories such as new scientific discovery, guidance, tools/techniques etc. By analysing drivers and solutions in this way, a strategy may be developed to meet industry needs and priorities both in the short and longer term (Figure 2.1). It should be noted that in addition to short and long term drivers (for example, legislation changes or climate change) specific industry needs and quick wins / opportunities will (and should) also directly affect how the strategy is implemented.

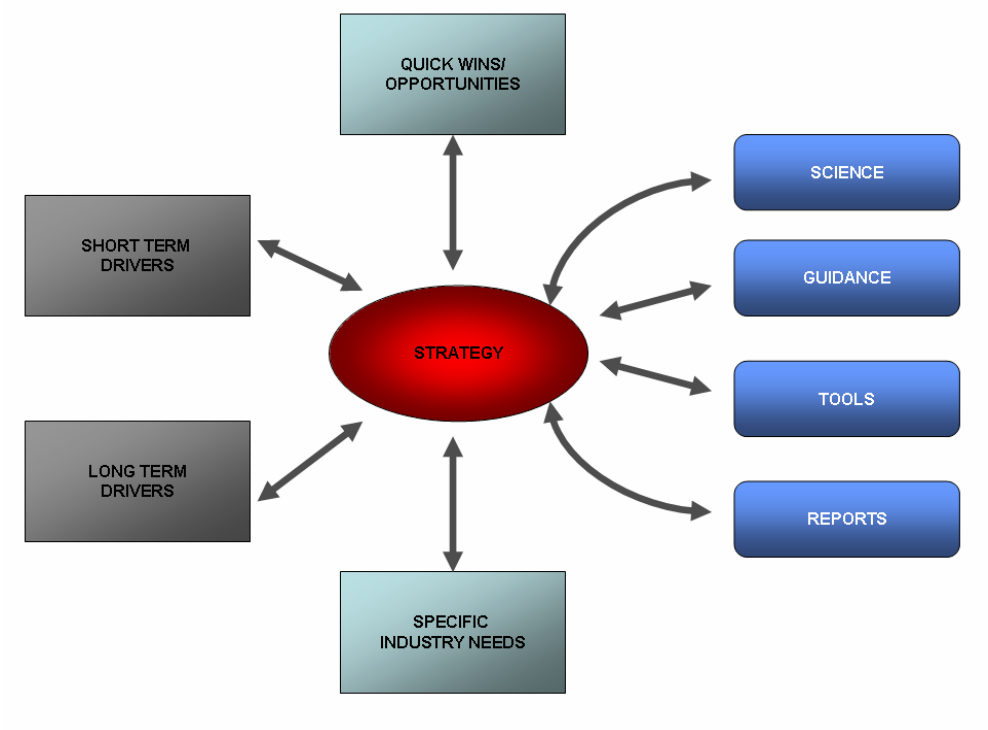

Figure 2.1: Factors contributing to an overall strategy for reservoir safety in the UK

Short term drivers are more easily identified than long term drivers, since they typically already exist, or are likely to exist in the very near future. Identification of long term drivers requires careful consideration of trends and subsequently a prediction of factors that are most likely to affect UK reservoir operation in the future. The following analysis considers short term to be within the next 5 years and long term to be 15-20 years.

2.1 Short Term Drivers

2.1.1 UK Legislation - Water 2003

The Water Act 2003 enhances reservoir safety by amending the Reservoir Act 1975 to:

a. transfer enforcement powers from Local Authorities to the Environment Agency in England and Wales and
b. empower the Secretary of State or the Assembly to direct owners of large raised reservoirs to prepare and maintain flood plans.

The requirement to prepare and maintain flood plans will be key to the effective management of the risks from reservoirs in the future. An Engineering Guide (Jacobs Babtie, 2006) which was commissioned by DEFRA has been developed to aid owners in developing these plans, but this is currently being revised by Atkins. The final guide will be key to establishing the risks posed by large dams and the management of those risks at each dam. In addition, the guide will facilitate provision of the information required to manage incidents at each dam, to the EA and Emergency Services, thus meeting the requirements of the Civil Contingencies Act, as discussed below.

2.1.2 UK Legislation - Civil Contingencies Act 2004

The Civil Contingencies Act (2004) will deliver a single framework for civil protection in the UK. In the context of emergency preparedness, risks can be from non-malicious events such as flooding as well as malicious events such as terrorist attacks, which could adversely affect an organisation and its ability to carry out its functions. The risk of major dam failure falls into both these categories. There is therefore a requirement to identify and quantify the risks posed by individual dams and establish contingency measures for response to emergencies arising from a dam failure.

2.1.3 European Legislation – The Water Framework Directive (Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy)

The Water Framework Directive has established a new, integrated approach to the protection, improvement and sustainable use of surface waters. The Directive requires that all rivers achieve either good ecological status or, if classified as a Heavily Modified Water Body, good ecological potential. This is to be implemented in the UK shortly. For reservoirs, this will require variable flows to be released, set by the time of year and the required ecological conditions downstream (SNIFFER, 2007). Thus specific variable flow releases will be required. There are a number of reservoirs which have no facilities to release water when the reservoir is below top water level. In many others the current flow release is fixed throughout the year and is of limited size. It can be expected that in some cases new facilities for release will be needed, and these can be difficult to provide in dams which do not already have them. There may also be the need to provide the facility to vary the release to provide freshets. This may well require the provision of automatically controlled powered valves.

2.1.4 European Legislation – The EU Floods Directive (The European Directive on the Assessment and Management of Flood Risks (2007/60/EC of 23 October 2007))

The aim of the EU Floods Directive is to reduce and manage the risks that floods pose to human health, the environment, infrastructure and property. According to the EU Floods Directive, Member States will have to reduce flood risk for those areas where the risk is deemed significant. In essence the Floods Directive requires member states to prepare the following assessments for the European Commission:

- preliminary flood risk assessments to identify areas that are at potentially significant flood risk, by 20 December 2011;
- flood hazard maps (showing the likelihood and flow of the potential flooding) and flood risk maps (showing the impact), by 20 December 2013;
- flood risk management plans (showing measures to decrease the likelihood or impact of flooding), by 22 December 2015; and
- updates every 6 years thereafter that take into account the impact of climate change.

The assessment process must be aligned with the environmental objectives of the Water Framework Directive and carried out in consultation with stakeholders.

The directive requires that all sources of flood risk be considered. Flood risk from reservoirs has not been explicitly excluded. Hence, it may be interpreted that flood risk arising from reservoirs is included within the directive requirements.

2.1.5 Succession Planning

The maintenance of reservoir safety in the UK is heavily dependent upon the availability of skilled, trained and knowledgeable staff to carry out inspections and assessments of dams. With numbers of qualified professionals falling, and construction based training opportunities reducing, there is a need to address the long term availability of these skilled staff.

2.2 Long Term Drivers

2.2.1 Climate Change

Climate change in the UK is projected to result in wetter winters, hotter and drier summers and more frequent and larger floods (magnitude and duration) (UKCIP02). Possible direct impacts that may arise as a result of climate change include:

1. More frequent extreme (in terms of magnitude and frequency) floods resulting in more severe and frequent overtopping of dams.
2. Requirement for increased spillway capacity to accommodate larger floods.
3. Requirement to reinforce spillways to prevent damage during longer duration flood events.
4. Requirement to raise dams to accommodate larger floods.
5. Increased magnitude of winds on reservoirs, increasing the frequency and height of overtopping due to waves.
6. Change in vegetation type and behaviour that might affect potential for moisture retention, and hence risk of cracking and potential internal erosion. Equally, changing vegetation type and / or state may affect surface erosion protection performance and will likely change maintenance requirements.
7. Increased erosive power of rainfall.
8. Desiccation of earth dams under hotter drier summers leading to cracks and increased risk of internal piping.

Probable indirect impacts of climate change include:

9. Shorter wetter winters and longer drier summers could lead to a change in the filling and drawdown sequence of reservoirs. This effect might be off-set to some extent by changes in the patterns of demand due to climate change, but there is the potential that the ‘excess’ water during the winter will need to be stored to meet deficits during summer. This could lead to a requirement to construct new, or modify existing reservoirs for both flood retention during winter and water supply during summer.
10. Operating regimes of existing reservoirs could also change to meet changes in the timing of demand, and also to provide flood retention benefits and prevent overtopping. Hence reservoirs may have to be drawn down mid season to accommodate floods that may occur later on in the filling season. This could present operational difficulties, and could introduce further uncertainty to water supply in the summer.

2.2.2 Ageing Dams - Deterioration

Many UK dams were constructed in the 1850s, 1880s and 1890s during dry spells when industrial water needs were increasing. The average age of large dams in England is 110 years. As these dams continue to age, there may be increasing concerns over safety. Inspection intervals may need to be revised based upon the age of a dam, and monitoring measures put in place. A number of monitoring techniques are currently available and it would be important to examine these in order to determine what might be best for UK dams.

Dams which are no longer needed may well be taken out of service by abandonment and discontinuance. This need may be accelerated by the likely requirements of the Water Framework Directive such as variable flow releases and also by the cost of operation including the preparation of emergency plans. There is also the question of the safety of decommissioned dams.

2.2.3 Dam Removal/Discontinuance

Dam removal is one method of reducing the risks posed by dams. In the US, dam removal has exceeded dam construction for the last 10 years with 80 dams removed in the last 2 years, mainly for safety reasons. So far there is little knowledge of the issues involved in dam removal and how best to cope with this

requirement. There is therefore a need to provide guidance on the procedure for safe dam removal from both an engineering and environmental/ecological perspective.

2.2.4 Sustainability and Increased Demand

There is a potential need for more reservoirs because of rising population combined with the reducing number of people in each home leading to a higher per capita demand. While leakage levels are reported to be decreasing (OFWAT, 2005), new homes are to be constructed with a much lower water usage, and OFWAT is setting targets for water companies to reduce the amounts of water delivered (OFWAT, 2007). It is not clear whether these measures will offset the projected increase in demand. In addition, the British Geological Survey study (BGS, 2007) found that groundwater pollution is likely to reduce the amount of ground water that can be treated economically. Climate change could lead to a reduction in the yield of direct water supply systems and a reduction in the yield of reservoirs. Thus, augmented water resources may well be needed, primarily in the south and east of the country. This could well require increased volumes of storage, possibly by raising existing dams, accepting treated sewage effluent into them, and possibly by a small number of new embankment dams.

2.2.5 Renewable Energy

Demand for renewable energy will also add pressure for the construction of new dams, and the retro-fitting of existing dams with hydro power facilities. Hydroelectric dams may require new draw-off systems to be installed and these can result in safety issues both during construction and operation. The Glendoe hydroelectric dam, currently under construction, is the highest head scheme to be built in the UK in 30 years. Further new hydro schemes may well be built.

2.2.6 Emergency Preparedness and Communication of Risks

With the possible increase in the frequency of occurrence of extreme flood events, a greater understanding of how to handle these in real time is required. Growing concern about risk, safety and terrorism means greater need for emergency preparedness and operational response, including increased stakeholder involvement, management and monitoring of reservoirs, mechanisms for assessing potential dam breach and downstream inundation, disaster preparedness, emergency operational planning, emergency action plans, and remedial measures. An important aspect is the extent to which details of low probability, but potentially extreme impact events, are placed in the public domain to avoid public alarm, an inappropriate response by insurers, and negative effects on house prices. The magnitude of uncertainty within supporting information (i.e. flood plans) should be recognised and appropriate for the uses that are proposed i.e. emergency planning v legislation v spatial planning.

2.2.7 Advances/trends in Science

Modelling methods across a number of disciplines related to reservoir safety, as well as monitoring techniques and equipment, have advanced significantly and provide opportunities to assess and monitor reservoir safety with greater levels of accuracy. Numerical and physical modelling enables the examination of unobservable scenarios and the prediction of responses to various scenarios. It will be important to examine input requirements, model assumptions and simplifications, and expected accuracy of outputs. Dealing with and ensuring consistent and appropriate levels of uncertainty within models will be important. In addition, guidance on the selection of appropriate methods, software and techniques is vitally important to ensure competent and reliable assessments. Modern monitoring techniques and equipment enable assessment of variables that provide an indication of dam and reservoir conditions, at appropriate time intervals and in real time. This has the potential to provide advanced warning of problems that could arise, and, if linked to control systems, can also enable real time control. Guidance on the most appropriate techniques is also important to ensure maximum benefit.

2.2.8 Risk and uncertainty

Dealing with risk and uncertainty is common in many, if not all, aspects of reservoir design, construction, operation and maintenance. The science of risk and uncertainty is rapidly evolving, and over the last decade a wide range of tools and techniques have been developed to support risk-based analyses. In the process of making reservoir safety decisions, it is necessary to consider a plethora of factors including public safety responsibilities, financial limitations, market or other pricing constraints, business criticality, public opinion, loss financing, liability, and due diligence. Hence, engineers are being challenged to justify expenditure associated with one risk-reduction measure relative to another. For a dam owner with a portfolio of dams, there is also a need to determine the priority with which to address issues related to his assets. Engineers

are therefore being asked to provide risk-based assessments which serve as inputs to a business decision making process in which dams are a key asset. Reservoir safety risks are therefore being managed in a more open, informed, and holistic manner than ever before. This trend towards a risk-based approach to reservoir safety management therefore requires a shift in approach to dam assessment. For instance, currently used deterministic methods such as the PMF do not suit this risk-based approach. It is important that the future research strategy ensures that appropriate methods and guidance are supported and encouraged to find a timely result to the problems.

2.3 Specific Industry Needs and 'Quick Wins'

Specific industry needs are those identified through consultation with engineers and owners within the profession. 'Quick wins' are situations where projects may be initiated because circumstances offer a unique advantage for rapid implementation, whether this is scientific, financial or a combination of both.

3. Methodology

3.1 Establishing the baseline

In developing this strategy, due to project budget and time constraints, it was not possible to undertake a thorough review of existing research to establish the state of research with respect to various reservoir safety issues. Instead, a preliminary review was undertaken of recent, current and proposed research being conducted internationally by Universities, Research Institutes, Dam Owners and others. However, it is imperative that the baseline of knowledge is established before any detailed assessments are undertaken. For this reason, many of the projects proposed will start with a preliminary stage which will review existing or previous work. The outcome of projects undertaken in this phase is likely to be documents reviewing the existing state of the topic and identifying/recommending further work required to address the problem. Some topics have already established baselines and can therefore move into a detailed programme of work, as soon as funding is available.

3.2 Defining research Needs

This section discusses the methodologies that were adopted in defining the research needs for the next 5 to 15 years and is summarised in the schematic in Appendix A.

Having identified research drivers affecting the strategy, an initial assessment of the existing research was undertaken for all aspects of reservoir safety. To this end, the broad topic of reservoir safety was broken down into disciplines, and searches conducted and summarised on research falling under each. The disciplines were defined as:

1. Appurtenant Structures
2. Climate Change[1]
3. Concrete Dams
4. Dam break Analysis
5. Embankment Dams
6. Hydrology and Hydraulics
7. Management
8. Monitoring
9. Risk and Emergency

Given project constraints, this initial assessment was restricted to research undertaken in approximately the last 5 years in most cases. In addition, early consultation was sought with dam owners and Panel Engineers. A letter (Appendix B) was sent to 11 owners and Panel Engineers inviting them to suggest their

[1] It should be noted that, although Climate Change is not a discipline, it is deemed to be a sufficiently important topic to warrant investigation on a scale similar to the 8 disciplines identified.

research requirements. The wider profession was also included in this initial consultation through a questionnaire (Appendix B) posted on the British Dam Society website. A database of research project details was developed as a result of the searches. Once research projects were identified, these were examined against the research needs arising from the drivers discussed above, to determine their relevance to any of the specific issues. From this assessment, research gaps were identified and specific research projects formulated including project scope, estimated cost and duration, expected outcomes and products (guidance, tools, methods, reports etc.).

3.3 Prioritisation of Research Projects

Having identified research gaps and formulated specific research projects it was then necessary to prioritise the projects in order of importance to reservoir safety. It was important that the prioritisation of projects took account of the views of the profession and is sanctioned by the profession. With this in mind, consensus was sought by first putting the proposed projects before experts and canvassing their opinion on the relative importance of each project. This was done by means of a second round of consultations via a 2-day workshop. Experts from all disciplines comprising reservoir safety (as listed in Section 3.2) were invited to attend a 2-day workshop, involving a presentation of the current state-of-practice of research under each discipline, followed by discussions and voting on the priority of each project presented. Table C1 in Appendix C is a list of workshop attendees. Following the workshop, the voting forms were posted on the BDS website and all members of BDS were emailed inviting them to vote.

3.3.1 Voting Method

Voters were asked to assign a score from 1 to 10 for each proposed project based on their assessment of the importance of the project, where 1-3 is low, 4-7 medium and 8-10 is high importance. They were also asked to assign a score of 1 to 3 for level of difficulty, where 1 is simple and 3 is complex. Lastly, voters were asked to assign an indicative cost for each project where they felt able to do so. Voters were also asked not to vote on projects in subject areas where they had insufficient knowledge or confidence. An example of the voting forms is provided in Appendix C, and a table of all projects voted for under each discipline is provided in Table E-2 in Appendix E.

The results of the voting were analysed and a prioritised list of research projects generated based on the analysis. A programme of research projects based on different levels of available funding was produced.

4. Results

4.1 Establishing the baseline

As discussed above, the research baseline was established by reviewing and summarising the recent, current and proposed research projects of relevance for each discipline related to reservoir safety. For this purpose a project database was set up, into which information on projects of relevance was updated. The project database was used to store and organise information gathered and, later on, to search and summarise the projects in order to assess the current state of practice under each discipline. In most cases, searches were done by first identifying published papers of relevance and linking those papers to research projects. In addition, researchers conducted internet searches of research institutes' home pages, and contacted research institutes directly, to find out what research was being carried out. The UK's Engineering and Physical Sciences Research Council (EPSRC) database on funded projects was also searched. The database therefore includes a list of 206 research projects and 315 papers resulting from the search. Table 4.1 lists the data fields that were populated for all research projects and published papers identified. Over 146 different journals were found with relevant articles on reservoir safety. Appendix D provides tables summarising some of the information gathered in the baseline study including, journals searched (Table D-1), institutes active in research relevant to reservoir safety (Table D-3) and research areas of interest related to reservoir safety (Table D-4), reproduced in Table 4.2.

The existing and current projects identified in this way were then investigated to examine where gaps exist in meeting the research needs (as outlined under the drivers). This analysis formed the basis of the initial list of projects to be prioritised.

Discipline	Project	Papers
Research area	✓	✓
Key Words	✓	
Title/Topic of project	✓	✓
Author		✓
Brief description	✓	
Date Published / presented		✓
Funding body Classification (Gov't, private etc.)	✓	✓
Sponsor / Funding Body	✓	✓
Sponsorship / Funding (Monetary value)	✓	
Corresponding Author, Location and Contact details		✓
Researcher/Key contact	✓	
E-mail Address	✓	
Location of research facility and organisation represented.	✓	✓
Country of dams	✓	✓
Country of research/location of dams studied (if relevant)	✓	✓
Related research projects		✓
Link to Abstract / paper		✓
Summary of Abstract		✓
Project Start Date	✓	
Project End Date (or expected)	✓	
Follow-on research / related research projects?	✓	✓
Comments	✓	✓
Other organisations related to the research	✓	✓
Related Published articles	✓	
Aspects of Dam Safety Covered by Research	✓	✓
Hyperlink to detailed description or relevant documents/websites etc.	✓	✓
Relevance to the UK	✓	✓
Identifiable extensions to research	✓	✓

Table 4.1: Information collected for each research paper

Research Area	
Acceptable overtopping	Ice Loading
Ageing of hydraulic structures	Improved boundary conditions for FE modelling of foundations
Appurtenant structures: Seismic	Internal erosion
Breach	Investigating use of mass shaker for assessing dam performance
Channel erosion	Landslide induced waves
Clogging of bottom outlets	Local scour
Concrete dams Integrity assessment	Loss of life analysis
Concrete repair guide	Loss of life prediction
Concrete dam anchors	Management
Concrete dam foundation	Mathematical and Experimental modelling
Continuous simulation	Methods for concrete repair underwater
Dam Break	Modelling
Dam Break - Breach modelling	Modelling flood impacts
Dam Break - Seismic	NDT for condition of concrete anchor bolts
Dam register	Optimising management operation
Dam safety general	Performance of grout admixtures
Dam safety GIS	Performance of plastic pipes
Dam safety management	Performance of seepage protection measures
Dam break - Concrete performance	Performance of steel struts
Dam break - Landslides	Predicting block performance under varying water pressure
Debris management	Predicting embankment soil performance
Detection of voids	Predicting shear key strength
Deterioration of concrete	probabilistic analysis
Development	Rainfall runoff modelling
Earth Systems Science	RCC stepped chute performance
Emergency Response	Reservoir wave overtopping
Extreme flood prediction	Risk analysis
FE or FD modelling of embankment dam soil structure / performance	Risk and Performance
Filter performance	Risk estimation
Flood discharge	Rockfill
Flood estimation	Safety
Flood forecasting	Sedimentology
Flood frequency analyses	Social effects of Dam Hazard
Flood Processes	Soil erodibility
Forecasting	Spillways
Geophysics	Stability
Geotech	Stilling basin performance
Human risk	Sustainable Development
Hydraulics	Tools for drain inspection
Hydrology	Unsaturated Soils
Hydropower	Use of geotextiles in embankment dams

Table 4.2: List of some of the research areas found for current and recent research projects

4.2 Defining Research Needs

4.2.1 Gap-identification and 1st Consultation

The identification of research gaps as outlined in section 4.1 above yielded a number of research projects of interest. In addition, the results of the 1st consultations with owners and Panel Engineers and via the questionnaire on the BDS website yielded a list of requirements as listed in Table 4.3 below. Table E-2 (Appendix E) is the final list of projects resulting from a combination of the Panel Engineer suggestions and the gaps-identification exercise and arising from discussions at the workshop, on which experts were invited to vote.

Suggested Research projects
Behaviour of masonry spillways
Wave impact forces on wave walls – in particular 'dry stone wave walls'
Wave estimation in reservoirs
Guidance on the design of fish ladders
Guidance on the location-designed maintenance of fish screens
Guidelines on the maintenance of gated structures
Rate of erosion in overflowing and overtopping
Flood Alleviation Structures – Guide on Design, Operation and Maintenance
The effects of climate change on dams
Flood detention reservoirs (Scope of guidance document on construction and maintenance of flood detention reservoirs.)
Rapid condition analysis for smaller embankments
Breach initiation and acceptable overtopping processes
Potential use of Internet and remote sensing technologies to support dam safety monitoring and emergency actions
Soil erodibility - Guidance on values; integration of international data; collection of representative UK data to support dambreak analyses (breach, piping, surface erosion etc)
Vegetation on Dams
Discontinuance of dams
Condition assessment of dams and foundations i.e. sound waves, radar, temperature sensing
Performance of existing masonry lined spillway channels under high velocities. Mechanisms of failure and design tools to determine resistance to 'plucking out' of stone sets
Review of performance of reinforced grass spillways/over-toppable embankments to supplement/update CIRIA Report Nr 116 and if appropriate further research, with updated guidance on selection/advantages of different products/types in different situations
Review of performance of different types of wave erosion protection particularly on small reservoirs, and if appropriate research.

Table 4.3: Lists of suggested projects from owners, Panel Engineers and others following 1st consultation

4.3 Workshop

Leading experts in the fields that make up the broad topic of reservoir safety were invited to a 2-day workshop to participate in the prioritisation of research projects. Appendix C contains a list of attendees on each day of the 2-day workshop. An average of 22 people attended the workshop over the two days. The workshop comprised 30 minute to 1 hour sessions for each of 9 disciplines. A presentation of the 'state of practice' based on the findings of the research into existing, recent and proposed projects, was given by each member of the project team, culminating in a presentation of the research projects that were being put forward for consideration. Following each presentation, the floor was opened up for discussion and attendees were invited to comment on the proposed list of projects, add projects to it, remove projects from it or indeed aggregate projects. Following the discussions, the attendees were invited to vote on the final list projects that resulted. Table E-2 (Appendix E) is a list of the final projects that were voted on, comprising the initial list of projects presented by the researchers and any additions/deletions and amendments to the list.

In addition to inviting people to vote on projects at the workshop, the voting forms were also made available on the BDS website following the workshop and all members of BDS (> 500) emailed to invite them to vote. The maximum number of voters comprising workshop attendees and people voting afterwards was 33.

4.3.1 Voting Results

Following the workshop, an analysis of the data was carried out. Projects were also further refined to include, outline scope, EA theme under which the project falls, project type, estimated costs, duration, beneficiaries, possible sources of funding and project criticality (what would happen if the project is not done). During the process of defining projects, it was found to be sensible to aggregate some projects further, while others could be subsumed within larger projects. A further pass through the list of projects was therefore carried out to ensure that there was no un-necessary overlap or double counting. Figures F-1 to F-9 in Appendix F present the results of the voting and shows histograms of scores assigned to each project under each discipline. It should be noted that projects originally listed in the voting forms, where they have been aggregated to form larger projects, are indicated in the project title.

4.3.2 Prioritised list of projects

The projects were prioritised on the basis of the mean score. It should be noted that the maximum number of voters on any one project was 33, the minimum was 15 and, on average, projects were voted on by 27 people. Hence the mean score was deemed to be an appropriate measure on which to base the prioritisation. Hence the project with the highest mean score was ranked number 1. The mean estimated costs and mean difficulty were also calculated and assigned to the projects. Project type was determined by an assessment of the score and difficulty using the following criteria:

1. If mean score < 6[2] and mean Difficulty < 2, Project type = LB/LD
2. If mean score >= 6 and mean Difficulty < 2, Project Type = HB/LD
3. If mean score >= 6 and mean Difficulty >=2, Project Type = HB/HD
4. If mean score < 6 and mean Difficulty >= 2, Project Types = LB/HD

These criteria are graphically represented in Figure 4.1. A traffic light system of shading has been employed as a means of distinguishing the different types of projects. High benefit projects are obviously the most desirable; hence this half of the quadrant is shaded green with different shades of green used to differentiate High Difficulty from Low difficulty projects in this half of the diagram.

High Benefit/Low Difficulty (HB/LD)

High Benefit/Low Difficulty projects are projects that are perceived to have broad application, are very important, and easy to achieve. The low level of difficulty implies that the project can be completed with relatively little short-term effort and potentially less funding. Such projects are obviously desirable. Examples include remaining tasks from a larger project or a task that, when accomplished will lead to a future program or project of great benefit. Hence scoping studies and reviews of existing research are likely to fall into this category.

[2] Where 6 is the average of the final scores in table G1. The maximum being 8.3 and the minimum 3.1

High Benefit/High Difficulty (HB/HD)

High Benefit/High Difficulty projects provide high benefit but are complex and therefore require longer-term effort, implying that they can be lengthy in duration and expensive to complete. However, the benefit derived from such projects is perceived to be worth the investment as they provide an essential outcome or product.

Low Benefit/Low Difficulty projects (LB/LD)

These projects are not of particularly high benefit but are relatively easy to achieve. Examples of such projects include projects investigating the requirement for further research on a topic that is currently perceived to be unimportant or its importance is not known. The initial investigation undertaken under the LB/LD project could lead to a change in perception of the importance of the problem by providing information to either rule it out as an issue, or give an indication of the scale of the issue.

Low Benefit/High Difficulty (LB/HD)

The least desirable projects are obviously those with low benefit and high difficulty. These are projects that require significant effort (duration and funding) but are perceived to provide relatively little benefit if completed.

Table 4.4 lists the top 10 research projects extracted from Table G.1 in Appendix G of the prioritised list of projects. Summary tables for each project are in Appendix H which includes a project brief, project duration, project cost and project type.

4.3.3 Discussion of Prioritisation

Of the top 10 projects listed, 70% are High benefit/Low difficulty projects, suggesting that they should be relatively easy to complete with high benefits achieved. The remaining 30% of projects are High Benefit/High Difficulty projects. The relative levels of difficulty and hence, the effort (time and cost) required to complete these projects is somewhat reflected in the estimated cost of the projects, with the 7 HB/LD projects totalling £755k, and the 3 HB/HD projects totalling £975k. Similarly, the 7 HB/LD projects total 108 months in duration, while the 3 HB/HD projects total 90 months.

Table 4-4 also shows the links to the drivers for the top 10 projects. The drivers underlying these projects include Ageing Dams, Climate Change, Risk Assessment, Risk Communication, Succession, Monitoring and legislative.

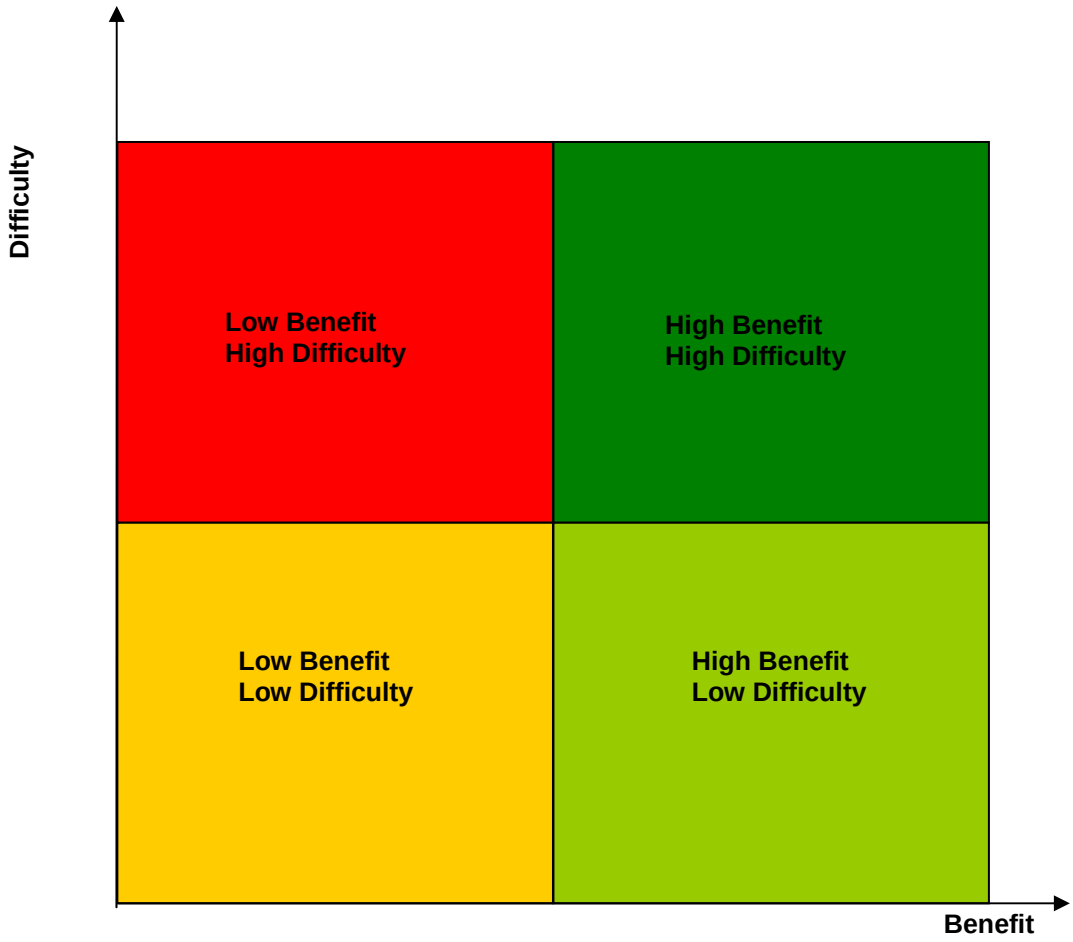

Figure 4.1: Project type diagram

Rank	Projects Descriptions	Output	Score Mean	Dur. (mths)	Est. Cost (£k)	Diff.	Project Type	Additional Sources of Funding[3]	Link to Drivers
1	Review latest knowledge on internal erosion leading to updated UK guidance	Scoping review --> revised guide	8.3	24	125	1.9	HB/LD	Owners	Ageing Dams; Monitoring
2	Review of Modes of Failure of Dams and Failure of Monitoring Techniques	Report and Guide	8.1	24	150	1.9	HB/LD	Owners	Ageing Dams; Monitoring; Risk Assessment
3	Research and guidance on the behaviour of masonry spillways	Science; Guidance	8.0	36	175	2.0	HB/HD	Owners, EPSRC,FEMA, CIRIA	Ageing Dams; Monitoring; Modelling
4	Publication - Lessons from Dam Incidents	Report	7.8	12	50	1.3	HB/LD	Owners/CIRIA	Risk Communication; Succession
5	Collect geotechnical and geological data of old dams for EA Database	Research / Database	7.7	12/36	100	1.9	HB/LD	Owners	Aging Dams; Succession
6	Review of **direct** Impacts of climate change on dams and reservoirs	Report	7.2	12	150	3.0	HB/HD	UKWIR/EC/ NERC	Climate Change
7	Review of existing methods and development of guidelines for dambreak assessment	Science and Guidance	7.1	12	85	1.9	HB/LD	EC	Modelling; Risk Assessment
8	Extreme flood hydrology 1) Finalise the improved methods for extreme rainfall event predictions; 2) Develop a tool for implementing the new method; 3) Develop a rainfall-runoff method appropriate for modelling extreme floods	New Method; Tool	7.1	42	650	2.3	HB/HD	NERC/EPSRC	Modelling; Climate Change; Risk Assessment; EUFD, WFD
9	Monitoring and measuring methods for embankment dams	Chapter in Guide	6.9	12	145	1.5	HB/LD	Owners/FEMA	Monitoring
10	Publication – A Guide to Instrumentation and Monitoring	Report and Guide	6.8	12	100	1.8	HB/LD	Owners//FEMA/ CIRIA	Monitoring

Table 4.4: Top 10 prioritised research projects extracted from full list in Table G1 (Appendix G).

[3] Additional Sources of funding refers to sources other than EA/DEFRA. It is assumed that all projects are additionally entitled to EA/DEFRA funding.

4.4 Sources of Funding

A key objective of this project, in addition to identifying and prioritising the research needs, was to examine alternative sources of funding other than Defra/EA. Appendix I is a review of alternative sources, which provides a summary description of each funding body, the type of projects funded, the annual value of funding and information on how to apply. A summary of this information is provided in Table 4.5 below. On the basis of this review, each project was assigned a list of additional sources of funding as a starting point for considering how these projects can be achieved.

Appendix I presents a variety of ways in which reservoir safety research work can be funded and advanced. In order to benefit from these additional sources of funding, Defra/EA must recognise and address a number of issues in advance, so that when an opportunity arises, it is not missed through an inability to proceed quickly.

Specific issues that should be considered:

1. Policy and procedure for collaborating on European funded projects
2. Methods of working in parallel with US or other national agencies
3. Ability to integrate research with other organisations or programmes on a match fund or industry contribution basis
4. Ability to react and work to other organisation deadlines or schedules

Each of these issues can be a cause for delay, and hence the possibility of a missed opportunity. EA/Defra should ensure that a clear policy exists and wherever possible, flexibility in approach is permitted, ahead of any specific opportunity arising. This is particularly relevant for reacting to European research and international collaborative research opportunities.

4.4.1 Recommended Actions for Additional Sources of funding

A total of 11 actions have been recommended in Appendix I. Their implementation would enhance R&D and funding opportunities in support of reservoir safety R&D in Great Britain. It is recognised that resources are finite, so a prioritisation of actions has been conducted. Table 4.6 summarises the actions with an assessment of indicative duration, difficulty, cost and potential cost benefit. The final column indicates an order of priority and quick wins (QWs) are identified. A review of priorities reveals that many of the recommended actions are short term and easy to implement and relatively low cost. This suggests that the majority of the actions could be undertaken within 6-12 months following this review and at minimal cost. This would have a positive effect on the launch of the new reservoir safety R&D programme, and present it as a truly integrated programme of research, recognised worldwide.

Research Body	Broad areas funded	Specific areas funded	Mechanisms of funding
EPSRC	Engineering and Physical Sciences	IT, material science, structural engineering	Collaborations, Strategic Partnerships, Research Grants, Network Grants, PhD funding, Industrial case awards
NERC	Earth Sciences	Atmospheric, earth, terrestrial and aquatic science	Research Grants, Consortium Grants, Partnership Research Grants, Student sponsorship (UK Institutes, or NERC approved institutes only)
ESRC	Social and Economic Research	Economic affairs, education and human development, environment and planning, government and law, industry and employment, social affairs	Support for academic institutions and research policy institutes, including universities, colleges of higher education and independent research institutes in the UK
UKWIR	Water Industry Research	Drinking water quality and health, toxicology, water resources, climate change, wastewater treatment and sewerage, leakage and metering, customer and regulatory issues	Collaboration with government, regulators and international organisations. Open tender to a wide range of companies, academic institutes.
EC	Environment, climate change, uptake of technology, promotion of small businesses, regeneration	Various	Issue annual 'work program' on which proposals are sought;
FEMA NDSP	Research addressing dam safety issues	Various	Allignment, collaborations
DSIG Canada	Research addressing dam safety issues (specific to Members of DSIG)	Various	Group comprised of dam owners and operating companies. Research identified my members, and funds established through member contributions.
CIRIA	Research related to the construction industry	Technical, legislation and regulation, training, management and economics issues across a number of sectors	Member driven across a number of market sectors (buildings and facilities, utilities and transportation infrastructure)

Table 4.5: Summary of Funding Bodies

Action	Duration	Difficulty	Indicative Cost	Indicative Cost Benefit	Priority
Action 1: The case for reservoir safety research must be presented in the appropriate EA format (ROAME) and that relevant forms/templates are provided stating specific project specifications.	**QW**	**QW**	**QW**	**QW**	**QW**
Action 2: Defra/EA should consider exploring the development of a Strategic Partnership with EPSRC and other partners to fund a collaborative centre for multidisciplinary reservoir safety research and training in UK universities. The Centre would be coordinated from the university of the lead academic. A Strategic Partnership would increase the available funding for the Defra/EA portfolio of recommended research. Partners could include dam owners, engineering consultancies specialising in reservoir safety, and the sister research councils NERC and ESRC, to cover the cross-disciplinary nature of the research. There are few UK universities currently conducting reservoir safety research, but some are working in closely related areas. The aim of the centre should be twofold: to bring university researchers together to apply their knowledge to reservoir safety research; to train graduates on the research in associated specialist areas, thus contributing in part to the succession training of reservoir safety experts.	**Long**	**Med**	**High**	**High**	**4**
Action 3: Defra/EA should review proposed reservoir safety R&D needs against the current FRMRCII (joint EPSRC/EA funded) research programme to identify any areas where common interests might be addressed. Immediate action is needed to benefit from FRMRCII which started in Spring 2008**.**	**QW**	**QW**	**QW**	**QW**	**QW**
Action 4: Defra/EA should consider identifying/employing/procuring a champion to proactively encourage the development of joint proposals for research council funding for research collaborations and networks between universities and other organisations. By stimulating research in the universities, the available funding for the recommended reservoir safety research projects would be increased.	**Short**	**Easy**	**Med**	**High**	**2**
Action 5: Defra/EA should consider publicising the list of recommended research projects and circulate it to UK universities conducting research in reservoir safety related areas. The list should be accompanied by a letter explaining the value of the projects and encouraging academics to develop proposals for research council funding for collaborative research projects. The value of initiative would be in stimulating greater activity in UK universities in reservoir safety research.	**QW**	**QW**	**QW**	**QW**	**QW**
Action 6: Defra/EA should identify research projects that cut across both dams safety and water resources issues and approach UKWIR with the view to jointly fund and project manage research in these areas.	**QW**	**Easy**	**Low**	**High**	**2**
Action 7a: If Defra/EA wish to be proactive in seeking European funding then in the short-term, they	**Short**	**Easy**	**Low-**	**High**	**1**

Action	Duration	Difficulty	Indicative Cost	Indicative Cost Benefit	Priority
should fund a detailed assessment of current and near future (i.e. within 12 months) EC research work programme opportunities, and feed UK research priorities back to Defra, EA and FLOODsite contacts to establish whether opportunities exist for feeding these into later EC research programmes.			**Med**		
Action 7b: The EA (Reservoir Safety) should consider establish methods for participating with EC projects prior to any specific call, to enable prompt responses to opportunities as they arise. These should include links with any formal group or people within the EA who may be responsible for bidding for and managing EC projects.	**Short**	**Easy**	**Low**	**Med**	**2**
Action 7c: Defra/EA should consider encouraging organisations familiar with EC research and reservoir safety issues to look for opportunities to develop EC research proposals in line with longer term R&D priorities.	**Short**	**Easy**	**Low**	**Med**	**2**
Action 8: Defra/EA should consider contacting the Defra managed, but EC funded, CRUE project. CRUE aims to coordinate flood risk analysis and management research at a national level, by funding research of common interest to participating countries. CRUE may be open to suggestions on specific reservoir safety/flood risk research needs.	**Short**	**Easy**	**Low**	**Med**	**2**
Action 9: EA/Defra should support an initial investigation to establish full details of research programmes of other countries active in dams safety research (such as the US , Canada and China), identifying areas of potential short and long term collaboration and funding opportunities.	**Short**	**Easy**	**Med**	**Med**	**2**
Action 10: Defra/EA should consider supporting the development of a specific area on the Defra/EA website and perhaps asking BDS if it was possible to develop a specific area on the BDS website to facilitate communication and dissemination of reservoir safety R&D directly to the dam community. The Defra/EA website and if acceptable the BDS email system, in conjunction with new web content, would enable updates on progress, key initiatives and opportunities to be communicated directly to the majority of the profession.	**Short (Long)**	**Easy**	**Low**	**?**	**2**
Action 11: In order to facilitate Actions 2, 4 and 7 above, EA/Defra should review policy, approach and procedures to better enable collaborative R&D between different UK institutions as well as international organisations involved in research relevant to dam safety.	**Short**	**Easy**	**Low**	**High**	**1**

Table 4.6: Summary of Actions for Additional Sources of Funding

Descriptive terms:

Duration:	Short	< 6 months
	Med	6 – 12 months
	Long	> 12 months
Difficulty:	Easy	No or minimal technical challenge
	Hard	Significant technical/administration challenge
Priority:	Broad clustering/prioritisation based upon indicative (subjective) descriptions	

Indicative cost:	Low	< £10K
	Med	£10 – 50K
	High	>£50K
Cost benefit:	High	Good return on investment
	Low	Poor return on investment

4.4.2 Differential Levels of funding

Three different levels of funding were examined in order to identify which projects could be funded each year. Annual funding of £250k per year, £500k per year and £1Million per year were examined as examples of what could be available each year from Defra/EA and other sources. Based on the assumption that projects will be undertaken in order of priority, projects were taken in turn and their costs summed until the total cost was within +/- 10% of the annual funding limit. Table 4.7, Table 4.8 and Table 4.9 below summarise the projects that can be funded in each year and the actual total costs per year with different annual budgets. With a £250k annual budget, only 31 of the 49 projects can be undertaken in the 15 year period, with an average of 3 projects receiving funding per year. With an annual budget of £500k all 49 projects can be funded in the 15 year period with an average of 4 projects funded per year and all projects being fully funded by year 11. With an annual budget of £1Million all projects will be fully funded by year 6 with an average of 8.5 projects funded per year. It should be noted that this assessment is purely based on estimated project costs, and no account is taken of the project duration. For simplicity, it has been assumed that projects will receive funding from the start year onwards until the project value is met, whatever the duration of the project. Table 4.10 to Table 4.12 show the research programmes for different levels of funding taking account of the year in which each project starts (based on the priority and the available funding), and the duration of the project.

Reference to Appendix I enforces the fact that efforts to increase funds from sources not normally considered for the reservoir research programme should be made a priority for those controlling the programme and, if successful, would accelerate the R&D programme. It is recognised that the programme will be revised annually and funding availability will change, hence the list of projects that can be funded in a given year will change. It must therefore be remembered that this prioritised list is a dynamic list which will change with time. The reasons for these changes could be many and varied and may include incidents and accidents that accelerate certain projects up the list, or an opportunity to undertake a particular project that is further down the list. In addition, further legislative changes would change the short-term focus of efforts.

Year	Projects	Total Cost (£k)
Year 1	1 & start 2	250
Year 2	2, 3 & 4	250
Year 3	5 & 6	250
Year 4	7 & start 8	250
Year 5	8	250
Year 6	8	250
Year 7	9, 10, start 11	250
Year 8	11, 12, 13, & 14	240
Year 9	15, 16 & 17	250
Year 10	18, 19, 20 Start 21	250
Year 11	21& start 22	250
Year 12	22, 23 & 24	250
Year 13	25	230
Year 14	26, 27, start 28	250
Year 15	28, 29, 30 & 31	195

Table 4.7: Indicative schedule of projects that could be undertaken with a £250k annual budget

Year	Projects	Total Cost (£k)
Year 1	1, 2, 3, &4	500
Year 2	5, 6, 7, Start 8	500
Year 3	8	485
Year 4	9, 10, 11, 12, 13, & 14	490
Year 5	15, 16, 17, 18, 19, 20, Start 21	500
Year 6	21, 22, 23& 24	545
Year 7	25, 26, 27, & 28	540
Year 8	29, 30, 31, & 32	535
Year 9	33, 34, 35, 36, 37 & 38	550
Year 10	39, 40, 41, 42 & 43	530
Year 11	44, 45, 46, 47, 48, 49	530

Table 4.8: Indicative Schedule of projects that could be undertaken with a £500k annual budget

Year	Projects	Total Cost (£k)
Year 1	1, 2, 3, 4, 5, 6, 7, start 8	1000
Year 2	8, 9, 10, 11, 12, 13, 14, start 15	975
Year 3	15, 16, 17, 18, 19, 20, 21, 22, 23	945
Year 4	24, 25, 26, 27, 28, 29, 30, 31, start 32	1000
Year 5	32, 33, 34, 35, 36, 37, 38, 39, 40	1000
Year 6	41, 42, 43, 44, 45, 46, 47, 48, 49	840

Table 4.9: Indicative schedule of projects that could be undertaken with a £1Million annual budget

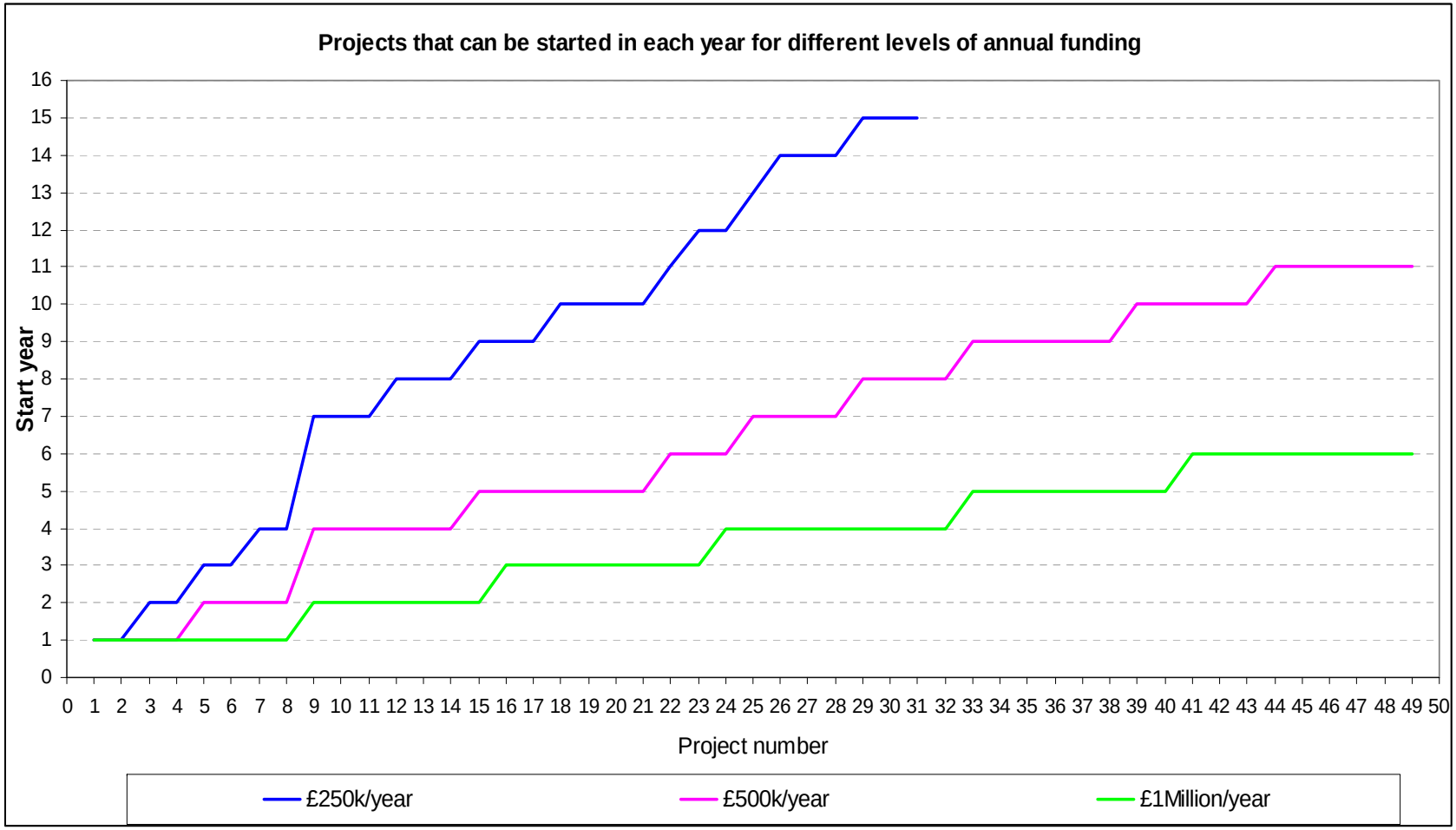

Figure 4.1: Project against start year for different levels of annual funding

			Year																
Project Rank	**Start year**	**Dur (yrs)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1	1	2																	
2	1	2																	
3	2	3																	
4	2	1																	
5	3	3																	
6	3	1																	
7	4	1																	
8	4	3.5																	
9	7	1																	
10	7	1																	
11	8	0.5																	
12	8	0.75																	
13	8	1																	
14	8	1																	
15	9	0.75																	
16	9	1																	
17	9	3																	
18	10	0.75																	
19	10	1																	
20	10	1.5																	
21	10	3																	
22	12	1																	
23	12	1.5																	
24	12	1																	
25	13	2.5																	
26	14	1																	
27	14	1																	
28	14	4																	
29	15	1																	
30	15	1																	
31	15	1.25																	

Table 4.10: Research Programme over the 15 year period, with an annual funding limit of £250k

	Year																
Project Rank	**Start year**	**Dur (yrs)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	1	2															
2	1	2															
3	1	3															
4	1	1															
5	2	3															
6	2	1															
7	2	1															
8	2	3.5															
9	4	1															
10	4	1															
11	4	0.5															
12	4	0.75															
13	4	1															
14	4	1															
15	5	0.75															
16	5	1															
17	5	3															
18	5	0.75															
19	5	1															
20	5	1.5															
21	5	3															
22	6	1															
23	6	1.5															
24	6	1															
25	7	2.5															
26	7	1															
27	7	1															
28	7	4															
29	8	1															
30	8	1															
31	8	1.25															
32	8	3.5															
33	9	1															
34	9	1															
35	9	1.5															
36	9	On going															
37	9	1															
38	9	3															
39	10	1															
40	10	2															
41	10	1.5															
42	10	1															
43	10	1															
44	11	1.5															
45	11	1															
46	11	1															
47	11	1															
48	11	1															
49	11	1															

Table 4.11: Research Programme over the 15 year period, with an annual funding limit of £500k

	Year																
Project Rank	**Start year**	**Dur (yrs)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	1	2															
2	1	2															
3	1	3															
4	1	1															
5	1	3															
6	1	1															
7	1	1															
8	1	3.5															
9	2	1															
10	2	1															
11	2	0.5															
12	2	0.75															
13	2	1															
14	2	1															
15	2	0.75															
16	3	1															
17	3	3															
18	3	0.75															
19	3	1															
20	3	1.5															
21	3	3															
22	3	1															
23	3	1.5															
24	4	1															
25	4	2.5															
26	4	1															
27	4	1															
28	4	4															
29	4	1															
30	4	1															
31	4	1.25															
32	4	3.5															
33	5	1															
34	5	1															
35	5	1.5															
36	5	On going															
37	5	1															
38	5	3															
39	5	1															
40	5	2															
41	6	1.5															
42	6	1															
43	6	1															
44	6	1.5															
45	6	1															
46	6	1															
47	6	1															
48	6	1															
49	6	1															

Table 4.12: Research Programme over the 15 year period, with an annual funding limit of £1Mill

5. Summary

The report sets out the development of the reservoir safety research strategy for a period of 5-15 years. The methodology and results are discussed and show that a logical, robust method of analysis was undertaken. The drivers for reservoir safety research, which represent the issues that will affect reservoir safety in the future and particularly within the timescale for which this strategy is being developed, were first identified. Next, the research baseline was established to identify previous and current research that is relevant to reservoir safety, from which research gaps were identified, and future projects proposed. In addition, the profession was widely consulted on several occasions and in several different ways, including a questionnaire on the BDS website, letters to owners, the 2-Day workshop to vote on projects and a further opportunity to vote on projects via direct emailing to all BDS members after the workshop, giving them the opportunity to vote for the projects on the BDS website.

The prioritised list of projects generated from this extensive consultation and assessment, was additionally examined to determine how they can be achieved. Hence, alternative sources of funding were examined and information provided on a variety of ways in which reservoir safety research work can be funded and advanced, other than through direct and individual funding from Defra/EA. A list of actions for accessing these additional sources of funding was also provided.

Finally, indicative schedules of research projects were provided showing what can be achieved for different levels of funding per annum.

6. Recommendations

1. The projects identified and prioritised here have been linked to the appropriate EA TAG theme (see project summary sheets in Appendix H). It is further recommended that projects are examined for synergies and collaborative opportunities within the TAGs, and to identify other projects within the other TAGs which could be linked to the projects listed here. It is possible that projects under other TAGs can be extended to include aspects of reservoir safety with little additional effort.

2. The prioritised list should be reviewed annually and projects moved up the list as appropriate where it is feasible and desirable to do so. Where possible, quick wins should be identified that could accelerate the timing of projects. For, example, if there is an incident at the dam that could provide useful information to inform an aspect of reservoir safety, then funding should be sought to undertake the necessary research. It should be recognised that the list provided here is flexible and would change depending on changes in priorities and drivers.

3. It is recommended that this list of prioritised projects is circulated as widely as possible to owners, and practitioners.

7. References

Jacobs Babtie, 2006. Engineering Guide to Emergency Planning for UK Reservoirs

Sniffer, 2007. Guidance on Environmental Flow Releases from Impoundments to Implement The Water Framework Directive

Ofwat, 2007. Letter to water companies (August 2007)
http://www.ofwat.gov.uk/aptrix/ofwat/publish.nsf/AttachmentsByTitle/rd1507_nes.doc/$FILE/rd1507_nes.doc

Ofwat, 2005. Security of supply leakage and the efficient use of water.

BGS, 2007. British Geological Society website
http://www.bgs.ac.uk/hydrogeology/PollProb.htm

UKCIP02, Climate Change Scenarios for the United Kingdom, The UKCIP02 Scientific Report, April 2002

Appendix A – Strategy Process Diagram

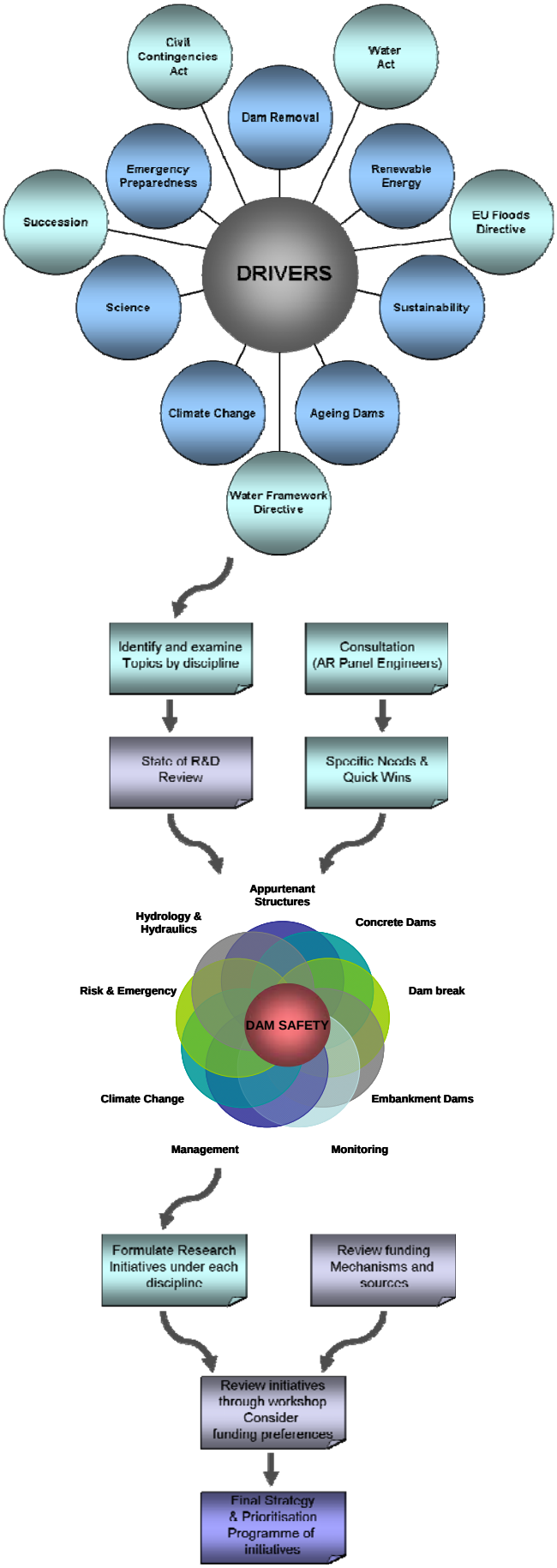

Figure A.1 – Schematic of research project derivation

Appendix B – Letter to Owners and Questionnaire

B.1 Letter To Owners

Your Ref:
Our Ref: 5042263/21/CO/008

29th August 2007

Ext No: 3011

Dear

Reservoir Research Strategy

As you hopefully are aware Atkins have been awarded a contract by Defra to write a strategy for reservoir research in the short term (5 years) and long term (15 years).

This strategy will identify projects, prioritise them and also identify sources of funding.

I write to ask if you, as a major owner of reservoirs, have any particular issues which you would like including in the strategy. It could be, for example, very specific, the hydraulic performance of masonry spillways or more general e.g. A Guide on Reservoir Maintenance, Flood Alleviation Dams or Gate Refurbishment and Maintenance.

I would be grateful if you could let me have any ideas you might have by the 14th September.

If you require any further information please do not hesitate to give me a ring.

I look forward to hearing from you.

With best regards

Yours sincerely
For and on behalf of Atkins Limited

Prof Andy Hughes
Director of Dams and Water Resources
Direct Line +44 (0)1372 753011
Mobile +44 (0)7834 506339

B.2 Questionnaire

ATKINS

Dam Safety R&D Review

A project, led by Atkins in association with HR Wallingford and the University of Bristol, is currently underway reviewing R&D relevant to UK dam safety and with the specific objectives of:

1. Establishing current initiatives and programmes of research (worldwide)
2. Establishing and prioritising UK dam safety needs
3. Reviewing funding sources and mechanisms

The project will deliver a prioritised programme of research for the UK along with a recommended approach for funding.

The Project Team welcomes all comments and suggestions regarding this process; please enter any information in the table below.

1 Recent, ongoing or planned R&D relating to dam safety *If you are aware of any research work that relates directly or indirectly to aspects of dam safety, we would like to hear about it. Please provide a brief description and, where possible, a contact email address and / or weblink. Relevant research could be individual, corporate, university, national or international.* [Add details here]
2 What R&D is needed? *Please let us know what R&D actions you feel are needed. This might range from making basic information or guidance available through to larger initiatives aimed at solving technical, design, operation and/or management issues. Add as many suggestions as you wish. Indicate your preferred priorities where possible.* [Add details here]
3 Funding *Resources to fund research are invariably finite. If you have any suggestions as to potential sources of funding and/or innovative ways of working, please provide details.* [Add details here]
4 Something else to add? *Add any additional comments here.* [Add details here]

Contributions are sought on this project by not later than **31st October 2007**. Please return this form either by:

Email: andy.hughes@atkinsglobal.com or margaretta.ayoung@atkinsglobal.com
Fax: 01372 754828
Post: c/o Dr Andy Hughes, Atkins, Woodcote Grove, Ashley Road, Epsom, Surrey. KT18 5BW.

In Association with HR Wallingford and University of BRISTOL

Appendix C – Workshop

Attendee Name	Organisation/Affiliation	Day 1	Day 2
Andy Hughes †	Atkins	✓	✓
Margaretta Ayoung†	Atkins	✓	✓
Wendy Daniell†	Bristol University	✓	✓
Chris Binnie†	Independent	✓	✓
Mark Morris	HR Wallingford	✓	✓
Mervyn Bramley	Independent	✓	✓
Cliff Kettle	Bachy Soletanche	✓	✓
Daniel Barnard	Bachy Soletanche	✓	✓
Colin Taylor	Bristol University	✓	×
Henry Hewlett	Consultant	✓	✓
Jonathon Hinks	Halcrow	✓	✓
Gary Tustin	EA	✓	✓
Bob Hatton	Defra/EA	✓	✓
Kevin Sene	Atkins	✓	✓
Marcus Francis	Jacobs	✓	✓
Christine Mcculloch	Oxford University	×	✓
David Brown	British Waterways	✓	✓
Jack McCarey	SWW	✓	✓
Lindsay Deuchar	Yorkshire Water	✓	✓
Bryn Philpott	Thames Water	✓	✓
John Ackers	Black & Veatch		✓
Norman Blacklock	Northumbrian Water	✓	✓
Jim Prentice	Northumbrian Water	✓	✓
Alex MacDonald	Jacobs		✓
William Allsop	HR Wallingford	✓	✓
Paul Samuels	HR Wallingford	×	✓
Alan Brown	Jacobs	✓	×

Table C.1: List of attendees at 2-Day Workshop on 31st Jan 2008 and 1st Feb 2008. †Project team members and presenters at workshop.

Defra Safety Research - R&D Review

Proposed Research Projects for Appurtenant Structures

	Project	Output	Score[1]	Indicative Cost[2]	Level of Difficulty[3]
A	Review tools to reduce O&M costs for extended life of spillways, i.e. repairs or inspections	Report			
B	Review and update CIRIA guide "Valves, pipework and associated equipment in dams - guide to condition assessment" to include gates and penstocks, paintwork, electrical & mechanical equipment,	Guide			
C	Compile & maintain a database of case studies on outlet works rehabilitation, inc. lessons learned, performance, costs	Database			
D	Develop new guide for mechanical & electrical design, & for automated control, for upgrading or rehabilitation of outlet works	Guide			
E	Guide on inspection, monitoring, maintenance and repair of tunnels	Guide			
F	Research to develop validated procedures for seismic assessment of appurtenant structures, particularly intake/outlet towers and spillway gates	Report			
G	Review alternative materials & techniques for embankment dam auxiliary spillways and structures designed to be overtopped, e.g. RCC spillways, stepped spillways, pre-cast concrete blocks. Review could lead to a guide	Report/Guide			
H	Review & guidance on techniques for installation and operation of replacement/upgraded draw-off systems to handle variable environmental flow releases from reservoirs	Report/Guide			
I	Guidance on the location, design and maintenance of fish screens	Guide			
J	Failure modes and processes for Appurtenant Structures	Research			

Instructions

[1] Score each project from 1-10 (1-3 low; 4-7 medium; 8-10 high)
[2] Suggest an indicative cost for research
[3] Score the level of difficulty from 1-3 (1 - simple, 3 - complex)

In Association with:

HR Wallingford Working with water
University of BRISTOL
Chris Binnie

Table C. 2: Example Voting form

Appendix D - Baseline Assessment

Name of Journal	
American Society Of Agricultural Engineers	International Journal Of Rock Mechanics And Mining Sciences
Applied Engineering In Agriculture	International Journal Of Sediment Research.
Chinese Science Bulletin	International Journal Of Water Resources Development
Climate Research	Iranian Journal Of Science And Technology
Engineering Geology	Journal Of Dam Safety
Journal Of Geotechnical And Geoenvironmental Engineering	Journal Of Earthquake Engineering
Journal Of Scientific & Industrial Research	Journal of Engineering Mechanical
Rock Mechanics And Rock Engineering	Journal of Geotech and Geoenvironmental Engineering
Acoustical Physics	Journal Of Geotechnical And Geoenvironmental Engineering
Advances In Engineering Software	Journal Of Hydraulic Engineering
Advances In Fracture And Failure Prevention, Pts 1 And 2 Key Engineering Materials	Journal Of Hydraulic Research
Advances In Geotechnical Engineering	Journal Of Hydroinformatics
Advances In Water Resources	Journal of Hydrological Engineering
American Society Of Agricultural Engineers	Journal Of Hydrology
Applied Engineering In Agriculture	Journal Of Hydrometeorology
Atmospheric Research	Journal of Infrastructure Systems
Canadian Geotechnical Journal	Journal Of Intelligent & Fuzzy Systems
Canadian Journal Of Civil Engineering	Journal Of Intelligent Material Systems And Structures
Civil Engineering	Journal Of Irrigation And Drainage Engineering-Asce 121
Civil Engineering And Environmental System	Journal Of Materials In Civil Engineering
Composite Structures	Journal Of Mechanical Behavior Of Materials
Computational Geosciences	Journal Of Professional Issues In Engineering Education And Practice 122
Computers & Structures	Journal Of Structural Engineering-Asce
Computers And Geotechnics	Journal Of Testing And Evaluation
Current Science	Journal Of The American Water Resources Association
Dam Engineering	Journal Of The Chinese Institute Of Engineers
Earth Planets And Space	Journal Of Urban Planning And Development
Earthquake Engineering & Structural Dynamics	Journal Of Water Resources Planning And Management
Earthquake Spectra	Land Degradation & Development
Ecological Economics	Meteorological Applications
Engineering Fracture Mechanics	Mining Engineering
Engineering Geology	Natural Hazards
Engineering Structures	Natural Hazards And Earth System Sciences
Environmental & Engineering Geoscience	North American Journal Of Fisheries Management
Environmental Geology	Optics And Laser Technology
Environmental Management	Regulated Rivers-Research & Management
Esri Professional Papers	River Research And Applications
Geomorphology	Rock Mechanics And Rock Engineering
Geophysics	Soil Dynamics And Earthquake Engineering
Geotech and Geoenvironmental Engineering	Stochastic Environmental Research And Risk Assessment
Geotechnical Engineering	Structural Engineering And Mechanics
Houille Blanche-Revue Internationale De L Eau	Structure And Infrastructure Engineering
Hydrological Processes	Theoretical And Applied Climatology
Hydrological Sciences Journal-Journal Des Sciences Hydrologiques	Water International
Hydrology And Earth System Sciences	Water Research
International Journal For Numerical And Analytical Methods In Geomechanics	Water Resources Research
International Journal Of Fracture	Water Science And Technology

Table D-1: Journals found containing relevant papers on reservoir safety

Discipline	Project	Papers
Research area	✓	✓
Key Words	✓	
Title/Topic of project	✓	✓
Author		✓
Brief description	✓	
Date Published / presented		✓
Funding body Classification (Gov't, private etc.)	✓	✓
Sponsor / Funding Body	✓	✓
Sponsorship / Funding (Monetary value)	✓	
Corresponding Author, Location and Contact details		✓
Researcher/Key contact	✓	
E-mail Address	✓	
Location of research facility and organisation represented	✓	✓
Country of dams	✓	✓
Country of research/location of dams studied (if relevant)	✓	✓
Related research projects		✓
Link to Abstract / paper		✓
Summary of Abstract		✓
Project Start Date	✓	
Project End Date (or expected)	✓	
Follow-on research / related research projects?	✓	✓
Comments	✓	✓
Other organisations related to the research	✓	✓
Related Published articles	✓	
Aspects of Dam Safety Covered by Research	✓	✓
Hyperlink to detailed description or relevant documents/websites etc.	✓	✓
Relevance to the UK	✓	✓
Identifiable extensions to research	✓	✓

Table D-2: Headings under which information was collected for research papers and projects found

Location
Babtie
BC Hydro
BIRMINGHAM UNIVERSITY: DEPT CIVIL ENGINEERING
BRISTOL UNIVERSITY: DEPT CIVIL ENGINEERING
Brown and Root
CAMBRIDGE UNIVERSITY: ENGINEERING DEPT
CARDIFF UNIVERSITY: SCHOOL OF ENGINEERING
CEH
COYNE ET BELLIER BUREAU D'INGENIEURS CONSEIL
CRANFIELD UNIVERSITY: SCHOOL OF ENGINEERING
Danish Coastal Authority (DCA)
DSIG - North America
DURHAM UNIVERSITY: SCHOOL OF ENGINEERING
EDF
Environment and Sustainable Development Dept. CESI RICERCA S.p.A. via Rubattino, 54. 20134 Milano - ITALY
FEMA
Finnish Environment Institute
France
GeoForschungsZentrum
Glasgow University and Durham University
Heriot Watt University
HERIOT-WATT UNIVERSITY: SCHOOL OF THE BUILT ENVIRONMENT
HR Wallingford
UNIVERSITE PARIS VI
LOUGHBOROUGH UNIVERSITY: DEPT CIVIL AND BUILDING ENGINEERING
Newcastle University, Civil Engineering and Geosciences Dept
QUEEN'S UNIVERSITY OF BELFAST: DEPT CIVIL ENGINEERING
SHEFFIELD UNIVERSITY: CIVIL AND STRUCTURAL ENGINEERING
University of Ghent
University of Florence, Italy
University Strathclyde
US Army Corps of Engineers, Pittsburgh, PA
US Army Corps of Engineers, Washington, DC
USACE EDRC (Engineer Research and Development Center)
USDA/HERU
USDA-ARS - Stillwater, Oklahoma
WL|Delft

Table D-3: Some of the main research institutes involved in research relevant to reservoir safety

Research Area	
Acceptable overtopping	Ice Loading
Ageing of hydraulic structures	Improved boundary conditions for FE modelling of foundations
Appurtenant structures: Seismic	Internal erosion
Breach	Investigating use of mass shaker for assessing dam performance
Channel erosion	Landslide induced waves
Clogging of bottom outlets	Local scour
Concrete dams Integrity assessment	Loss of life analysis
Concrete repair guide	Loss of life prediction
Concrete dam anchors	Management
Concrete dam foundation	Mathematical and Experimental modelling
Continuous simulation	Methods for concrete repair underwater
Dam Break	Modelling
Dam Break - Breach modelling	Modelling flood impacts
Dam Break - Seismic	NDT for condition of concrete anchor bolts
Dam register	Optimising management operation
Dam safety general	Performance of grout admixtures
Dam safety GIS	Performance of plastic pipes
Dam safety management	Performance of seepage protection measures
Dambreak - Concrete performance	Performance of steel struts
Dambreak - Landslides	Predicting block performance under varying water pressure
Debris management	Predicting embankment soil performance
Detection of voids	Predicting shear key strength
Deterioration of concrete	probabilistic analysis
Development	Rainfall runoff modelling
Earth Systems Science	RCC stepped chute performance
Emergency Response	Reservoir wave overtopping
Extreme flood prediction	Risk analysis
FE or FD modelling of embankment dam soil structure / performance	Risk and Performance
Filter performance	Risk estimation
Flood discharge	Rockfill
Flood estimation	Safety
Flood forecasting	Sedimentology
Flood frequency analyses	Social effects of Dam Hazard
Flood Processes	Soil erodibility
Forecasting	Spillways
Geophysics	Stability
Geotech	Stilling basin performance
Human risk	Sustainable Development
Hydraulics	Tools for drain inspection
Hydrology	Unsaturated Soils
Hydropower	Use of geotextiles in embankment dams

Table D-4: Some of the research areas found under reservoir safety research

Appendix E - Results of 1st Consultation and Gap-Identification

E.1 Panel Engineers Suggestion

Suggested Research projects
Behaviour of masonry spillways
Wave impact forces on wave walls – in particular ‘dry stone wave walls’
Wave estimation in reservoirs
Guidance on the design of fish ladders
Guidance on the location-designed maintenance of fish screens
Guidelines on the maintenance of gated structures
Rate of erosion in overflowing and overtopping
Flood Alleviation Structures – Guide on Design, Operation and Maintenance
The effects of climate change on dams
Flood detention reservoirs (Scope of guidance document on construction and maintenance of flood detention reservoirs.)
Rapid condition analysis for smaller embankments
Breach initiation and acceptable overtopping processes
Potential use of Internet and remote sensing technologies to support dam safety monitoring and emergency actions
Soil erodibility - Guidance on values; integration of international data; collection of representative UK data to support dambreak analyses (breach, piping, surface erosion etc)
Vegetation on Dams
Discontinuance of dams
Condition assessment of dams and foundations i.e. sound waves, radar, temperature sensing
Performance of existing masonry lined spillway channels under high velocities. Mechanisms of failure and design tools to determine resistance to 'plucking out' of stone sets
Review of performance of reinforced grass spillways/over-topable embankments to supplement/update CIRIA Report Nr 116 and if appropriate further research, with updated guidance on selection/advantages of different products/types in different situations
Review of performance of different types of wave erosion protection particularly on small reservoirs, and if appropriate research.

Table E-1: List of suggested research projects from Owner, Panel Engineers and respondents to the questionnaire.

Proposed Research Projects

Appurtenant Structures		
A	Review tools to reduce O&M costs for extended life of spillways, i.e. repairs or inspections	Report
B	Review and update CIRIA guide "Valves, pipework and associated equipment in dams - guide to condition assessment" to include gates and penstocks, paintwork, electrical & mechanical equipment, renovation/replacement techniques. Updated guide would include guidance on failure modes, selecting gates & valves, sliplining conduits.	Guide
C	Compile & maintain a database of case studies on outlet works rehabilitation, inc. lessons learned, performance, costs	Database
D	Develop new guide for mechanical & electrical design, & for automated control, for upgrading or rehabilitation of outlet works	Guide
E	Guide on inspection, monitoring, maintenance and repair of tunnels	Guide
F	Research to develop validated procedures for seismic assessment of appurtenant structures, particularly intake/outlet towers and spillway gates	Report
G	Review alternative materials & techniques for embankment dam auxiliary spillways and structures designed to be overtopped, e.g. RCC spillways, stepped spillways, pre-cast concrete blocks. Review could lead to a guide	Report/Guide
H	Review & guidance on techniques for installation and operation of replacement/upgraded draw-off systems to handle variable environmental flow releases from reservoirs	Report/Guide
I	Guidance on the location, design and maintenance of fish screens	Guide
J	***Failure modes and processes for Appurtenant Structures***	*Research*
Climate Change		
A	Review and attempt to quantify the likely direct impacts of climate change on dams and reservoirs	Report
B	Review and attempt to quantify indirect impacts on dams and reservoirs	Report
C	Develop framework for quantifying and incorporating climate change uncertainty into dam design	Guidance
D	Investigate methods and technologies to help dams adapt to climate change: Flexible dam design to enable updating and enhancement of structures at low cost	Guidance
E	Review management methods, inspection standards and inspection intervals and development new requirements to take account of Climate change	Guidance
Concrete Dams		
A	Review & update 1996 CIRIA "Engineering guide to the safety of concrete and masonry dam structures in the UK"	Guide
B	Review methods for maintenance & repair of concrete dams, & techniques for assessing their impact on dam maintenance, operation & performance	Report
C	Review of available techniques for non-linear numerical material & interface modelling in concrete dams including lift joints & damage models (e.g. hydraulic fracture, degradation)	Report
D	Review of available techniques for non-linear numerical material & interface modelling of significant factors for foundation rocks & dam-foundation interfaces (e.g. uplift, joint sliding and separation)	Report
E	Review of published work on physical and chemical degradation phenomena in dam concrete & techniques for identifying degradation and its causes	Report
F	Research to develop techniques to assess material properties of dam concrete in-situ (on existing dams) & in the laboratory on specimens from dams	Test Methods
G	Review of non-destructive testing techniques & their applicability to dams, leading to a guide or to identify appropriate research	Report or Guide
H	***Research to identify failure modes and processes***	Report or Guide

Dambreak Analysis		
A	Review latest knowledge on **internal erosion** leading to updated UK guidance. [Scoping --> guidance]	Scoping review --> revised guide
B	**Uncertainty[1]**: (a) Understand and assess for different stages of dambreak; (b) Methods to transfer between models; (c)Methods to communicate and manage for application.	Research, Guidance
C	**Uncertainty[2]: Structure Failure Prediction**: Review and define methods for failure prediction that provide consistent levels of certainty within the predictions for earth, concrete, masonry, appurtenant structure failure modes	Research, Guidance
D	**Structure Failure [1]: Soil erodibility** and testing equipment. Build from existing RTD. Establish database for UK soils and states allowing risk / rate of internal erosion and breach to be refined for UK dams	Scope; Science; Guidance
E	**Structure Failure [2]: Wave action and overtopping**. Improved prediction, force calculations and overtopping methods. Assess performance of grass cover for UK dams (overtopping simulator)	Scope; Science; Guidance
F	**Structure Failure [3]: Real structure state.** Improve science / techniques for modelling failure of real structures, considering variation in soil state, zoned materials and climate change effects.	Science; Guidance; models
G	**Flood modelling and mapping**: Establish science and guidance on appropriate roughness values for dambreak simulation; resolution and accuracy of topographic data; model mesh and mapping	Science and Guidance
H	**Data and Forensics**: Construct team, process, funding and permissions for rapid response collation and storage of key process data relating to extreme floods, structure failure/breach or dambreak	Data
I	**Training:** Undertaking and validating dambreak analyses	Training
J	**Uptake from existing FRM research**: Ensure that techniques, models, methods from existing FRM research are brought into dam safety applications	Uptake / Integration
K	***Review of existing methods and development of guidelines for raid development***	*Review*
Embankment Dams		
A	Leakage monitoring and measuring	Review
B	Retrofitting of filters to cope with internal erosion	Review
C	Guide to safety of embankment dams	Updated Guide
D	Rapid condition analysis of small embankments	Guide
E	Effects of climate change on embankments	Report
F	Methods of raising embankment dams	Guide
G	Grout curtains: Deterioration and latest methods	Report
H	Remote monitoring of embankments	Report
I	Need for dam instrumentation	Report/Guide
J	Decommissioning of dams	Guide
K	Renewable energy	Guide
L	Design of flood storage reservoirs	Research
M	Assessment of embedded energy	Guide
N	***Update the guide of Small Embankment Dams***	*Updated guide*
O	***Use of innovative materials for embankment dams***	*Research*
P	***Compendium of design and assessment of embankment dams- collaboration of work***	*Research*
Q	***Climate change effects embankment dams focusing on vegetation***	*Guide*
R	***Collect geotechnical and geological data of old dams for EA Database***	*Research / Database*
S	***Grout and cutoffs***	*Research*

Hydrology and Hydraulics		
A	Finalise the improved methods for extreme rainfall event predictions (underway); Develop a tool for implementing the new method	New Method; Tool
B	Review methods for predicting return period of events > 10,000 year to support risk-based assessments	Scoping review --> revised guide.
C	Dev. guidelines on design of real time monitoring networks for reservoir monitoring and flood forecasting	Guidance
D	Real-time control methods - real time control of reservoirs to reduce overtopping risks at the reservoir, and to reduce flooding risks further downstream	Methods; Guidance
E	Guidance on the optimum approaches to reservoir forecasting techniques for different types of reservoirs and outflow arrangements	Guidance
F	Research and guidance on the behaviour of masonry spillways – understanding the role of surface gaps	Science; Guidance
G	Waves on reservoirs: Wave height prediction in shallow and deep water where interference of wave trains occurs	Science; Guidance
H	Guidance on the design, construction, operation and maintenance of flood detention reservoirs	Guidance
I	Wave impact forces on wave walls – in particular 'dry stone wave walls'. Adequacy of wave walls to withstand waves. Guidance on wave wall protection	Guidance
J	Investigate Innovative materials for spillway design.	Research
K	***Update the flood and reservoir safety manual***	*Update*
L	***Develop a rainfall runoff model appropriate for modelling extreme floods.***	*New Method; Tool*
Management		
A	Development of UK-based Risk Assessment Methodology - PRA	Guide
B	Publication - Lessons from Dam Incidents in the UK	Report
C	Guidance on public safety at dams	Guide
D	Development of a web-based GIS management system for dams	Tool
E	***Management Communication Strategy***	*Strategy*
Monitoring		
A	Review existing, new & emerging sensor technologies for monitoring civil infrastructure & suitability for the condition assessment of dams & foundations. This could lead to a guide and/or further research	Report and Guide
B	Review computational intelligence methods & suitability for intelligent early-warning systems for dams, including monitoring, processing, decision making and prediction. Research could be recommended.	Report
C	Review modes of failure of dams and failure of the monitoring techniques.	Report and Guide
D	*Sliplining of Conduits*	*Research*
E	***Frequency of inspection monitoring***	*Report*
Risk and Emergency Planning		
B	Review science and practice supporting **emergency planning for dams** (including UK, EC and US projects). Identify gaps in knowledge and best practice	Scoping review --> R&D needs & best practice
E	**Risk Communication:** Review users / needs; identify different effective methods / formats; identify methods for communicating and instructing the public.	Research, Guidance
F	***Training people for event management. Guidance on role responsibility or in response to emergency planning.***	Training, Guidance
G	***Impact on infrastructure as enforced by EU directive.***	Research

Table E-2: List of projects voted on at the 2-day workshop. This list is a combination of the results of the gap-identification exercise, the 1st consultation (suggestions from owners, panel engineers etc.) and suggestions added at the workshop (in blue text).

Appendix F - Voting Results

F.1 Introduction

The results of the voting are summarised in histograms for each discipline. Projects are lettered in the histograms corresponding to the original letters assigned to projects in the voting forms (See Appendix E. Where projects have been combined in the final list of projects, they have been plotted using the combined scores, and all letters comprising the final project are listed in the first column.

It should be noted that a total of 33 people voted based on numbers attending the 2-day workshop and those voting by downloading the voting forms from the BDS website afterwards.

F.2 Appurtenant Structures

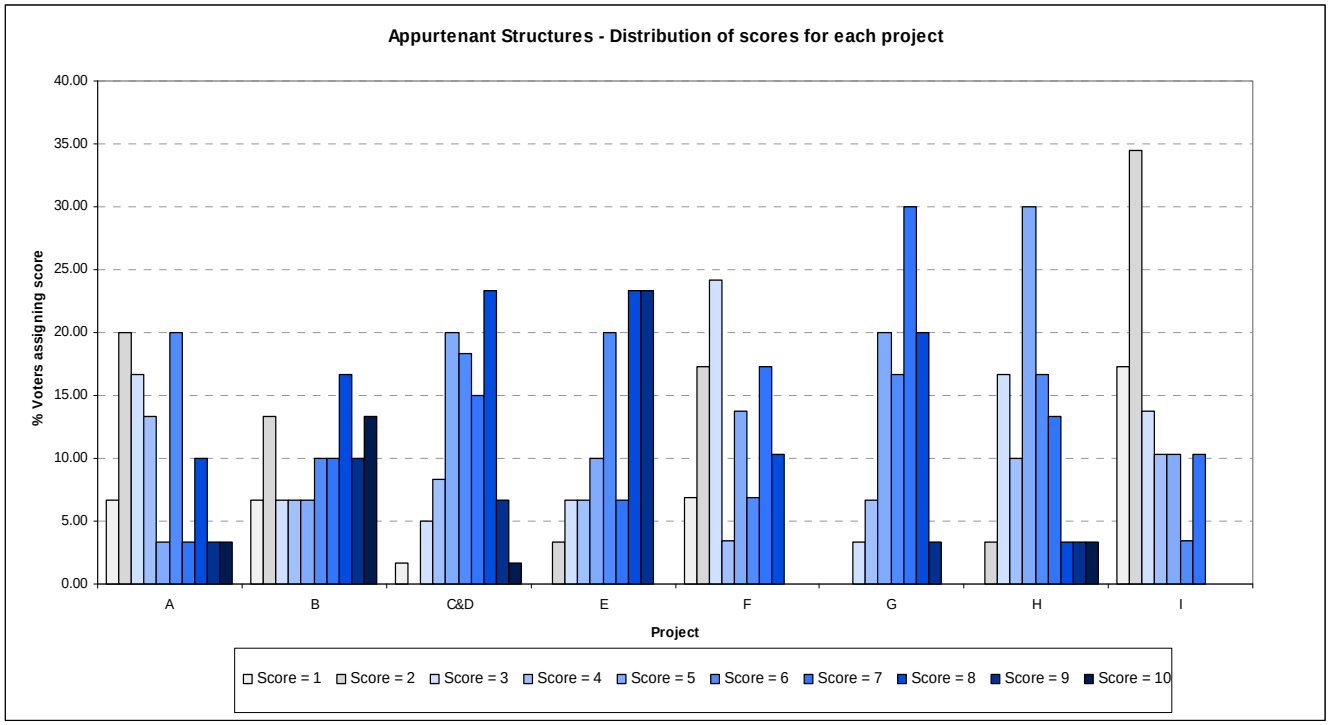

Figure F.1: Distribution of scores for each project – Appurtenant Structures

	Project Title	Mean Score
A	Review tools to reduce O&M costs for extended life of spillways	4.5
B	Review and Update of CIRIA Guide to Valves, Pipe work and Associated Equipment	6.0
C&D	A Guide to Mechanical and Electrical Equipment in Dams	6.3
E	Guide on inspection, monitoring, maintenance and repair of tunnels	6.7
F	Procedures for the Assessment of Intake Towers and Gates.	4.4
G	Review Alternative Materials & Techniques for Embankment Dam Auxiliary Spillways	6.4
H	Review & Guidance on Techniques for Installation and Operation of Draw off System	5.3
I	Guidance on the location, design and maintenance of fish screens	3.1

Table F.1: Appurtenant Structures projects

F.3 Climate Change

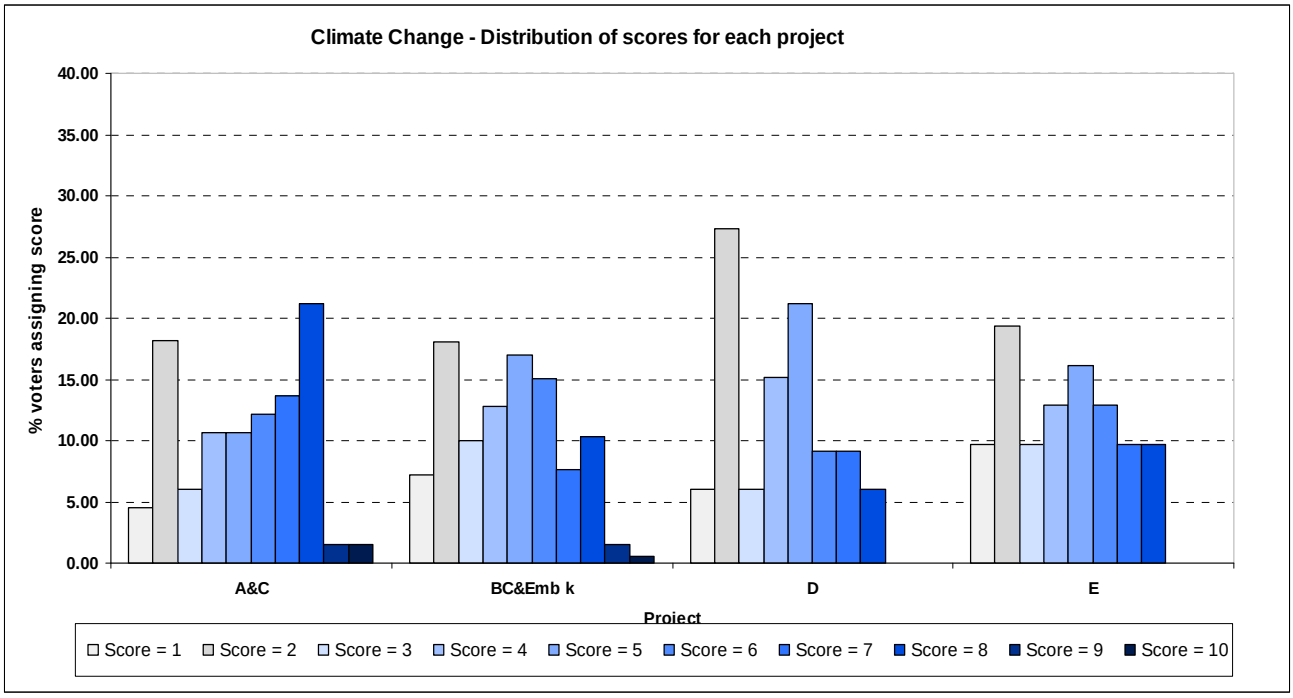

Figure F.2: Distribution of scores for each project – Climate Change

	Project Title	Mean Score
A&C	Review of **direct** Impacts of climate change on dams and reservoirs	7.2
BC & Emb K	Review of **indirect** Impacts of climate change on dams and reservoirs	4.5
D	Investigate methods and technologies to help dams adapt to climate change	4.1
E	Review management methods, inspection standards and inspection intervals and develop new requirements to take account of climate change.	4.3

Table F.2: Climate Change Projects

F.4 Concrete Dams

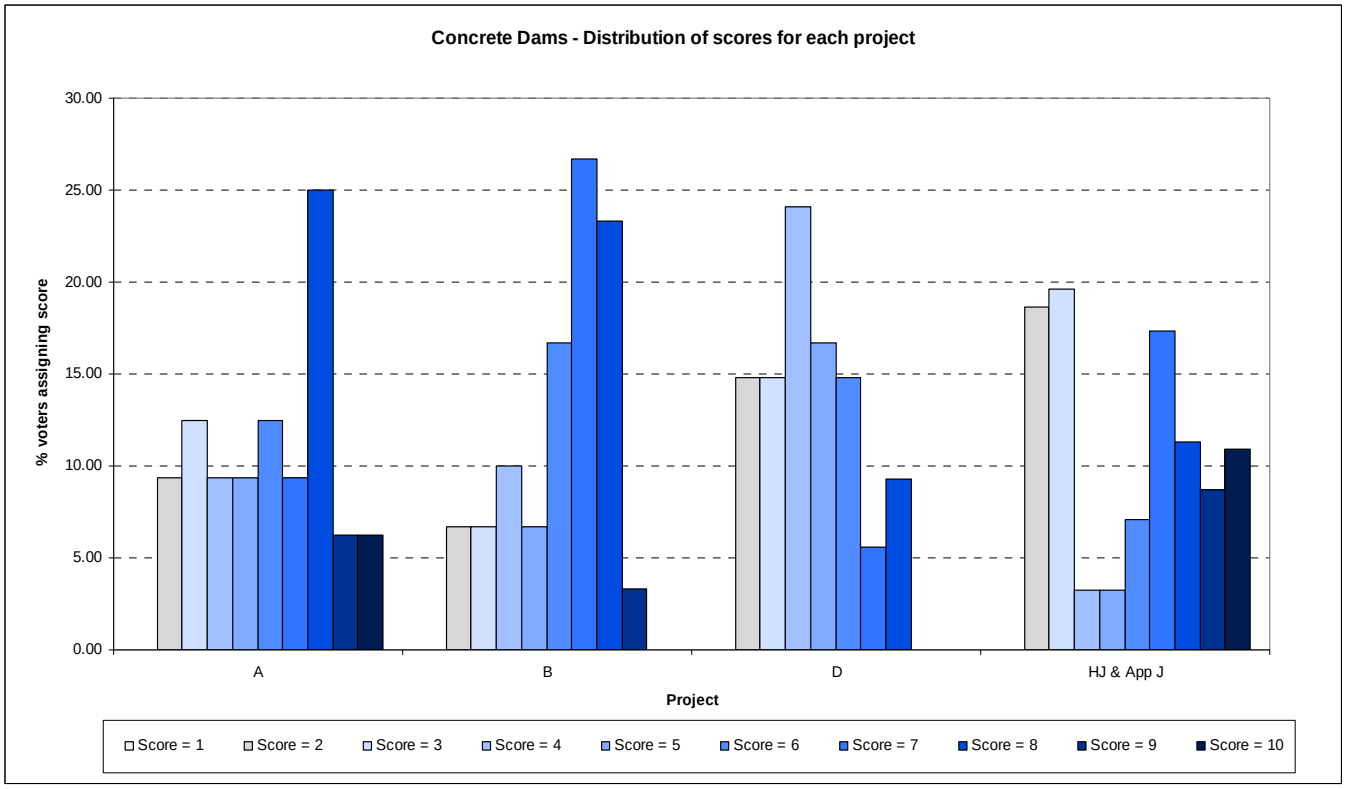

Figure F.3: Distribution of scores for each project – Concrete Dams

	Project Title	Mean Score
A	Review and Update of 1996 Engineering Guide to the Safety of Concrete and Masonry Dams	6.0
B	Manual on the degradation and repair of concrete dams	6.1
C&D	Non-linear numerical analysis of concrete dams and their foundations	4.7
H& App J	Research to identify failure modes and processes	6.3

Table F.3 - : Concrete Dams Projects

F.5 Dam Break Analysis

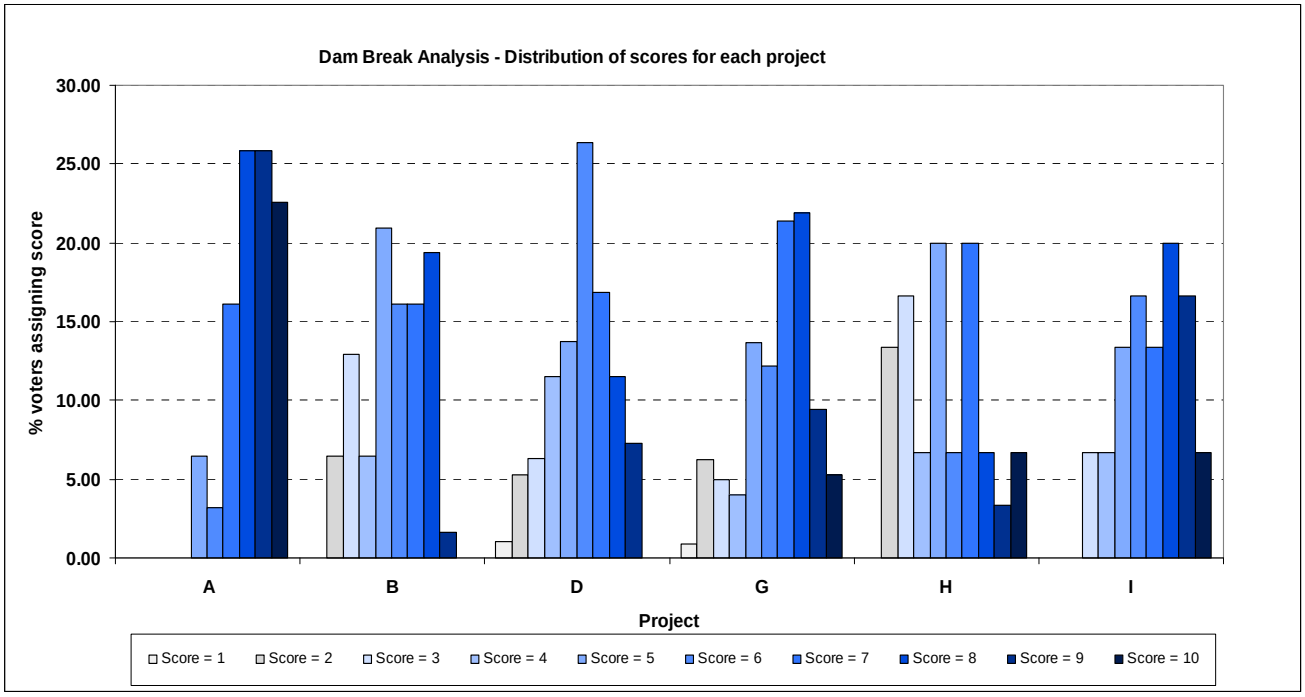

Figure F.4: Distribution of scores for each project – Dambreak Analysis

	Project Title	Mean Score
A	Review latest knowledge on internal erosion leading to updated UK guidance	8.3
BC	Understanding and reducing uncertainty within dambreak analyses	5.7
DEF	Dambreak analysis – Structure failure mechanisms	6.5
GJK & (Risk and Emerg G)	Review of existing methods and development of guidelines for dambreak assessment	7.1
H	Dambreak analysis – Data and forensics	5.3
I	Training in dambreak analysis and evaluation	6.8

Table F.4: Dambreak Analysis Projects

F.6 Embankment Dams

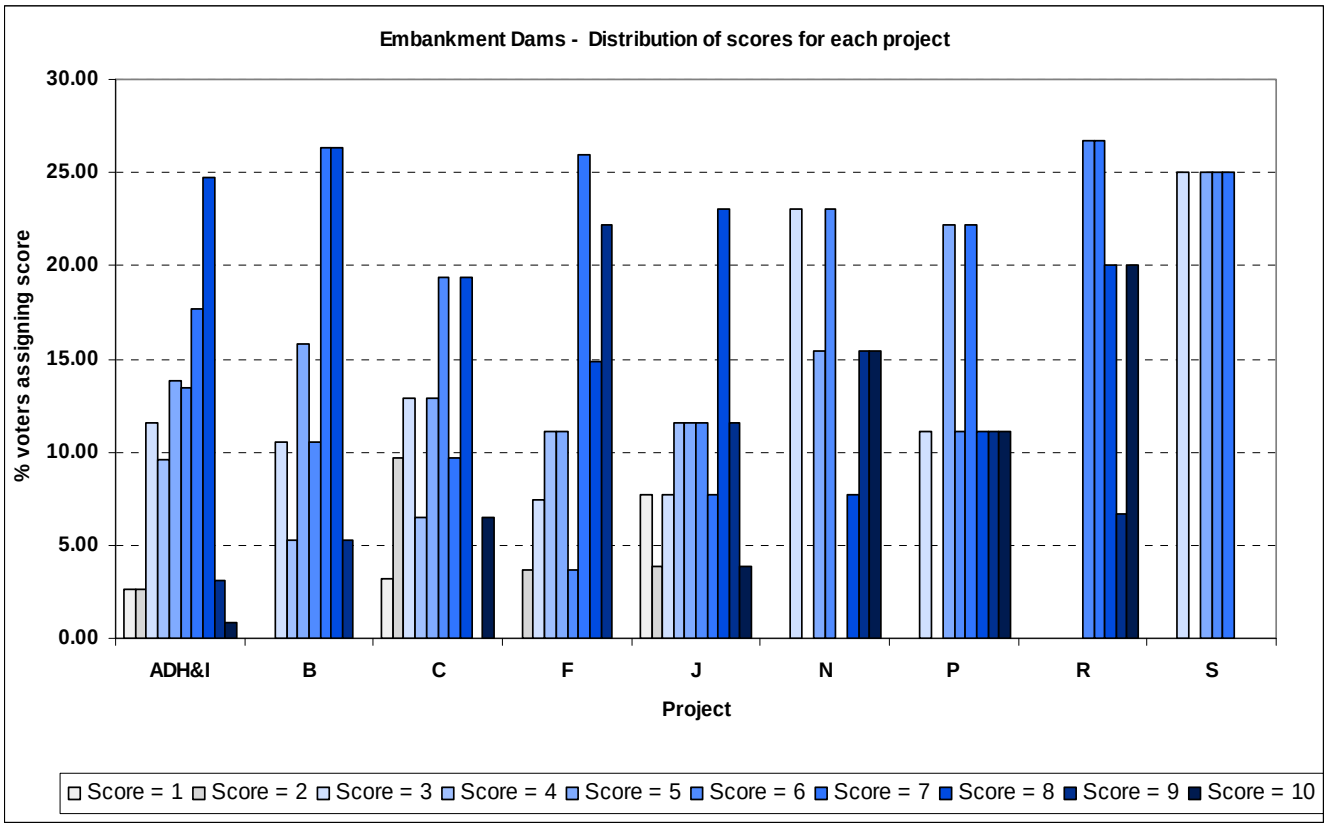

Figure F.5: Distribution of scores for each project – Embankment Dams

	Project Title	Mean Score
ADHI	Monitoring and measuring methods for embankment dams	6.9
B	Retrofitting of filters to cope with internal erosion	6.4
C	Guide to Safety of Embankment Dams Update	5.5
F	Methods of raising embankment dams	6.5
J	Decommissioning of dams	5.9
N	Update the Guide to the Design of Small Embankment Dams	6.4
P	Compendium of design and assessment of embankment dams- collaboration of work	6.7
R	Collect geotechnical and geological data of old dams for EA Database	7.7
S	Embankment and Grout Curtains & Cutoffs	6.0

Table F.5: Embankment Dams Projects

F.7 Hydrology and Hydraulics

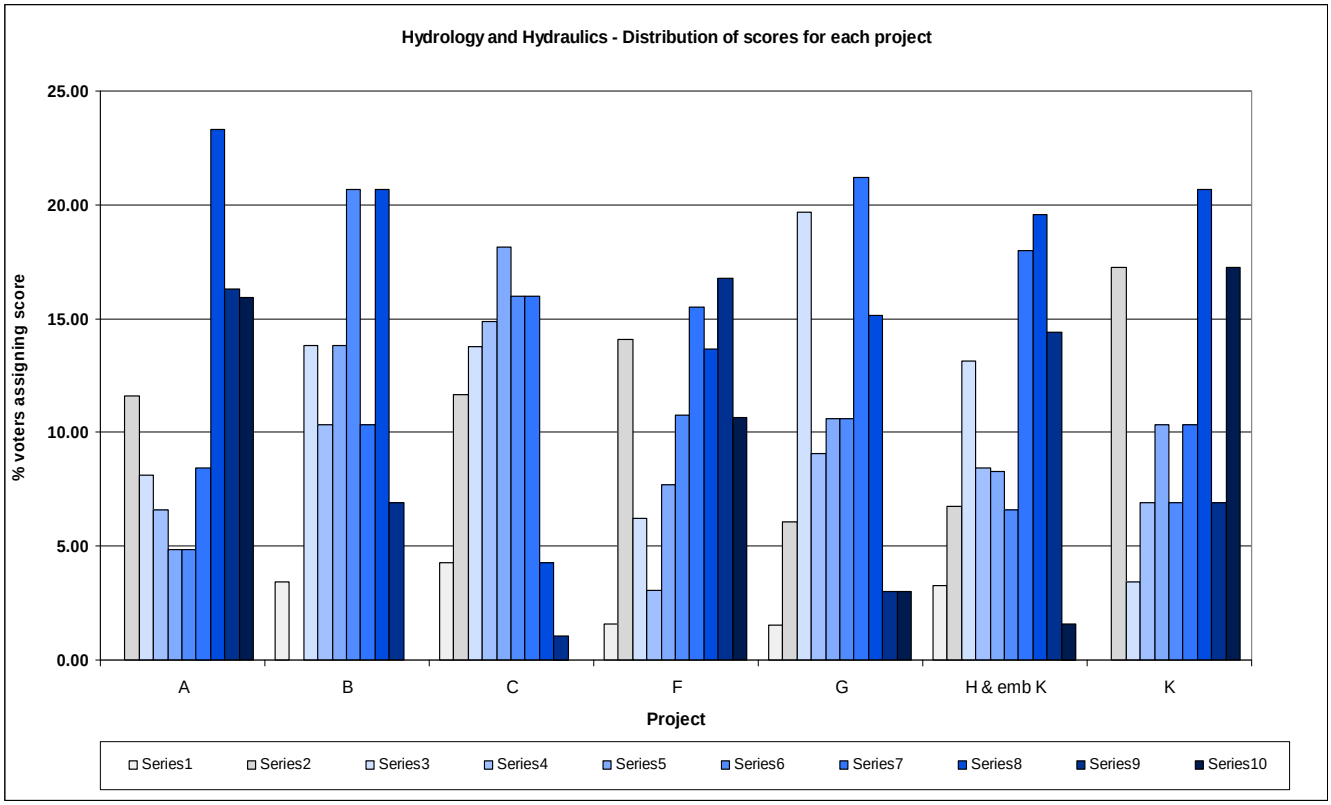

Figure F.6: Distribution of scores for each project – Hydrology and Hydraulics

	Project Title	Mean Score
A&L	Extreme flood hydrology 1) Finalise the improved methods for extreme rainfall event predictions; 2) Develop a tool for implementing the new method; 3) Develop a rainfall-runoff method appropriate for modelling extreme floods	7.1
B	Review methods for predicting return period of events > 10,000 years to support risk-based assessments.	5.8
CDE	Application of Reservoir flood forecasting and control to UK reservoirs	4.5
F&J	Research and guidance on the behaviour of masonry spillways	8.0
GI	Waves on reservoirs – 1) Wave height prediction in shallow water where interference of wave trains occurs; 2) wave impact forces on wave walls – in particular 'dry stone' walls and adequacy of wave walls to withstand waves and; 3) Guidance on wave wall protection	5.1
H	Revise CIRIA Guide 'Design of Flood Storage Reservoirs – B14'	6.6
K	Update the 'Floods and Reservoir Safety: An Engineering Guide' document	6.4

Table F.6: Hydrology and Hydraulics Projects

F.8 Management

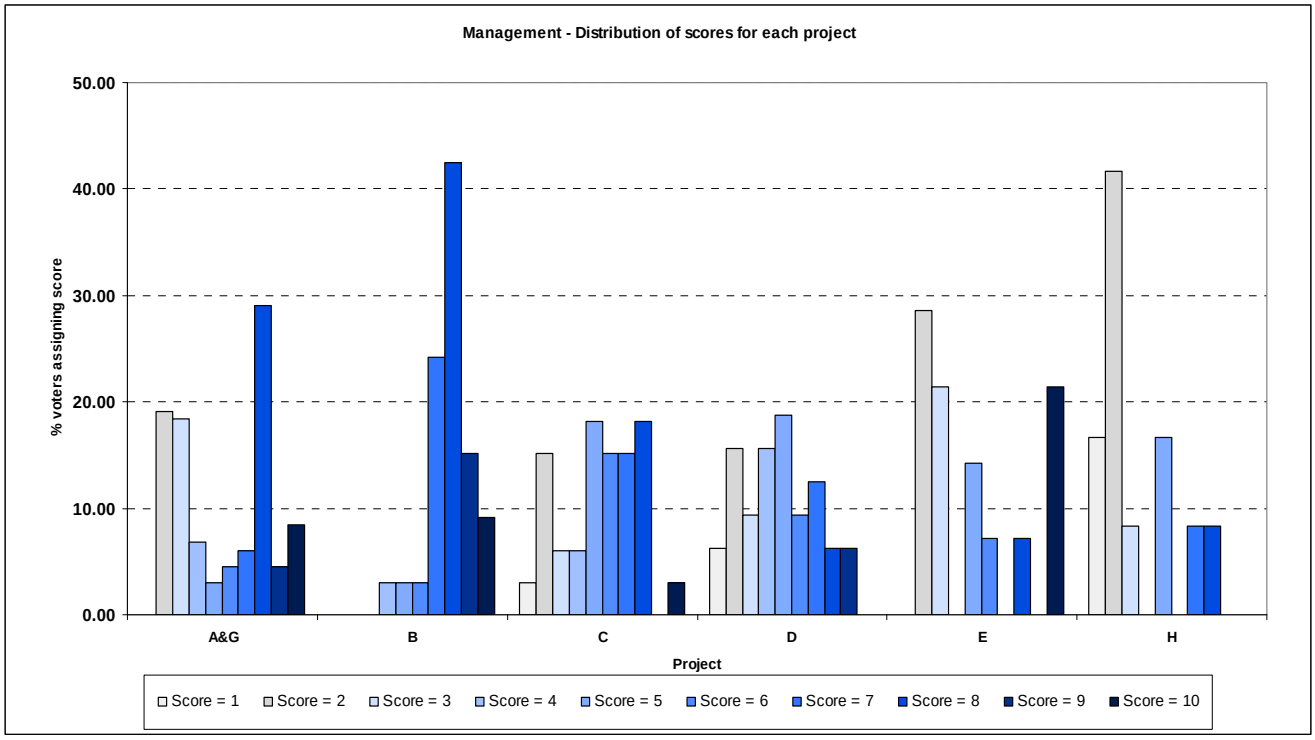

Figure F.7: Distribution of scores for each project – Management

	Project Title	Mean Score
AG	Development of UK-based Risk Assessment Methodology - PRA	6.3
B	Publication - Lessons from Dam Incidents	7.8
C	Guidance on public safety at dams	5.4
D	Development of a web-based GIS management system for dams	4.7
E	Management Communication Strategy	5.1
H	Knowledge optimisation on data (after B,E)	3.3

Table F.7: Management Projects

F.9 Monitoring

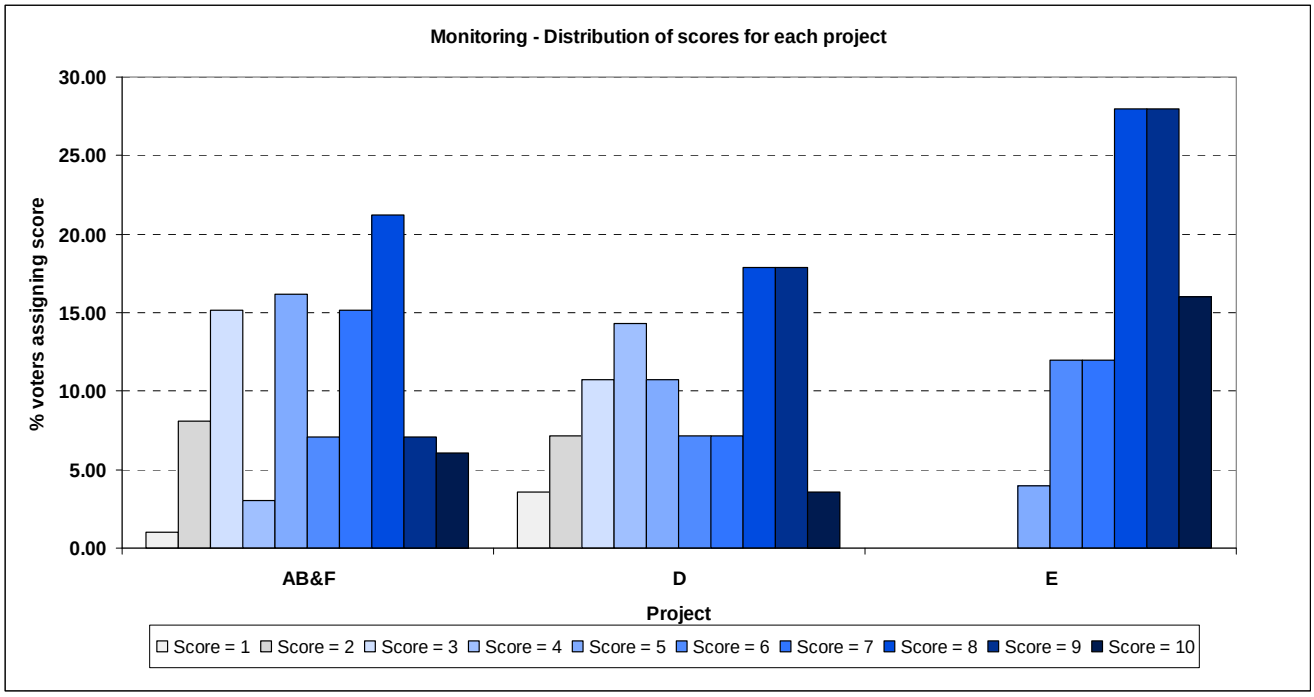

Figure F.8: Distribution of scores for each project – Monitoring

	Project Title	Mean Score
ABF	Publication – A Guide to Instrumentation and Monitoring	6.8
D	Slip Lining of Conduits	5.9
E	Review of Modes of Failure of Dams and Failure of Monitoring Techniques	8.1

Table F.8: Monitoring Projects

F.10 Risk and Emergency

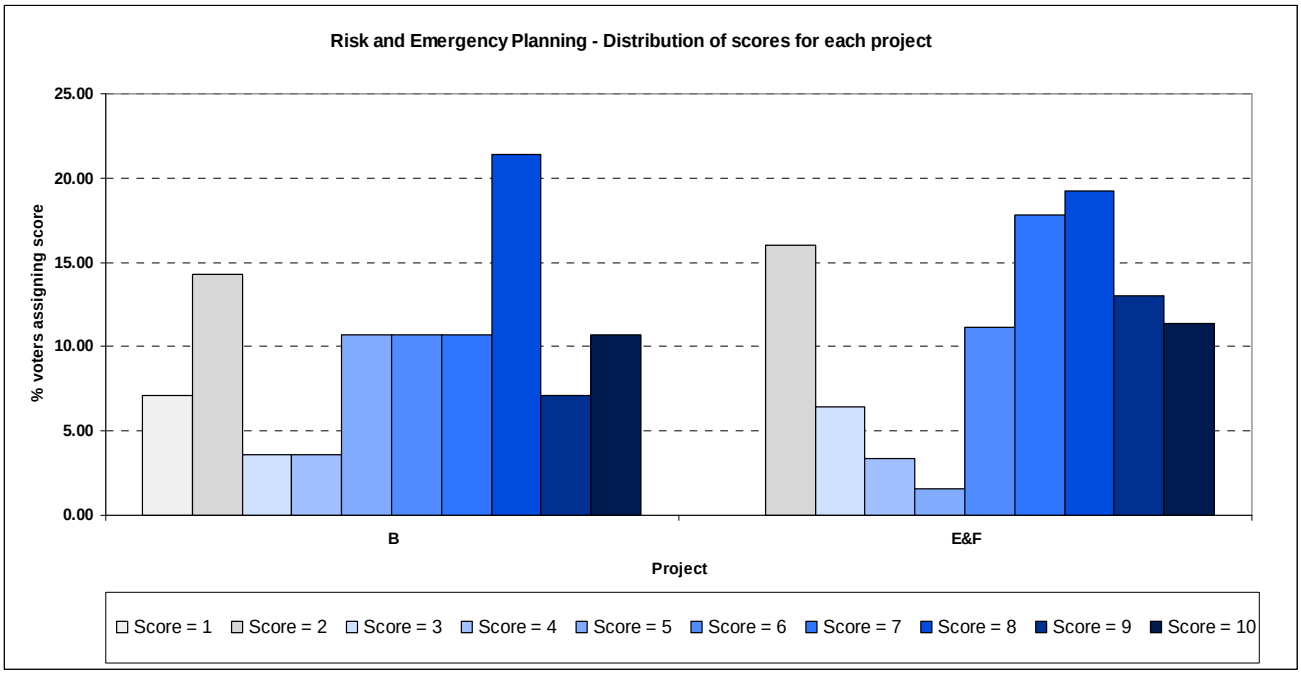

Figure F.9: Distribution of scores for each project – Risk and Emergency Planning

	Project Title	Mean Score
B	Review science and practice supporting emergency planning for dams (including UK, EC and US projects).	6.0
EF	Training for event management	6.7

Table F.9: Risk and Emergency Planning Projects

Appendix G : Final Prioritised list of Research Projects

G.1 Introduction

The prioritised list of research projects is presented in Table G.1. The columns are as follows:

Column 1 – Rank. Order of priority based on value of the mean score (from highest to lowest)

Column 2 – Original letter assigned to project in voting form

Column 3 – Discipline under which project appears in voting forms

Column 4 – Project Description

Column 5 – Output. This is the expected outcome of the project on completion (report, guide, science, tool etc). Here the term 'science' means new scientific discovery.

Column 6 – Mean score. This is the mean of all scores assigned to the project by voters

Column 7 – Difficulty. This is based on the mean difficulty assigned to the project by voters

Column 8 – Project Type. HB/LD, HB/LD, LB/LD, LB/HD as defined in Section 4.3.3

Column 9 – Project duration in months

Column 10 – Estimated cost in £k

Colum 11 – Additional sources of funding, as identified in the sources of funding review (Appendix I). Note that it is assumed that all projects will be additionally eligible for EA/Defra Funding.

Rank		Discipline	Projects Descriptions	Output	Score Mean	Duration (mths)	Est Cost (£k)	Difficulty	Project Type	Additional Sources of Funding
1	A	Dambreak	Review latest knowledge on internal erosion leading to updated UK guidance	Scoping review --> revised guide	8.3	24	125	1.9	HB/LD	Owners
2	E	Monitoring	Review of Modes of Failure of Dams and Failure of Monitoring Techniques	Report and Guide	8.1	24	150	1.9	HB/LD	Owners
3	F&J	H&H	Research and guidance on the behaviour of masonry spillways	Science; Guidance	8.0	36	175	2.0	HB/HD	Owners, EPSRC,FEMA, CIRIA
4	B	Management	Publication - Lessons from Dam Incidents	Report	7.8	12	50	1.3	HB/LD	Owners/CIRIA
5	R	Emb dams	Collect geotechnical and geological data of old dams for EA Database	Research / Database	7.7	12/36	100	1.9	HB/LD	Owners
6	A&C	Climate Change	Review of **direct** Impacts of climate change on dams and reservoirs	Report	7.2	12	150	3.0	HB/HD	UKWIR/EC/NERC
7	GJK (EMG)	Dambreak	Review of existing methods and development of guidelines for dambreak assessment	Science and Guidance	7.1	12	85	1.9	HB/LD	EC
8	A&L	H&H	Extreme flood hydrology 1) Finalise the improved methods for extreme rainfall event predictions; 2) Develop a tool for implementing the new method; 3) Develop a rainfall-runoff method appropriate for modelling extreme floods	New Method; Tool	7.1	42	650	2.3	HB/HD	NERC/EPSRC
9	ADHI	Emb dams	Monitoring and measuring methods for embankment dams	Chapter in Guide	6.9	12	145	1.5	HB/LD	Owners/FEMA
10	ABF	Monitoring	Publication – A Guide to Instrumentation and Monitoring	Report and Guide	6.8	12	100	1.8	HB/LD	Owners//FEMA/CIRIA
11	I	Dambreak	Training in dambreak analysis and evaluation	Training	6.8	6	20	1.3	HB/LD	Owners
12	EF	Risk & Em	Training for event management	Research, Guidance	6.7	9	100	1.9	HB/LD	Owners/NERC/EPSRC

Rank		Discipline	Projects Descriptions	Output	Score Mean	Duration (mths)	Est Cost (£k)	Difficulty	Project Type	Additional Sources of Funding
13	E	App structures	Guide on inspection, monitoring, maintenance and repair of tunnels	Guide	6.7	12	50	1.7	HB/LD	CIRIA
14	P	Emb dams	Compendium of design and assessment of embankment dams-collaboration of work	Research	6.7	12	75	1.6	HB/LD	CIRIA
15	H	H&H	Revise CIRIA guide 'Design of Flood Storage Reservoirs – B14'	Guidance	6.6	9	85	1.5	HB/LD	CIRIA
16	F	Emb dams	Methods of raising embankment dams	Guide	6.5	12	60	1.8	HB/LD	EPSRC/NERC/ CIRIA
17	DEF	Dambreak	Dambreak analysis – Structure failure mechanisms	Scope; Science; Guidance	6.5	36	120	2.0	HB/HD	EPSRC/NERC/ FEMA/DSIG/EC
18	N	Emb dams	Update the guide of Small Embankment Dams	Updated guide	6.4	9	30	1.3	HB/LD	CIRIA
19	K	H&H	Update the 'Floods and Reservoir Safety: An Engineering Guide' manual	Update	6.4	12	60	1.5	HB/LD	CIRIA/Owners
20	B	Emb dams	Retrofitting of filters to cope with internal erosion	Review	6.4	18	45	2.1	HB/HD	EC/DSIG/FEMA
21	G	App structures	Review Alternative Materials & Techniques for Embankment Dam Auxiliary Spillways	Report/Guide	6.4	36	320	2.0	HB/HD	FEMA/DSIG/EC
22	DC	App structures	A Guide to Mechanical and Electrical Equipment in Dams	Guide	6.3	12	75	1.9	HB/LD	CIRIA
23	AG	Management	Development of UK-based Risk Assessment Methodology - PRA	Guide	6.3	18	150	2.3	HB/HD	Owners
24	H (App J)	Conc Dams	Research to identify failure modes and processes	Report or Guide	6.3	12	100	1.9	HB/LD	FEMA/DSIG/EC
25	B	Conc Dams	Manual on the degradation and repair of concrete dams	Report	6.1	30	230	1.5	HB/LD	CIRIA
26	B	App structures	Review and Update of CIRIA Guide to Valves, Pipe work and Associated Equipment	Guide	6.0	12	60	1.5	HB/LD	Owners/CIRIA

Rank		Discipline	Projects Descriptions	Output	Score Mean	Duration (mths)	Est Cost (£k)	Difficulty	Project Type	Additional Sources of Funding
27	A	Conc Dams	Review and Update of 1996 Engineering Guide to the Safety of Concrete and Masonry Dams	Guide	6.0	12	50	1.2	HB/LD	Owners/CIRIA
28	S	Emb dams	Embankment and Grout Curtains & Cutoffs	Research	6.0	48	200	1.5	HB/LD	CIRIA/EPSRC/NERC/
29	B	Risk & Em	Review science and practice supporting emergency planning for dams (including UK, EC and US projects).	Scoping review --> R&D needs & best practice	6.0	12	30	1.3	LB/LD	FEMA/DSIG/EC
30	D	Monitoring	Slip Lining of Conduits	Research	5.9	12	30	1.3	LB/LD	NERC/
31	J	Emb dams	Decommissioning of dams	Guide	5.9	15	75	1.7	LB/LD	FEMA/DSIG/Owners/CIRIA
32	B	H&H	Review methods for predicting return period of events > 10,000 years to support risk-based assessments.	Scoping review --> revised guide.	5.8	42	400	2.1	LB/HD	NERC/Owners/ FEMA/ DSIG
33	BC	Dambreak	Understanding and reducing uncertainty within dambreak analyses	Research, Guidance	5.7	12	120	2.5	LB/HD	EC/DSIG/FEMA
34	C	Emb dams	Guide to safety of embankment dams	Updated Guide	5.5	12	75	1.4	LB/LD	CIRIA
35	C	Management	Guidance on public safety at dams	Guide	5.4	18	35	1.5	LB/LD	EC/DSIG/Owners
36	H	Dambreak	Dambreak analysis – Data and forensics	Data	5.3	Ongoing	100	2.0	LB/HD	EC/DSIG/FEMA
37	H	App structures	Review & Guidance on Techniques for Installation and Operation of Draw off System	Report/Guide	5.3	12	75	1.5	LB/LD	Owners/CIRIA
38	GI	H&H	Waves on reservoirs – 1) Wave height prediction in shallow water where interference of wave trains occurs; 2) wave impact forces on wave walls – in particular 'dry stone' walls and adequacy of wave walls to withstand waves and; 3) Guidance on wave wall protection	Science; Guidance	5.1	24/36	150	1.9	LB/LD	EPSRC/NERC/EC/CIRIA/FEMA/DSIG

Rank		Discipline	Projects Descriptions	Output	Score Mean	Duration (mths)	Est Cost (£k)	Difficulty	Project Type	Additional Sources of Funding
39	E	Management	Management Communication Strategy	Strategy	5.1	12	20	1.0	LB/LD	CIRIA
40	D	Management	Development of a web-based GIS management system for dams	Tool	4.7	24	200	2.5	LB/HD	Owners
41	C&D	Conc Dams	Non-linear numerical analysis of concrete dams and their foundations	Report	4.7	18	120	1.7	LB/LD	EPSRC/NERC/
42	A	App structures	Review tools to reduce O&M costs for extended life of spillways	Report	4.5	12	40	1.6	LB/LD	Owners/CIRIA
43	BC&Emb K	Climate Change	Review of **indirect** Impacts of climate change on dams and reservoirs	Report	4.5	12	150	3.0	LB/HD	UKWIR/EC
44	CDE	H&H	Application of Reservoir flood forecasting and control to UK reservoirs	Guidance	4.5	18	150	1.5	LB/LD	UKWIR/Owners
45	F	App structures	Procedures for the Assessment of Intake Towers and Gates.	Report	4.4	12	50	2.0	LB/HD	CIRIA
46	E	Climate Change	Review management methods, inspection standards and inspection intervals and develop new requirements to take account of climate change.	Guidance	4.3	12	50	1.9	LB/LD	UKWIR/EC
47	D	Climate Change	Investigate methods and technologies to help dams adapt to climate change	Guidance	4.1	12	100	2.4	LB/HD	UKWIR/EC
48	H	Management	Knowledge optimisation on data (after B,E)	Tools	3.3	12	150	2.5	LB/HD	Owners
49	I	App structures	Guidance on the location, design and maintenance of fish screens	Guide	3.1	12	30	1.2	LB/LD	CIRIA

Table G.1: Final Prioritised list of research projects

Appendix H – Project Summary Tables

H.1 Introduction

Summary tables are presented for each project covering the following:

1) Project Rank
2) Priority Score – The mean score as stated in Table G.1
3) Project Title - where projects have been merged from the original list on the voting forms, this has been indicated in the project title
4) Project Scope – a brief description of the main aims of the project. It should be noted that this is an outline scope only, and it is expected that a full scope will be developed when the project is carried forward.
5) EA theme – the relevant EA theme that the project will fall under
6) Output – Project outcome or product (report, guide, tool etc.)
7) Estimated cost
8) Duration
9) Beneficiaries of the project
10) Additional Sources of funding – The sources listed are additional sources of funding as discussed in Appendix I. Note that it is assumed that all projects will be additionally eligible for EA/Defra funding.
11) Outcome if not done – this gives an indication of the criticality of the project to reservoir safety
12) Project Type – High Benefit/Low Difficulty (HB/LD), High Benefit/High Difficulty (HB/HD), Low Benefit/Low Difficulty (LB/LD), Low Benefit/High Difficulty (LB/HD).

<table>
<tr><td>Rank: 1</td><td>Priority Score: 8.3</td></tr>
<tr><td colspan="2">Project Title: Dambreak A: Review latest knowledge on internal erosion leading to updated UK guidance</td></tr>
<tr><td colspan="2">Project Scope:
Internal erosion is a common cause of dam failures, yet our understanding of, and ability to predict the processes involved is relatively limited. However, during recent years there has been considerable research effort undertaken and much of this has been reported via the European Club of ICOLD. Indications are that the science and concepts being considered are tending in a similar direction to those being developed under breach formation research, and focus around the issue of soil erodibility.

With a significant volume of work reported, now is a good time to review the progress and current state of the art both with respect to scientific processes and wider management approaches. The aim here is to identify what knowledge can be used now and what issues or areas of research require further attention.

Stage 1 of this work is a scoping review, to establish current scientific and management knowledge
Stage 2 of this work would be to provide up-to-date guidance on how to manage internal erosion.</td></tr>
<tr><td>EA Theme: Sustainable Asset Management</td><td>Output: Scoping review → revised guide</td></tr>
<tr><td>Cost:
1) Review of current state of art (science and management)
2) Industry guide on internal erosion</td><td>
£ 25,000
£100,000</td></tr>
<tr><td>Duration:
1) Review of current state of art (science and management)
2) Industry guide on internal erosion</td><td>
6 months
18 months</td></tr>
<tr><td>Beneficiaries: Panel Engineers/Owners/Dam Engineers/Consultants
Guidance = All</td><td>Additional Sources of funding:
Owners</td></tr>
<tr><td colspan="2">Outcome if not done:
Fail to make use of current best practice (leading to greater costs in the long term) and continuing risk of failure due to internal erosion.</td></tr>
<tr><td colspan="2">Project type: HB/LD</td></tr>
</table>

<table>
<tr><td>Rank: 2</td><td>Priority Score: 8.1</td></tr>
<tr><td colspan="2">Project Title: Monitoring E: Review of Modes of Failure of Dams and Failure of Monitoring Techniques</td></tr>
<tr><td colspan="2">Project Scope:
A study of modes of failure and the failure of monitoring techniques is required by the profession. This would be a report on problems and case histories associated with modes of failure and then possibly a guide which would aim to provide more information to the profession on problems experienced. The guide would seek to illustrate modes of failure, detection techniques, repair techniques and also cover monitoring techniques and surveillance methods.</td></tr>
<tr><td>EA Theme: Incident Management and Community Engagement (IMCE).</td><td>Output: Report and Guide</td></tr>
<tr><td>Cost:
1) Study of failure modes and failure of monitoring techniques
2) Development of a guide on problems and case histories</td><td>
1) £ 50,000
2) £100,000</td></tr>
<tr><td>Duration:
1) Study of failure modes and failure of monitoring techniques
2) Development of a guide on problems and case histories</td><td>
12 months
12 months</td></tr>
<tr><td>Beneficiaries: Owners/Designers/Panel Engineers</td><td>Additional Sources of funding: Owners</td></tr>
<tr><td colspan="2">Outcome if not done: There is a possibility that failures might continue and that monitoring techniques might not meet the needs of the profession.</td></tr>
<tr><td colspan="2">Project type: HB/LD</td></tr>
</table>

<table>
<tr><td>Rank: 3</td><td>Priority Score: 8.0</td></tr>
<tr><td colspan="2">Project Title: Hydrology and Hydraulics F&J: Research and guidance on the behaviour of masonry spillways</td></tr>
<tr><td colspan="2">Project Scope:
Scour from spillway and outlet jets can undermine chutes and cause structural damage. There is a requirement to investigate the depth and rate of scour and to develop a method to calculate scour hole formation and dimensions. Research into the rate of sour from high velocity jets impacting masonry spillways and outlet valves. In addition, large-scale model testing to investigate the properties of water jets impacting on cohesion-less beds. Hence, the project would:

1) Review existing research on the behaviour of masonry spillways
2) Develop understanding of processes, including the role of surface gaps and develop numerical and physical models for predicting scour of spillways under high velocity flows. Utilise field observations from real incidents such as Ulley, where possible.
3) Investigate innovative materials for spillway design for increasing spillway protection and capacity.</td></tr>
<tr><td>EA Theme: Sustainable Asset Management /Modelling And Risk</td><td>Output: Report and Guidance</td></tr>
<tr><td>Cost:
1) Review existing research on the behaviour of masonry spillways
2) Develop understanding of processes, including the role of surface gaps and develop numerical and physical models for predicting scour of spillways under high velocity flows.
3) Investigate innovative materials for spillway design for increasing spillway protection and capacity.</td><td>
£50,000

£75,000

£50,000</td></tr>
<tr><td>Duration:
1) Review existing research on the behaviour of masonry spillways
2) Develop understanding of processes, including the role of surface gaps and develop numerical and physical models for predicting scour of spillways under high velocity flows
3) Investigate innovative materials for spillway design for increasing spillway protection and capacity.</td><td>

12 months

12 months

12 months</td></tr>
<tr><td>Beneficiaries: Panel Engineers/Owners/Dam Engineers/Consultants</td><td>Additional Sources of funding: Owners, EPSRC, FEMA, CIRIA</td></tr>
<tr><td colspan="2">Outcome if not done: Dams will be at risk of failure if spillways fail. Need to understand processes that will lead to failure to be able to predict them. Failure to undertake this project could lead to increased incidences of spillway failure leading to dam breach.</td></tr>
<tr><td colspan="2">Project type: HB/HD</td></tr>
</table>

Rank: 4	**Priority Score: 7.8**
Project Title: Management B: Publication – Lessons from Dam Incidents	
Project Scope: A very useful publication entitled 'Lessons from Dam Incidents' was published in the past. With the advent of incident reporting and data on a significant number of incidents, accidents and failures in the UK it is considered a worthwhile exercise to draw all this experience and knowledge together to the benefit of all in the profession.	
EA Theme: Incident Management and Community engagement (IMCE)	**Output:** Report
Cost:	£50,000
Duration:	12 months
Beneficiaries Owners/Designers/Consulting Engineers/Panel Engineers	**Additional Sources of funding**: Owners/CIRIA
Outcome if not done. Lack of knowledge transfer, failure to learn from mistakes, reoccurrence of problems.	
Project type: HB/LD	

Rank: 5	**Priority Score: 7.7**
Project Title: Embankment Dams R: Collect Geotechnical Data & Geological Data for Old Dams for EA database	
Project Scope: In order to increase our knowledge about our dams it is suggested that the EA database be extended to hold geotechnical and geological data where known. It may be possible to extend the project to include the actual investigation of a number of dams and their foundations. This project will help to increase our knowledge about the materials used in the construction of our dams and their foundations and reduce the risk of failure.	
EA Theme: Sustainable Asset Management	**Output:** Research/Database
Cost:	£100,000
Duration:	12 months
Beneficiaries Owners/Designers/Panel Engineers	**Additional Sources of funding**: Owners
Outcome if not done We will continue to lack knowledge about our dams and their foundations and therefore unable to link incidents and accidents to geotechnical/ geological data.	
Project type: HB/LD	

Rank: 6	**Priority Score: 7.2**
Project Title: Climate Change A&C: Review of **direct** Impacts of climate change on dams and reservoirs	
Project Scope: Direct climate change impacts are likely to be mainly hydrological and geotechnical and include, increased magnitude and frequency of extreme floods, changes in seasonality of floods, increased magnitude of winds on reservoirs. The impacts of climate change on reservoirs will therefore include: ▪ A requirement to increase the size and reinforce spillways to accommodate larger floods ▪ Requirement to raise dams to accommodate larger floods ▪ Larger waves in reservoirs ▪ Increased vegetation cover of earth dams ▪ Possible desiccation of earth dams ▪ Increased erosive power of rainfall ▪ Land slides and debris flow ▪ Increased sedimentation of reservoirs There is little research that have attempted to quantify these impacts on reservoirs and fewer still that have examined methods for quantifying the uncertainty in these predictions. This project proposes to examine these direct impacts in detail, and develop a framework for quantifying and incorporating climate change uncertainty into dam design. It will also be important to examine the combined effects of all of these impacts on reservoirs, so that the appropriate mitigation measures can be taken. The main aims of the project are to: 1) Review and attempt to quantify the likely impacts of climate change on dams and reservoirs; 2) Develop framework for quantifying and incorporating climate change uncertainty due to direct impacts into dam design.	
EA Theme: Modelling and Risk/Sustainable Asset Management	**Output**: Report
Cost:	£150,000
Duration:	12/36 months
Beneficiaries: Panel Engineers/Owners/Dam Engineers/Consultants/Emergency responders.	**Additional Sources of funding**: UKWIR/EC/NERC
Outcome if not done: The combination of all of the expected impacts could mean that reservoirs overtop and fail more frequently. If this project is not done, then it will be impossible to plan for the mitigation of these impacts.	
Project type: HB/HD	

<table>
<tr><td>Rank: 7</td><td>Priority Score: 7.1</td></tr>
<tr><td colspan="2">Project Title: Dambreak G,J,K & Risk and Emergency G Review of existing methods and development of guidelines for dambreak assessment</td></tr>
<tr><td colspan="2">Project Scope:
A review of existing methods and practice for dambreak modelling resulting in clear industry guidance on appropriate and current best practice for different end users and applications (and hence uncertainty) within the modelling process. This review and guidance would cover all issues relating to dambreak analysis ranging from hydrology, structure failure and breach through flood routing and mapping. This guidance would dispel any existing confusion relating to the suitability of different numerical modelling packages for dambreak applications – considering approaches from rapid through to detailed assessment. The review would also ensure that relevant knowledge from current research within a range of large flood risk management programmes (FLOODsite, FRMRCI, FRMRCII, RIMAX etc) is included along with requirements from the impending Floods Directive, (including impact assessment, critical infrastructure etc).</td></tr>
<tr><td>EA Theme: Incident Management and Community Engagement</td><td>Output: Science and Guidance</td></tr>
<tr><td>Cost:
1) Review of current state of art and production of industry best practice guidance</td><td>£85,000</td></tr>
<tr><td>Duration:
1) Review of current state of art and production of industry best practice guidance</td><td>12 months</td></tr>
<tr><td>Beneficiaries: Panel Engineers/Owners/Dam Engineers/Consultants
Guidance = All</td><td>Additional Sources of funding:
EC</td></tr>
<tr><td colspan="2">Outcome if not done:
Fail to make use of current best practice (→ costs more in the long term)</td></tr>
<tr><td colspan="2">Project type: HB/LD</td></tr>
</table>

<table>
<tr><td>Rank: 8</td><td>Priority Score: 7.1</td></tr>
<tr><td colspan="2">Project Title: Hydrology and Hydraulics A&L: Extreme flood hydrology 1) Finalise the improved methods for extreme rainfall event predictions;
2) Develop a tool for implementing the new method; 3) Develop a rainfall-runoff method appropriate for modelling extreme floods</td></tr>
<tr><td colspan="2">Project Scope:
In 2002 Defra commissioned CEH to develop an improved method for predicting extreme rainfall events. This project has derived rainfall growth curves for extreme events (>100 year), based on historical data for extreme events alone, an improvement on the existing FEH and FSR rainfall growth curves. The improved method will therefore provide increased confidence in the magnitude of extreme events. The CEH research has over run. In addition, the improved method does not include a tool with which to implement the new method. The development of a tool will be the subject of Phase II of this project which is due to be let shortly. There is feeling among the profession that the project also needs to examine whether the existing rainfall-runoff models are appropriate for use with the new extreme rainfall data. Research is currently underway in Australia and Canada to develop models that better represent the processes that are in operation during extreme flood events – instead of using models developed and validated on normal events. There needs to be some consideration of whether the existing model structures of FEH and FSR rainfall-runoff models are appropriate for use with the new extreme rainfall data. The scope of the proposed project can therefore be sub-divided into three phases:
1) Finalise the current CEH project developing the method for predicting extreme rainfall
2) Undertake Phase II of the project to develop a tool with which to apply the new method
3) Develop a rainfall-runoff method appropriate for modelling extreme floods</td></tr>
<tr><td>EA Theme: Modelling and Risk</td><td>Output: New method, Tool</td></tr>
<tr><td>Cost:
1) Finalise the current CEH project
2) Phase II – develop tool for applying extreme rainfall
3) Phase III – develop appropriate R-R model for extreme flood modelling</td><td>
£100,000
£250,000
£500,000</td></tr>
<tr><td>Duration:
1) Finalise the current CEH project
2) Phase II – develop tool for applying extreme rainfall
3) Phase III – develop appropriate R-R model for extreme flood modelling</td><td>6 months
12 months
24 months</td></tr>
<tr><td>Beneficiaries: Panel Engineers/Owners/Dam Engineers/Consultants</td><td>Additional Sources of funding:
NERC/EPSRC</td></tr>
<tr><td colspan="2">Outcome if not done: The completion of the current CEH project is imperative. The profession needs a definitive methodology for the accurate prediction of extreme flood hydrographs for the assessment of spillway capacities and dam breach assessments.</td></tr>
<tr><td colspan="2">Project type: HB/HD</td></tr>
</table>

<table>
<tr><td>Rank: 9</td><td>Priority Score: 6.9</td></tr>
<tr><td colspan="2">Project Title: Embankment Dams A,D,H&I: Monitoring and measuring methods for embankment dams</td></tr>
<tr><td colspan="2">Project Scope:

There have been developments in monitoring and measuring methods for embankment dams, including the application of geophysical techniques to monitor embankment leakage, the use of remote sensing to monitoring geotechnical parameters of dams etc. There is a need to examine these developments and assess their applicability to UK dams.

1) Review and investigate monitoring and measuring methods for embankment dams to cover: a) Monitoring and measuring of all parameters; b) Remote sensing methods for embankment dams; c) establish the need for dam instrumentation; d) rapid condition assessment of small embankments.
2) Update the guide to embankment dams to provide guidance on these methods.</td></tr>
<tr><td>EA Theme: Modelling and Risk</td><td>Output: Chapter in guide</td></tr>
<tr><td>Cost:
1) Review monitoring and measuring methods
2) Update the guide to embankment dams</td><td>
£70,000
£75,000</td></tr>
<tr><td>Duration:
1) Review monitoring and measuring methods
2) Update the guide to embankment dams</td><td>
12 months</td></tr>
<tr><td>Beneficiaries Panel Engineers/Owners/Dam Engineers</td><td>Additional Sources of funding:
Owners</td></tr>
<tr><td colspan="2">Outcome if not done: Poorly monitored dams leading to failure</td></tr>
<tr><td colspan="2">Project type: HB/LD</td></tr>
</table>

Rank: 10	**Priority Score: 6.8**
Project Title: Monitoring A,B&F: Publication – A Guide to Instrumentation and Monitoring	
Project Scope: A Guide to Instrumentation and Monitoring techniques available for dams is required. This would include a review of existing, new and emergency sensor technologies for monitoring. It would also include computational intelligence methods for early warning systems, and the decision making process for flood forecasting. This would also lead to recommendations on inspection and monitoring regimes and the frequency of inspection/examination.	
EA Theme: Modelling and risk	**Output:** Report and Guide
Cost:	£100,000
Duration:	12 months
Beneficiaries Owners/Designers/Panel Engineers	**Additional Sources of funding**: Owners
Outcome if not done: Monitoring and surveillance is one of the most important areas of work to ensure reservoir safety. Lack of knowledge in this are could lead to failures.	
Project type: HB/LD	

Rank: 11	**Priority Score: 6.8**
Project Title: **Dambreak I:** Training in dambreak analysis and evaluation	
Project Scope: Dambreak analysis is a specialist area where there is often little data against which to validate modelling results. Studies show a far greater dependence of results upon modeller skills and judgement than traditional river modelling. Training is proposed, aimed at improving understanding and skills of both modellers and engineers likely to be required to validate or accept dambreak modelling results.	
EA Theme: Modelling And Risk / Incident Management and Community Engagement	**Output:** Training
Cost: 1) Training in dambreak modelling	£20,000
Duration: 1) Training in dambreak modelling	9 months
Beneficiaries: Panel Engineers/Owners/Dam Engineers/Consultants Panel engineers / consultants → owners	**Additional Sources of funding**: Owners
Outcome if not done: Poorer quality studies	
Project type: HB/LD	

<table>
<tr><td>Rank: 12</td><td>Priority Score: 6.7</td></tr>
<tr><td colspan="2">Project Title: Risk and Emergency E&F Training for event management</td></tr>
<tr><td colspan="2">Project Scope:
To provide practical training and guidance on event management – what to expect.
Training to draw on the experience of those who have been involved in past events to provide practical training and guidance on what to expect and how to react during an extreme event. A key aspect to event management is appreciation and effective communication of risks, whether between professionals or to the general public. A review of best practice in risk communication will underpin preparation of the training material. The output will provide a guidance document and a training programme.</td></tr>
<tr><td>EA Theme: IMCE</td><td>Output: Research and guidance</td></tr>
<tr><td>Cost:
1) Review of risk communication and preparation of training material</td><td>£100,000</td></tr>
<tr><td>Duration:
1) Review of risk communication and preparation of training material</td><td>12months</td></tr>
<tr><td>Beneficiaries: Panel Engineers/Owners/Dam Engineers/Consultants
Panel Engineers/Owners/Dam engineers / Consultants</td><td>Additional Sources of funding:
Owners</td></tr>
<tr><td colspan="2">Outcome if not done:
Not best practice, engineers not trained to meet the demands of emergency situations which could lead to failures.</td></tr>
<tr><td colspan="2">Project type: HB/LD</td></tr>
</table>

Rank:13	**Priority Score: 6.9**
Project Title – Appurtenant Structures E: Guide on the Inspection, Monitoring, Maintenance and Repair of Tunnels	
Project Scope: Many of the dams in the UK have tunnels associated with drawoffs, spillways etc. Some of these tunnels have experienced problems or movement. As the age of our dams increase the problem will become more severe. A guide on the inspection, monitoring, maintenance and repair of tunnels will provide Inspecting Engineers with a means of comprehensively assessing and mitigating problems associated with the aging of these structures.	
EA Theme: Sustainable Asset Management	**Output**: Guide
Cost:	£50,000
Duration:	12 months
Beneficiaries Panel Engineers/Owners/Consultants	**Additional Sources of funding**: CIRIA
Outcome if not done: The amount of damage to the tunnels associated with our dams will increase. Increased risk of failure with ageing	
Project type: HB/LD	

Rank: 14	**Priority Score: 6.9**
Project Title –Embankment Dams P: Compendium of design and assessment of embankment dams – collaboration of work	
Project Scope: A design compendium/manual aimed at UK practice is required to capture the current 'state of art' design practised by the profession. The manual would seek to record all aspects of good design for future generations	
EA Theme: Sustainable Asset Management	**Output**: Guide
Cost:	£75,000
Duration:	12 months
Beneficiaries Panel Engineers/Owners/Consultants	**Additional Sources of funding**: CIRIA
Outcome if not done: Poor design and failures	
Project type: HB/LD	

<table>
<tr><td>Rank: 15</td><td>Priority Score: 6.6</td></tr>
<tr><td colspan="2">Project Title: Hydrology & Hydraulics H: Revise CIRIA guide ‘Design of Flood Storage Reservoirs – B14’</td></tr>
<tr><td colspan="2">Project Scope:
The CIRIA Guide to the ‘Design of flood storage reservoirs’ B14 (1993) includes practical guidance on the design of storage reservoirs for flood control in partly urbanised catchment areas. It includes guidance on hydrological procedures, guidance on embankment and overflow structures and the selection of flow control devices and guidance on operation and maintenance issues.

A number of drivers will impact on the requirement for, and the management and maintenance of flood storage reservoirs in the future. Firstly, given the climate change predictions for wetter winters and drier summers, it is possible that more flood detention reservoirs will need to be built to mitigate the increased flood risk. In addition, shorter wetter winters and longer drier summers could lead to a change in the filling and drawdown sequence of supply reservoirs so there is the potential that the ‘excess’ water during the winter will need to be stored to meet deficits during summer. This could lead to a requirement to construct new, or modify existing, reservoirs for both flood retention during winter and water supply during summer. Thus operating regimes of existing reservoirs could also change to meet changes in the timing of demand (a possible indirect impact of climate change), and also to provide flood retention benefits and prevent overtopping. Hence existing reservoirs may need to be modified to meet multiple uses including flood detention. It will therefore be important to examine reservoir drawdown capacities and the capacity and integrity of low level outlets. Other drivers such as the Water Framework Directive will additionally require all reservoirs, including flood storage reservoirs to meet enhanced water quality criteria. This will include the requirement to include structures to provide compensation flow downstream of all reservoirs. The project comprises the following components:
1) Revision of existing guide to the design, construction, operation and maintenance of flood detention reservoirs to include climate change, legislative change and future development issues.
2) Include guidance on the methods for adapting existing storage reservoirs for flood detention including drawdown capacities and the integrity of low level valves, prevention of cracking of cores when reservoirs are empty for long periods and optimising real time control of maximise benefits.</td></tr>
<tr><td>EA Theme: Sustainable Asset Management</td><td>Output: Guidance</td></tr>
<tr><td>Cost:
1) Revision of existing guide
2) Update guide to include adaptation of storage reservoirs</td><td>
£55,000
£30,000</td></tr>
<tr><td>Duration:
1) Revision of existing guide
2) Update guide to include adaptation of storage reservoirs</td><td>
3 months
6 months</td></tr>
<tr><td>Beneficiaries: Panel Engineers/Owners/Dam Engineers/Consultants/Emergency responders/Planners (involved in SUDS designs).</td><td>Additional Sources of funding: CIRIA</td></tr>
<tr><td colspan="2">Outcome if not done: Continued inconsistency in standards and design criteria applied to flood detention reservoirs.</td></tr>
<tr><td colspan="2">Project type: HB/LD</td></tr>
</table>

Rank: 16	**Priority Score: 6.5**
Project Title – Embankment Dams F: Methods of Raising Embankment Dams	
Project Scope: At a time when water resources are becoming scarcer and when the demand for water is increasing in some areas there will be more and more need to raise existing dams. A number of dams have been raised and valuable lessons can be learned from those exercises. It is likely that the output would be a Guide which not only deals with the engineering issues but includes the aspects of planning, environmental assessment etc.	
EA Theme: Sustainable Asset Management	**Output**: Guide
Cost:	£60,000
Duration:	12 months
Beneficiaries Designers/Consulting Engineers/Owners/Panel Engineers	**Additional Sources of funding**: Owners/CIRIA
Outcome if not done: Lack of transfer of knowledge and experience.	
Project type: HB/LD	

<table>
<tr><td>Rank:17</td><td>Priority Score: 6.5</td></tr>
<tr><td colspan="2">Project Title: Dambreak D, E & F: Dambreak analysis – Structure failure mechanisms</td></tr>
<tr><td colspan="2">Project Scope:
In order to undertake a dambreak analysis it is necessary to predict how the dam might partially or catastrophically fail. The degree of uncertainty related to this prediction is high. Improving our knowledge of failure processes will both reduce the uncertainty inherent within a dambreak analysis and also improve our ability to design, construct and manage a dam in a manner less likely to fail – i.e. reduce the risk of failure.

Analysis of three processes leading to failure are identified here. These are wave action, leading to overtopping; erosion of grass through overtopping and overflowing; and the science of soil state and erodibility

1) Waves: review and update guidance on wind and waves over reservoirs in light of recent research and climate change predictions
2) Grass: revisit the CIRIA design data (limited), explore application of the wave overtopping simulator to validate and extend the grass performance data
Soils: Review existing R&D on soil erodibility; establish a UK database on soil erodibility and provide guidance on implications for failure modes, including consideration of climate change effects</td></tr>
<tr><td>EA Theme: SAM</td><td>Output: Scope; Science; Guidance;</td></tr>
<tr><td>Cost:
1) Analysis of waves
2) Analysis of grass
3) Analysis of soils</td><td>
£40,000
£40,000
£40,000</td></tr>
<tr><td>Duration:
1) Analysis of waves
2) Analysis of grass
3) Analysis of soils</td><td>
12 months
12 months
12 months</td></tr>
<tr><td>Beneficiaries: Panel Engineers/Owners/Dam Engineers/Consultants
Panel Engineers / Consultants / Owners</td><td>Additional Sources of funding:
EPSRC/NERC/FEMA/DSIG/EC</td></tr>
<tr><td colspan="2">Outcome if not done: Inappropriate design and management operations</td></tr>
<tr><td colspan="2">Project type: HB/HD</td></tr>
</table>

Rank: 18	**Priority Score: 6.4**
Project Title – Embankment Dams N: Update the Guide to Small Embankment Dams	
Project Scope: The Guide to the Design of Small Embankment Dams was written in 1996. There is a need to edit, revise and update the Guide to reflect current practice. This could reflect aspects of climate change, hydrology, and knowledge from incidents and accidents.	
EA Theme: Sustainable Asset Management	**Output:** Updated Guide
Cost:	£30,000
Duration:	9 months
Beneficiaries: Small Dam Owners and Developers/Designers	**Additional Sources of funding**: CIRIA
Outcome if not done: Small dams will continue to be built in accordance with the old Guides with designs/constructions which could be unsuitable.	
Project type: HB/LD	

Rank: 19	**Priority Score: 6.4**
Project Title: **Hydrology and Hydraulics K:** Update the publication 'Floods and Reservoir Safety: An Engineering Guide' manual	
Project Scope: The floods and reservoir safety manual is a key guidance document for the assessment of flood risks to reservoirs and the design and maintenance of spillways. The following aspects of the guide need to be revised and updated: 1) Criteria for the categorisation of reservoirs. A revision of the criteria for categorisation of reservoirs is imminent and will reflect a move away from simply categorisation on the basis of loss of life. Instead categorisation will now include other consequences such as a. Disruption to critical utilities due to failure of critical infrastructure b. Disruption to commercial and other activity on a large scale, for example, due to closure of essential transport links. 2) Hydrological assessments. There is currently some confusion about the appropriate method to use for deriving the PMF flood hydrograph. This confusion arose following the release of FEH and was the impetus for the current CEH project to develop a method for extreme rainfall prediction. Depending on the outcome of projects A and B, there may be new methodologies available for deriving the design flood, and there may be changes to the design flood of interest for each category. 3) Guidance on wave surcharge calculations are expected to change to include more complex calculations to take account of complex wave interference due to complex reservoir and wave wall geometries. All of these developments will need to be incorporated within a revised 'Floods and Reservoir Safety: An Engineering Guide' Manual. This project therefore assumes that Hydrology and Hydraulics projects A, B, and G are completed.	
EA Theme: Sustainable Asset Management / Modelling and Risk	**Output:** Updated Guide
Cost:	£60,000
Duration:	12 months
Beneficiaries: Panel Engineers/Owners/Dam Engineers/Consultants	**Additional Sources of funding**: CIRIA/Owners
Outcome if not done: The Floods and Reservoir Safety Manual is a comprehensive guide for the assessment of flood risks from reservoirs, and plays a vital role in the assessment of those risks. If this document is not updated to reflect current best practice there will be inconsistencies in the application of best practice which could lead to inaccurate assessments being carried out.	
Project type: HB/LD	

Rank:20	**Priority Score: 6.4**
Project Title: Embankment Dams B: Retrofitting of Filters to Cope with Internal Erosion	
Project Scope: As a result of risk assessment techniques being applied to dams, internal erosion is often defined as the most likely mode of failure. One of the ways to reduce the likelihood of failure is to retrofit filters to existing dams. Direction in the form of a review or Guide is needed to assist in the retrofitting of filters in dams and should include methods of investigation, design and construction.	
EA Theme: MAR and SAM	**Output:** Review
Cost:	£45,000
Duration:	18 months
Beneficiaries Small Dam Owners and Developers/Designers	**Additional Sources of funding**: EC/DSIG/FEMA
Outcome if not done People may place filters which are ineffective which could result in failures	
Project type: HB/HD	

Rank: 21	**Priority Score: 6.4**
Project Title: Appurtenant Structures G: Review Alternative Materials & Techniques for Embankment Dam Auxiliary Spillways	
Project Scope: In the past a number of guidance documents have been produced, relating to the design of reinforced grass spillways and stepped block spillways for example. It is recommended that this Guidance be reviewed and if necessary revised to include the wealth of experience that has been gained and also to report on 'new' materials such as RCC and different precast concrete blocks. It may be necessary, and it would be advantageous if more research could be done into the erosion resistance of grass.	
EA Theme: Sustainable Asset Management	**Output:** Report/Guide
Cost: 1) If just Guide 2) If research	 £70,000 £250,000
Duration: 1) If just Guide 2) If research	 12 months 24 months
Beneficiaries: Owners/Designers/Consulting Engineers/Panel Engineers	**Additional Sources of funding**: FEMA/DSIG/EC
Outcome if not done Spillway and spillway systems may be designed that are not fit for purpose and could result in failure of the spillway systems.	
Project type: HB/HD	

Rank: 22	**Priority Score: 6.3**
Project Title: Appurtenant Structures D&C: A Guide to Mechanical and Electrical Equipment in Dams	
Project Scope: A Guide to the Mechanical and Electrical Equipment in Dams is required. This Guide would look at M&E equipment, automated control, upgrading methods, and rehabilitation methods. The Guide would include a database of case studies, on rehabilitation works, lessons learned and costs.	
EA Theme: Sustainable Asset Management	**Output**: Guide
Cost:	£75,000
Duration:	12 months
Beneficiaries: Owners/Designers/Panel Engineers	**Additional Sources of funding**: CIRIA
Outcome if not done: Mistakes will continue to be made with M&E equipment/upgrading and rehabilitation works.	
Project type: HB/LD	

Rank: 23	**Priority Score: 6.3**
Project Title: Management A&G: Development of UK Based Risk Assessment Methodology	
Project Scope: An 'Interim Guide to Quantitative Risk Assessment' has been written and published but it has not been well received by the profession and received criticism for being flawed, unnecessarily complex and not giving reproducible results. A complete revision is required. A scoping exercise to define the extent of the project has already been let and this will lead to work being defined to produce a new methodology to risk assessment for the UK.	
EA Theme: Modelling and Risk	**Output:** Guide
Cost:	£150,000
Duration:	18 months
Beneficiaries Owners/Consultants/Panel Engineers	**Additional Sources of funding**: Owners
Outcome if not done: The UK is moving to a risk based approach and the lack of a system of risk assessment will result in the lack of a useful tool to use in the area of reservoir safety.	
Project type: HB/HD	

Rank: 24	**Priority Score: 6.3**
Project Title – Concrete Dams H & Appurtenant Structures J: Research to identify Failure Modes and Processes	
Project Scope: Understanding failure modes is a fundamental issue for risk-based analysis. Identification of failure modes and processes for concrete dams and appurtenant structures gives us a means of learning from our mistakes, identifying bad and good design features, and assets with lessons to be learned for monitoring and surveillance. A review of the existing research on failure modes followed by research into failure modes and processes is required.	
EA Theme: MAR & SAM	**Output:** Report or Guide
Cost:	£100,000
Duration:	12 months
Beneficiaries Owners/Designers/Panel Engineers	**Additional Sources of funding**: FEMA/DSIG/EC
Outcome if not done. Lack of knowledge could lead to incidents/accidents based on poor design.	
Project type: HB/LD	

<table>
<tr><td>Rank: 25</td><td>Priority Score: 6.1</td></tr>
<tr><td colspan="2">Project Title: Concrete Dams B: Manual on the degradation and repair of concrete dams</td></tr>
<tr><td colspan="2">Project Scope:
Manual on degradation and repair of concrete dams to include: 1) Review methods for maintenance & repair of concrete dams, & techniques for assessing their impact on dam maintenance, operation & performance; 2) Review of published work on physical and chemical degradation phenomena in dam concrete & techniques for identifying degradation and its causes; 3) Research to develop techniques to assess material properties of dam concrete in-situ (on existing dams) & in the laboratory on specimens from dams; 4) Review of non-destructive testing techniques & their applicability to dams, leading to a guide or to identify appropriate research.</td></tr>
<tr><td>EA Theme: SAM</td><td>Output: Report</td></tr>
<tr><td>Cost:
1) Review maintenance and repair methods
2) Review published work on physical and chemical degradation
3) Research to develop techniques to assess material properties in situ and in the laboratory
4) Review of non-destructive testing techniques and applicability</td><td>
1) £30,000
2) £50,000
3) £100,000
4) £50,000</td></tr>
<tr><td>Duration:
1) Review maintenance and repair methods
2) Review published work on physical and chemical degradation
3) Research to develop techniques to assess material properties in situ and in the laboratory
4) Review of non-destructive testing techniques and applicability</td><td>
1) 6 months
2) 6 months
3) 12 months
4) 6 months</td></tr>
<tr><td>Beneficiaries: Panel Engineers/Owners/Dam Engineers/Consultants</td><td>Additional Sources of funding: CIRIA</td></tr>
<tr><td colspan="2">Outcome if not done: Ageing dams will pose an increasing risk to the public.</td></tr>
<tr><td colspan="2">Project type: HB/LD</td></tr>
</table>

Rank: 26	**Priority Score: 6.0**
Project Title: Appurtenant Structures B: Review and Update of CIRIA Guide to Valves, Pipe work and Associated Equipment	
Project Scope: A publication entitled 'valves, pipe work and associated equipment in dams; A Guide to Condition Assessment has already been produced. A number of elements have changed/improved in the interim period and it is considered that the Guide can be updated and extended to include guidance on paintwork and protection systems, failure modes, selection guidance for gates and valves and renovation and replacement technique.	
EA Theme: SAM	**Output:** Guide
Cost:	£60,000
Duration:	12 months
Beneficiaries: Owners/Consultants/Panel Engineers/Manufacturers	**Additional Sources of funding**: CIRIA/Owners
Outcome if not done: Valve and penstock installations will be at risk if increased occurrence of failure or malfunction. The failure to collect and disseminate information and experience will lead to lack of knowledge transfer.	
Project type: HB/LD	

Rank: 27	**Priority Score: 6.0**
Project Title: Concrete A: Review and Update of 1996 Engineering Guide to the Safety of Concrete and Masonry Dams	
Project Scope: An 'Engineering Guide to the Safety of Concrete and Masonry Dams' was produced in 1996. It is considered that it would be beneficial to revise, edit and update the Guide with perhaps chapters on failure modes, deterioration processes and perhaps even something on RCC dams.	
EA Theme: SAM	**Output**: Guide
Cost:	£50,000
Duration:	12 months
Beneficiaries Owners/Designers/Consulting Engineers/Panel Engineers	**Additional Sources of funding**: CIRIA/Owners
Outcome if not done: Adverse effect on knowledge of the failure modes and processes associated with our concrete dams.	
Project type: HB/LD	

Rank:28	**Priority Score: 6.0**
Project Title: Embankment S: Embankment and Grout Curtains & Cutoffs	
Project Scope: In recent years a number of new methods of forming cut-offs in a variety of depths in a variety of materials have been developed. In addition there have been advances in the development of grout materials and grouting techniques. The profession feels there is a need for a document which brings all of the 'state of the art' information brought together. There is also a need to study whether grout curtains deteriorate.	
EA Theme: MAR & SAM	**Output:** Research
Cost: Phase I - Guide Phase II - Research into deterioration	 £50,000 £150,000
Duration: Phase I - Guide Phase II - Research into deterioration	 12 months 36 months
Beneficiaries Designs/Panel Engineers/Owners	**Additional Sources of funding**: CIRIA/EPSRC/NERC/
Outcome if not done. Grout curtains will deteriorate with time leading to increased leakage or the wrong methods and materials might be used.	
Project type: HB/LD	

Rank: 29	**Priority Score: 6.0**
Project Title: **Risk and Emergency B:** Review science and practice supporting emergency planning for dams (including UK, EC and US projects)	
Project Scope: A review of science and practice supporting emergency planning for dams is proposed. There have been a considerable number of programmes during the past decade, including UK, EC and US projects, which have included fundamental research through to implementation in practice. The UK could learn by reviewing proposed approaches and how these have or have not worked well in practice. This review would identify best practice as well as gaps in knowledge.	
EA Theme: IMCE	**Output:** Review/best practice guide
Cost: 1) International review of emergency planning theory and practice	£30,000
Duration: 1) International review of emergency planning theory and practice	12 months
Beneficiaries: Panel Engineers/Owners/Dam Engineers/Consultants Panel Engineers/Owners//Consultants	**Additional Sources of funding**: FEMA/DSIG/EC
Outcome if not done: Duplication of effort; not best practice;	
Project type: LB/LD	

Rank: 30	**Priority Score: 5.9**
Project Title: Monitoring D: Slip Lining of Conduits	
Project Scope: A number of techniques have been developed in recent years for lining of conduits either as a structural liner or a means of preventing leakage. There may be a need for research into new technologies but otherwise there is a need to bring together the methods and techniques in a single document.	
EA Theme: Sustainable Asset Management	**Output:** Research
Cost:	£30,000
Duration:	12 months
Beneficiaries EA/Defra/Owners/Manufacturers	**Additional Sources of funding**: NERC
Outcome if not done. Without this summary the wrong technique may be employed.	
Project type LB/LD	

Rank: 31	**Priority Score: 5.9**
Project Title: Embankment Dams J: Decommissioning of Dams	
Project Scope: In a number of areas around the world a need to decommission dams has arisen. This may be because of a change of circumstance leading to the removal of the need for the dam, a replacement scheme, environmental concerns, or even safety concerns. In this regard it is necessary to decommission/demolish/remove the dam but this is often not an easy process. Aspects that need to be considered include floods, environmental protection and enhancement, appropriate materials, as well as planning and environmental issues and public safety etc. The proposed research would be on Guide to the Decommissioning of Dams.	
EA Theme: Sustainable Asset Management	**Output:** Guide
Cost:	£75,000
Duration:	15 months
Beneficiaries Owners/Consultants/Panel Engineers/Environmentalists	**Additional Sources of funding**: FEMA/DSIG/Owners/CIRIA
Outcome if not done We will continue to carry out schemes which perhaps do not meet the most appropriate needs of reservoir safety, environmental aspects etc.	
Project type: LB/LD	

<table>
<tr><td>Rank: 32</td><td>Priority Score: 5.8</td></tr>
<tr><td colspan="2">Project Title: Hydrology and Hydraulic B: Review methods for predicting return period of events > 10,000 years to support risk-based assessments</td></tr>
<tr><td colspan="2">Project Scope:
The UK dams profession is moving towards a risk-based approach to dams safety assessment. A risk-based approach requires an assignment of probability to all components of dam safety. The PMF continues to be the standard design flood event for high risk dams, but there is no return period associated with it. In other countries around the world, the T-year flood (normally the 10,000 year) is being used in preference to the PMF as it provides a probability of occurrence which can be used in risk based assessments. In other countries, research is being conducted to try to assign meaningful probabilities to the PMF (such as the use of paleohydrology in the USA, multi-fractals and GIS applications). There is also debate about whether the PMF is an overly conservative design flood to use and whether the extremely small risk of failure justifies the large expenditure for spillway design to accommodate extreme floods. The use of single peak events such as the PMF and T-year design hydrographs as opposed to multi-peaked storms is also being examined. The scope of the project being proposed here is as follows:
1) Phase I – Examine the feasibility of retaining the PMF as the design flood of interest in light of the move towards a risk-based approach.
2) Phase II – Review methods for extending the T-year flood frequency curve beyond the 10,000 year event.
3) Phase III –Develop an appropriate method/tool for extending the T-year rating curve beyond the 10,000 year return period. Including an assessment of the uncertainty in estimation of extreme floods.</td></tr>
<tr><td>EA Theme: MAR</td><td>Output: Scoping review/review of methods/tool</td></tr>
<tr><td>Cost: 1) Phase I Feasibility of retaining the PMF
2) Phase II – Review methods for extending the T-year FFC.
3) Phase III –Develop an appropriate method/tool for extending the T-year rating curve beyond the 10,000 Year.</td><td>£50,000
£100,000
£250,000</td></tr>
<tr><td>Duration: 1) Phase I Feasibility of retaining the PMF
2) Phase II – Review methods for extending the T-year FFC
3) Phase III –Develop an appropriate method/tool for extending the T-year rating curve beyond the 10,000 year</td><td>6 months
12 months
24 months</td></tr>
<tr><td>Beneficiaries: Panel Engineers/Owners/Consultants/Emerg responders</td><td>Additional Sources of funding: NERC/ FEMA/DSIG/Owners</td></tr>
<tr><td colspan="2">Outcome if not done: It would be impossible to implement a truly risk-based approach to dam safety assessment without a probability being assigned to the design event.</td></tr>
<tr><td colspan="2">Project type: LB/HD</td></tr>
</table>

Rank: 33	**Priority Score: 5.7**
Project Title: **Dambreak B&C**: Understanding and reducing uncertainty within dambreak analyses	
Project Scope: Dambreak analyses require an assessment of very rare and extreme flood conditions. Typically, there is little data or information upon which to calibrate or validate models, whether relating to structure failure processes, flood routing or flood impact. Hence dambreak analyses require considerable judgement and expertise to be applied, as well as use of appropriate numerical models. The acceptable degree of uncertainty within a dambreak analysis depends upon the end user and application. Some uses will require a greater resolution and accuracy of result than others. Currently, little is known about the real magnitude of uncertainty within the various stages of a dambreak analysis, other than a perception that there could be considerable margins. The work proposed here is to establish the magnitude of uncertainty within the various stages of a dambreak analysis and identify how to estimate and transfer these uncertainties between the various stages so that an overall understanding of uncertainty associated with an overall dambreak analysis may be presented to the end user. This work will include an assessment of the different levels of uncertainty associated with the different analysis approaches currently taken, identify where inconsistent levels of analysis may be often implemented. The project output would be a technical report that may be used to update guidance on dambreak modelling and advise end users on appropriate levels of analysis and uses of dambreak results.	
EA Theme: IMCE	**Output:** Research/Guidance
Cost: 1) Investigation of uncertainty within dambreak analyses	 £120,000
Duration: 1) Investigation of uncertainty within dambreak analyses	 12 months
Beneficiaries: Panel Engineers/Owners/Dam Engineers/Consultants Owners	**Additional Sources of funding**: EC/DSIG/FEMA
Outcome if not done: Inappropriate use of dambreak analysis data	
Project type: LB/HD	

Rank: 34	**Priority Score: 5.5**
Project Title – Embankment Dams C: Guide to the Safety of Embankment Dams	
Project Scope: A Guide to the Safety of Embankment Dams was written in 1990 and revised and edited with a second edition published in 1999. With advances in a number of fields including instrumentation and monitoring, surveillance, remedial works and information for incidents and accidents, it is considered necessary to edit and revise the current document and produce a third version.	
EA Theme: SAM	**Output**: Updated Guide
Cost:	£75,000
Duration:	12 months
Beneficiaries Panel Engineers/Owners/Dam Engineers	**Additional Sources of funding**: CIRIA
Outcome if not done: Adverse effect on knowledge of techniques affecting safety of our dams.	
Project type: LB/LD	

Rank: 35	**Priority Score: 5.4**
Project Title: Management C: Guidance on Public Safety of Dams	
Project Scope: A number of initiatives to increase public safety at dams, particularly in regard to education of the public with regard to risks, communication strategies, signage etc. are being undertaken around the world (ICOLD, OPG, Vattenfall). This applies particularly to situations where water levels can vary dramatically as a result of releases of water for example, when associated with hydro plants and is particularly important for owners and operators to avoid causing death and injury and having legal claims made against them.	
EA Theme: Incident Management and Community Engagement	**Output:** Guide
Cost:	£35,000
Duration:	18 months
Beneficiaries Owners/Designers	**Additional Sources of funding**: EC/DSIG/Owners
Outcome if not done Public and owners at risk	
Project type: LB/LD	

Rank: 36	**Priority Score: 5.3**
Project Title: Dambreak H: Dambreak analysis – Data and forensics	
Project Scope: Conditions arising during a dambreak are typically very extreme and can be orders of magnitude larger than a natural flood event for that location. Predicting dambreak conditions (as part of a dambreak analysis) is difficult and requires considerable judgement since models are often being applied to situations where little or no data exists for validation. Hence, when a dambreak does occur, it provides an extremely rare and useful opportunity to collect data on all aspects of the process, from structure failure, through flood routing to flood impacts. However, during an event, attention is typically paid to emergency management activities rather than data collection. Immediately after an event, attention is paid to damage limitation and recovery rather than data collection. The proposal is to establish a team of experts with the objective of analysing extreme events and collecting data. Permissions and funding would be agreed in principal allowing the team to take immediate action and gain immediate access during an event. This will permit the collection of valuable knowledge which will help improve understanding and management of later events as well as the accuracy of dambreak analyses.	
EA Theme: IMCE / MAR	**Output**: Data
Cost: Forensics team and event analysis	 £100,000 (assuming 3 incidents/year)
Duration: Forensics team and event analysis	 Ongoing
Beneficiaries: Panel Engineers/Owners/Dam Engineers/Consultants/All	**Additional Sources of funding**: EC/DSIG/FEMA
Outcome if not done: Failure to learn from past experience	
Project type: LB/HD	

Rank:37	**Priority Score: 5.3**
Project Title – Appurtenant Structures H: Review & Guidance on Techniques for Installation and Operation of Draw off System	
Project Scope: Owners and dam designers and Panel Engineers face problems associated with releasing large quantities of water. The demands are either due to the demand from Panel Engineers to reduce the water level by up to 1 metre within 1 day assuming no inflow on the demand via European Union directives to provide a freshet flow. These freshet flows are supposed to mimic the 'normal' environmental changes in flow. The project seeks to give guidance on replacing/ upgrading draw off systems.	
EA Theme: Strategy and Policy Development	**Output:** Report/Guide
Cost:	£75,000
Duration:	12 months
Beneficiaries: Owners/ EA	**Additional Sources of funding**: CIRIA/Owners
Outcome if not done The UK may not meet the EU directives and also owners will seek to have increased drawdown facilities but fail to meet requirements.	
Project type: LB/LD	

<table>
<tr><td>Rank: 38</td><td>Priority Score: 5.1</td></tr>
<tr><td colspan="2">Project Title: Hydrology & Hydraulics G&I: Waves on reservoirs – 1) Wave height prediction in shallow water where interference of wave trains occurs; 2) wave impact forces on wave walls – in particular ‘dry stone’ walls and adequacy of wave walls to withstand waves and; 3) Guidance on wave wall protection.</td></tr>
<tr><td colspan="2">Project Scope:
Floods and Reservoir Safety (1996) currently provides guidance on the calculation of wave height for reservoirs with wave walls of simple configurations. This can be supplemented with Wallingford report SR 459 – Reservoir Dams: wave conditions, wave overtopping and slab protection (1996) which provides further guidance. While these documents provide a good starting point for reference, they do not provide guidance on complex reservoir and/or wave wall geometries. Continued use of the guides as they stand, could lead to serious under-estimation of wave height. The scope of the project is therefore, broadly to revise the current guidance contained with Floods and Reservoir Safety (1996) to address the following:
1) Guidance on wave height prediction in shallow and deep water for different reservoir and wave wall geometries.
2) Review wave impact forces on wave walls and provide guidance on acceptable values, in order to access the adequacy of wave walls to withstand impacts.
3) Review existing research and update guidance on wave wall protection.</td></tr>
<tr><td>EA Theme: Modelling and Risk</td><td>Output: Report/Guide</td></tr>
<tr><td>Cost:
1) Wave height prediction for different reservoir and wave wall geometries.
2) Guidance on wave impact forces on wave walls and acceptable
3) Review existing research and update guidance on wave wall protection</td><td>
£30,000
£70,000
£50,000</td></tr>
<tr><td>Duration:
1) Wave height prediction for different reservoir and wave wall geometries.
2) Guidance on wave impact forces on wave walls and acceptable
3) Review existing research and update guidance on wave wall protection</td><td>
12 months
12 months
6 months</td></tr>
<tr><td>Beneficiaries: Panel Engineers/Owners/Dam Engineers/Consultants/Emergency responders</td><td>Additional Sources of funding: EPSRC/NERC/EC/CIRIA/FEMA/DSIG</td></tr>
<tr><td colspan="2">Outcome if not done: Continued under-estimation of wave height and continued risk of overtopping due to incorrect wave surcharge predictions leading to incorrect wave wall design heights.</td></tr>
<tr><td colspan="2">Project type: LB/LD</td></tr>
</table>

Rank: 39	**Priority Score: 5.1**
Project Title: Management E: Management Communication Strategy	
Project Scope: A communication strategy is required to cover initiatives, developments and relevant research across the EA, Defra and all relevant bodies that will affect dam safety.	
EA Theme: Incident Management and Community Engagement (IMCE)	**Output:** Strategy
Cost:	£20,000
Duration:	12 months
Beneficiaries Owners/Regulators	**Additional Sources of funding**: CIRIA
Outcome if not done. There will continue to be a lack of knowledge and communication.	
Project type: LB/LD	

Rank: 40	**Priority Score: 4.7**
Project Title: Management D&G: Development of a Web Based GIS Management System of Dams	
Project Scope: As the power of GIS and data management systems increases it is considered that there may well be application of the techniques to manage systems of dams. This management system will include a database on dams within which data will be held and collated. This database will support QRA validation. This needs to be developed as a management tool.	
EA Theme: Strategy and Policy Development / SAM	**Output:** Tool
Cost:	£200,000
Duration:	24 months
Beneficiaries Owners	**Additional Sources of funding**: Owners
Outcome if not done: Without tools such as this owners will continue with their current systems and may not react as quickly as they might.	
Project type: LB/HD	

Rank: 41	**Priority Score: 4.7**
Project Title: Concrete Dams C&D: Non-linear numerical analysis of concrete dams and their foundations	
Project Scope: Sophisticated modelling has traditionally been done in US and the rest of Europe, but less so in the UK. There is uncertainty as to the applicability of these models. The UK could benefit from getting more involved in this type of research in the future. However, it will be essential to first undertake a review of the available techniques for non-linear numerical material and interface modelling of significant factors for foundation rocks and dam-foundation interfaces (e.g. uplift, joint sliding and separation) to assess the applicability to the UK.	
EA Theme: MAR & SAM	**Output:** Review
Cost:	£120,000
Duration:	18 months
Beneficiaries	**Additional Sources of funding**: EPSRC/NERC
Outcome if not done:	
Project type: LB/LD	

Rank: 42	**Priority Score: 4.5**
Project Title: Appurtenant Structures A: Review tools to reduce O&M costs for extended life of spillways	
Project Scope: With recent problems at spillway a report is required to give information on inspections – how, what to look for, when/frequency, and repair methods to minimise O & M costs at spillways and extend the life of our spillways.	
EA Theme: SAM	**Output:** Report
Cost:	£40,000
Duration:	12 months
Beneficiaries: Owners/Panel Engineers/Designers	**Additional Sources of funding**: CIRIA/Owners
Outcome if not done: We could get continuing damage to our spillways.	
Project type: LB/LD	

Rank: 43	**Priority Score: 4.5**
Project Title – Climate Change B&C, Embankment K: Review of **indirect** Impacts of climate change on dams and reservoirs	
Project Scope: There are a number of potential indirect climate change impacts that could affect dams safety in the future, including: 1. Changes in the timing of demand due to changes in length of wet and dry periods. 2. Decreasing yield from all sources leading to increased pressures on existing resources and potentially the need to build new reservoirs 3. Increased requirement for renewable energy leading to the building of new or retrofitting of old dams for hydroelectric power. There is a need to understand and quantify these impacts as well as the uncertainty in the predictions in order to plan for them. In addition there needs to be guidance on methods of incorporating these likely impacts into dam assessment, design, maintenance and planning. There are similar requirements for research into some of the indirect climate change impacts on water resources and it would be useful if any research being done under dam safety, is in line with other relevant research. The main aims of the project are to: 1) Review and attempt to quantify the likely indirect impacts of climate change on dams and reservoirs; 2) Develop a framework for quantifying and incorporating climate change uncertainty due to indirect impacts into dam design.	
EA Theme: SAM & MAR	**Output:** Report
Cost:	£150,000
Duration:	24 months
Beneficiaries: Panel Engineers/Owners/Dam Engineers/Consultants/Emergency responders/Planners/Water resources planners.	**Additional Sources of funding**: UKWIR/EC
Outcome if not done: The combination of all of the expected indirect impacts could mean that reservoirs overtop and fail more frequently. If this project is not done, then it will be impossible to plan for the mitigation of these impacts.	
Project Type: LB/HD	

<table>
<tr><td>Rank:44</td><td>Priority Score: 4.5</td></tr>
<tr><td colspan="2">Project Title: Hydrology and Hydraulics C,D&E: Application of Reservoir flood forecasting and control to UK reservoirs</td></tr>
<tr><td colspan="2">Project Scope:
There is a requirement under the EU Floods Directive (EUFD) and the UK Civil Contingencies Act to identify and provide mitigation measures for all sources of flooding. Recent developments in computing power and modelling software have led to increasing use of flood forecasting models to support flood warning services in the UK and overseas for flood risk management. While flood forecasting and control have been applied to river networks, there are few examples of its application to reservoirs in the UK. Flood forecasting can provide advantages including, additional lead time to mobilise staff and the emergency services/workforce, decision support in complex situations, more time to implement risk reduction measures before the event (e.g. drawdown of reservoirs, diverting flows to offline storage such as washlands, installing temporary barriers and sandbags), when used in combination with control measures, can be an effective flood mitigation measure. This project will examine how flood forecasting and control can best be applied to reservoir systems in the UK and will cover the following:
1. Development of guidelines for design of real time monitoring networks for reservoir monitoring and flood forecasting;
2. Review real-time control methods – real time control of reservoirs to reduce overtopping risks at the reservoir
3. Guidance on the optimum approaches to reservoir forecasting techniques for different types of reservoirs and outflow arrangements</td></tr>
<tr><td>EA Theme: Modelling and Risk./ Incident Management and community engagement</td><td>Output: Guidance</td></tr>
<tr><td>Cost:
1. Development of guidelines for the design of real time monitoring networks for reservoir monitoring and flood forecasting;
2. Review real-time control methods – real time control of reservoirs to reduce overtopping risks at the reservoir.
3. Guidance on the optimum approaches to reservoir forecasting techniques for different types of reservoirs and outflow arrangements</td><td>
£30,000
£100,000

£20,000</td></tr>
<tr><td>Duration
1. Development of guidelines for the design of real time monitoring networks for reservoir monitoring and flood forecasting;
2. Review real-time control methods – real time control of reservoirs to reduce overtopping risks at the reservoir.
3. Guidance on the optimum approaches to reservoir forecasting techniques for different types of reservoirs and outflow arrangements</td><td>
6 months
6 months

6 months</td></tr>
<tr><td>Beneficiaries: Panel Engineers/Owners/Dam Engineers/Consultants/Emerg responders</td><td>Additional Sources of funding: UKWIR/Owners</td></tr>
<tr><td colspan="2">Outcome if not done: Flood forecasting networks are likely to increase in extent and could cover all sources of flooding to meet legislative requirements. Failure to examine flood forecasting for reservoirs flood risk mitigation will be a missed opportunity to link into this integrated approach to flood risk man.</td></tr>
<tr><td colspan="2">Project type: LB/LD</td></tr>
</table>

Rank: 45	**Priority Score: 4.4**
Project Title Appurtenant Structures F: Procedures for the Assessment of Intake Towers and Gates.	
Project Scope: Research is needed to report and develop validated procedures for the seismic assessment of auxiliary/appurtenant structures and in particular intake towers/outlet towers and spillway gates.	
EA Theme: Sustainable Asset Management	**Output:** Report
Cost:	£50,000
Duration:	12 months
Beneficiaries: Owners/ Designers/ Panel Engineers	**Additional Sources of funding**: CIRIA
Outcome if not done: Designers and Panel Engineers will continue to design installations without. However, seismic risk is not considered to be a high risk to UK dams.	
Project type: LB/HD	

Rank: 46	**Priority Score: 4.3**
Project Title: Climate Change E: Review management methods, inspection standards and inspection intervals and develop new requirements to take account of climate change.	
Project Scope: Guidance in required on the management methods that could/should be adopted by owners/undertakers with respect to inspection standards, inspection intervals and other mitigation measures that can be adopted to minimise the impact of climate change. In addition, as dams age they will be more susceptible to the expected impacts of climate change. Hence, more regular inspections may be required for older dams, or other type of dams that may be more susceptible to climate change. These guidelines could be included in the guides to the various types of dams within a chapter on climate change impacts.	
EA Theme: Sustainable Asset Management	**Output:** Review/Guidance
Cost:	£50,000
Duration:	12 months
Beneficiaries: Panel Engineers/Owners/Dam Engineers/Consultants/Emergency responders/Planners/Water resources planners	**Additional Sources of funding**: UKWIR/EC
Outcome if not done. If this project is not done there may not be standardisation of management methods for taking account of climate change.	
Project type: LB/LD	

<table>
<tr><td>Rank:47</td><td>Priority Score: 4.1</td></tr>
<tr><td colspan="2">Project Title: Climate Change D: Investigate methods and technologies to help dams adapt to climate change</td></tr>
<tr><td colspan="2">Project Scope:
There are a number of potential indirect climate change impacts that could affect dams safety in the future, including:
1. Changes in the timing demand and due to changes in length of wet and dry periods.
2. Decreasing yield from all sources leading to increased pressures on existing resources and potentially the need to build new reservoirs
3. Increased requirement for renewable energy leading to the building of new or retrofitting of old dams for hydroelectric power.

There is a need to understand and quantify these impacts as well as the uncertainty in the predictions in order to plan for them. In addition there needs to be guidance on methods of incorporating these likely impacts into dam assessment, design, maintenance and planning. There are similar requirements for research into some of the indirect climate change impacts on water resources and it would be useful of any research being done under dam safety, is in line with other relevant research.</td></tr>
<tr><td>EA Theme: Sustainable Asset Management</td><td>Output: Guidance</td></tr>
<tr><td>Cost:</td><td>£100,000</td></tr>
<tr><td>Duration:</td><td>12 months</td></tr>
<tr><td>Beneficiaries: Panel Engineers/Owners/Dam Engineers/Consultants/Emergency responders/Planners/Water resources planners</td><td>Additional Sources of funding: UKWIR/EC</td></tr>
<tr><td colspan="2">Outcome if not done: If this project is not undertaken there will continue to be poor understanding of the potential indirect impacts of climate change on dam safety. The combination of direct and indirect impacts could put dams at risk of failure. It is therefore important to understand these impacts in order to plan for them in a meaningful and fully integrated manner.</td></tr>
<tr><td colspan="2">Project type: LB/HD</td></tr>
</table>

Rank:48	**Priority Score: 4.0**
Project Title: Management H: Knowledge optimisation on data (after Management projects B and E)	
Project Scope: The EA has a facility at present which holds information on UK dams but there is a significant amount of missing information. The UK register of dams needs updating and continual updating. Dam owners hold their own information of dams, and consultants build up and hold information on dams on which they carry out studies. This information is not centrally available to people outside of the consultancies undertaking the work. In addition, Panel Engineers carrying out inspections generate bits of information which again, is not centrally available. A substantial amount of information can be gleaned on each dam, if the various pieces of information held in disparate locations can be brought together and held centrally, to be made available for all subsequent people working on the dam and indeed for the regulator to be assured that they hold all definitive information on each dam. A definitive database of information on each dam will also eliminate the potential for duplication of effort. There also needs to decide what data should be held on dams. There is also a need to tie this database in to any GIS database management system that is developed for dams in the future (linked to Management project B,C and E).	
EA Theme: Sustainable Asset Management	**Outcome:** Database
Cost:	£150,000
Duration:	12 months to set up database and gather information, but updating will need to be ongoing
Beneficiaries:	**Additional Sources of funding**: Owners
Outcome if not done: Information on dams will continue to be held in separate locations with no knowledge transfer. The regulator will not have the optimum knowledge of the dams they regulate and there will continue to be a duplication of information/effort.	
Project type: LB/HD	

Rank: 49	**Priority Score: 3.1**
Project Title: Appurtenant Structures I: Guidance on the Location, Design and Maintenance of Fish Screens	
Project Scope: Fish screens are a recurring problem for dam owners and Panel Engineers alike as they catch debris and artificially raise water levels. There are a number of ways of preventing fish leaving the reservoir which could be explored and documented. This could be linked with a Guide in the design of fish passes.	
EA Theme: MAR	**Output:** Guide
Cost:	£30,000
Duration:	12 months
Beneficiaries: Owners/Fishing Clubs/Panel Engineers/Designers	**Additional Sources of funding**: CIRIA
Outcome if not done: Screens of an appropriate design will be put in place.	
Project type: LB/LD	

Appendix I – Review of Funding Options and Opportunities in Support of Reservoir Safety Research and Development

I.1 Introduction

I.1.1 Objective

The objective of this review is to identify possible sources and mechanisms for funding, support or collaboration that would enhance the ability to undertake Research & Development supporting reservoir safety in England and Wales. Existing reservoir safety R&D in England and Wales is funded through the joint Defra/EA Flood and Coastal Erosion Research Programme. The opportunities stated here are designed to support and enhance this research & development.

I.1.2 Overview

Various sources for potential funding and support have been presented, with consideration of possible approaches to complement and enhance existing funding by EA/Defra (Section 2). In identifying the approaches, a number of limiting issues that affect our ability to make use of the opportunities, as they arise, were noted. These have been outlined in Section 3, with recommendations to overcome the limitations. Finally, recommended actions are summarised (Section 4).

I.2 Potential Funding Opportunities

There is a large number of funding sources and types, ranging from small scale financial support for individual researchers through to funding of large integrated programmes of research. Fund sources should not be limited to the UK; many reservoir safety issues are common worldwide and hence research can gain support from European and international funding groups and organisations.

A number of specific fund sources and opportunities have been identified, and are briefly described in this section with suggested actions to secure funds or add value to the research programme.

I.2.1 EA/Defra Flood and Coastal Erosion Risk Management Programme

EA/Defra fund a joint Flood and Coastal Erosion Risk Management (FCERM) Research Programme. Research is divided into four themes:

1. Strategy and policy development (SPD)
2. Modelling and risk (MAR)
3. Sustainable asset management (SAM)
4. Incident management and community engagement (ICM)

For more information see http://www.defra.gov.uk/environ/fcd/research/RandAboutProg.htm

Each theme develops and manages a programme of research. Common concepts and approaches are adopted across all themes to ensure a consistent approach to flood risk analysis and management by EA/Defra.

Reservoir Safety research, previously funded by Defra, will move into the FCERM programme. A transitional period will exist during 2008/9, where research funding (£250K) will be ring fenced for reservoir safety research. From 2009 onwards, reservoir safety research, as proposed by the Reservoir Safety Advisory Group (RSAG), will compete for funding through the FCERM programme. Hence, funding levels may rise or fall relative to the previous annual budget of £250K. Additionally, existing research programmes under the SPD, MAR, SAM and ICM themes should start to consider reservoir safety issues as part of their project specifications.

I.2.2 EA/Defra – Suggested Actions

The Defra/EA FCERM R&D programme will continue to offer a basic source of finance for reservoir safety R&D. In order to compete for funds within this programme, it will be necessary to present a developed and prioritised programme of research projects, using the standard forms and detailing adopted within the programme. (For more information on EA procedure and forms, see http://www.defra.gov.uk/science/funding/fund_index.htm).

Action 1: The case for reservoir safety research must be presented in the appropriate EA format (ROAME) and that relevant forms/templates are provided stating specific project specifications.

I.3 Research Councils

Each year, the UK's seven Research Councils invest around £2.8 billion in research covering the full spectrum of academic disciplines from the medical and biological sciences to astronomy, physics, chemistry and engineering, social sciences, economics, environmental sciences and the arts and humanities. The Research Councils that fund research of relevance of reservoir safety are primarily EPSRC, and secondarily NERC and ESRC.

I.3.1 EPSRC (Engineering and Physical Sciences Research Council)

EPSRC is the main UK government agency for funding research and training in engineering and the physical sciences, investing around £500 million a year in a broad range of subjects – from mathematics to materials science, and from information technology to structural engineering. EPSRC operate to meet the needs of industry and society by working in partnership with universities to invest in people, scientific discovery and innovation. Its work complements other research investors including other research councils, government agencies, industry and the European Union. EPSRC actively encourage a range of partnerships and collaborations across disciplines and boundaries.

EPSRC funding is flexible and provides different opportunities for industry and other organisations to collaborate on research with world-leading UK universities. Various mechanisms that enable and stimulate research are described below, and include Strategic Partnerships, Research Grants, and Network Grants. Other mechanisms include funding to encourage organisations to support postgraduate students on industry-based or university-based projects, through sponsorship of Engineering Doctorates (EngDs) and Industrial CASE Awards.

EPSRC Strategic Partnerships

Strategic Partnerships are formal arrangements between EPSRC and other organisations to jointly support research, training and other activities in UK universities. A partnership can involve one or several organisations, and gives a framework for supporting mutually-beneficial activities. When EPSRC agree to co-fund research, it generally matches the partner's contribution, with the total co-funding being from one to ten million pounds, depending on the scope of the activities. The activities must be large-scale and of strategic significance. EPSRC are interested, for example, in supporting partnerships that stimulate areas of low activity in research and training that are of value to the UK. With the low level of reservoir safety research being conducted in UK universities, and the low number of graduate engineers trained in reservoir safety, it is likely that EPSRC would be interested in discussing joint support for research and training in this particular area. Organisations interested in developing a strategic partnership first need to contact EPSRC to discuss this opportunity.

Defra has recently formed a strategic partnership with EPSRC, ESRC and NERC to jointly support the establishment (in 2008) of a Collaborative Centre of Excellence in Understanding and Managing Natural and Environmental Risks, with up to £1.2 million funding. The Centre will facilitate the provision of world-leading knowledge, understanding and management of risk to provide an evidence

base to inform policy development by Defra and other policy makers. The key objectives are: to draw together insights from leading-edge research; to facilitate knowledge flow between Defra and the research community; to enhance knowledge exchange between researcher and policy-makers to enhance their ability to measure, articulate, compare and respond to the diverse range of risks for which they are responsible.

In a similar vein, the Flood Risk Management Consortium (FRMRC II), which commenced in October 2007, is supported by EPSRC in collaboration with the EA/Defra Joint R&D programme on Flood and Coastal Defence, UKWIR, the Scottish Office, the NI Rivers Agency and NERC. Previously, the parties co-funded an interdisciplinary research consortium (FRMRC I) to investigate the prediction, prevention and mitigation of flooding. The research portfolio for FRMRC I addressed key issues in flood risk management by generating new and original under-pinning science, while being consistent within the agreed objectives of the funding agencies. This philosophy is being carried over into the second funding phase (FRMRC II). The consortium consists of academic institutions working with stakeholders and users in the public and private sectors.

EPSRC Research Grant - Responsive Mode

These grants cover various disciplines within engineering, including: water and coastal engineering; built environment; structural engineering; engineering materials; instrumentation; mechanical engineering; machinery and plant - all of relevance to reservoir safety. UK Higher Education Institutions apply for the grants, and EPSRC actively encourages collaboration from industry, commerce or other organisations to support applications, although funding from a third-party is not mandatory. There is no limit on the value of the grant, and applications can be submitted at any time.

Responsive mode grants are flexible, funding projects from small travel grants to multi-million pound research programmes, with whatever duration of funding is required, e.g. up to six years. Funding covers a range of activities, including research projects, feasibility studies, instrument development, equipment, travel and collaboration, and long-term funding to develop or maintain critical mass. EPSRC encourage high-risk/high-return research proposals relating to new concepts or techniques.

EPSRC Network Grant

The aims of Networks are to create new interdisciplinary research communities and topics in Engineering, by developing interaction between the research community and appropriate science, technology and industrial groups. Networks are expected to lead to new collaborative multidisciplinary research proposals. UK Higher Education Institutions apply for the research grants, there is no limit on the value of the grant, and applications may be submitted at any time.

EPSRC Engineering Doctorate (EngD)

The EngD is equivalent to a PhD but is tailored to students who want to do research in industry while working towards a doctoral-level qualification. The student spends about 75% of their time working in their sponsoring company on an industry-relevant project (or portfolio of projects) that presents genuine research challenges. The rest of the time the student attends specialist technical and professional development courses at a university. At the end of the four-year programme, students have a doctoral qualification and the skills to be successful in an industrial environment.

EPSRC supports a number of EngD Centres with awards for student stipends and tuition fees. Companies can sponsor EPSRC students or their own employees, and normally pay a contribution to the host centre. There are currently 24 centres across the UK covering a range of research areas and industrial sectors, some of which would be relevant to reservoir safety.

EPSRC Industrial CASE Awards

A CASE Award is a three-and-a-half year postgraduate student award allocated to a UK-based company to enable it to take the lead in defining, and arranging, a research project with an academic partner of its choice. EPSRC provides funds for the student's stipend and tuition fees and incidental research costs. The company provides a supplementary minimum of one-third of the EPSRC contribution, approximately £21,000 over the project duration. The company hosts the student for at least 3 months at their premises and pays the associated travel and subsistence costs to the student.

Companies may apply for CASE awards through the annual Industrial CASE pool competition, with the deadline for applications normally around May each year. Major companies are also allocated CASE awards where they collaborate financially on EPSRC funded research and on studentships.

NERC and ESRC run similar CASE Award schemes.

I.3.2 NERC (Natural Environment Research Council)

NERC funds and manages research and training in earth system science, and covers the full range of atmospheric, earth, terrestrial and aquatic sciences. NERC invests about £220 million a year to fund scientific research in universities and at its own sites. Applicants for grants must be employed by an eligible UK research organisation (Higher Education Institution, NERC Research or Collaborative Centre) or other NERC recognised research organisation.

NERC Responsive Research Grants

Responsive research grants provide financial support, of a minimum of £25,000, for scientists who put forward ideas for innovative and high quality research projects. Applications are welcomed for multidisciplinary projects that fall mainly within NERC's remit, but also cover areas within the remit of a sister research council. Applications must be submitted by 1st July and 1st December each year.

NERC Consortium Grants

These grants support focused, coordinated, collaborative research into specific issues that cannot be addressed through other NERC funding modes. To promote flexibility and collaboration, consortium grants blur the boundaries between existing NERC funding modes. Applicants first submit a concept note for approval by the Science and Innovation Managers. The maximum limit on proposals is £3·5 million for up to five years. Applications must be submitted by 1st July and 1st December each year.

NERC Partnership Research Grants

These grants support collaborative research activities between academic researchers and public or private sector partners. The total project partner contribution must be a minimum of 25% of the project cost. Awards are for a minimum of £25,000, and are usually made for up to three years, but can be for longer. Applicants should be based in UK Higher Education Institutions and NERC research and collaborative centres. Project partners may be private sector companies and public sector organisations, including local, regional and national authorities, regulators, non-departmental public bodies, non-governmental organisations and charities. Applications must be submitted by 1st July and 1st December each year.

NERC Small Research Grants

These grants provide funding for small discrete projects, e.g. proof-of-concept studies, pump-priming exercises, etc., which are curiosity-motivated research either basic, strategic or applied. Funding is limited to £25,000, and the annual closing date for applications is 1st September.

I.3.3 ESRC (Economic and Social Research Council)

ESRC is the UK's largest funding agency for social and economic research. It focuses on six research areas: economic affairs, education and human development, environment and planning, government and law, industry and employment, and social affairs. It supports independent, high quality research relevant to business, the public sector and voluntary organisations. ESRC invests around £181 million annually to support research in academic institutions and research policy institutes.

Research Grants Scheme

Awards ranging up to £1.5 million can be made to eligible institutions to enable individuals or research teams to undertake research from small projects through to a large-scale surveys. Eligible institutions include universities, colleges of higher education and independent research institutes in the UK. There is considerable flexibility when it comes to subject area, as long the suggested topic falls within ESRC's remit. Applications may be submitted at any time.

I.3.4 Research Councils – Suggested Actions

Action 2: Defra/EA should consider exploring the development of a Strategic Partnership with EPSRC and other partners to fund a collaborative centre for multidisciplinary reservoir safety research and training in UK universities. The Centre would be coordinated from the university of the lead academic. A Strategic Partnership would increase the available funding for the Defra/EA portfolio of recommended research. Partners could include dam owners, engineering consultancies specialising in reservoir safety, and the sister research councils NERC and ESRC, to cover the cross-disciplinary nature of the research. There are few UK universities currently conducting reservoir safety research, but some are working in closely related areas. The aim of the centre should be twofold: to bring university researchers together to apply their knowledge to reservoir safety research; to train graduates on the research in associated specialist areas, thus contributing in part to the succession training of reservoir safety experts.

Action 3: Defra/EA should review proposed reservoir safety R&D needs against the current FRMRCII (joint EPSRC/EA funded) research programme to identify any areas where common interests might be addressed. Immediate action is needed to benefit from FRMRCII which started in Spring 2008**.**

Action 4: Defra/EA should consider identifying/employing/procuring a champion to proactively encourage the development of joint proposals for research council funding for research collaborations and networks between universities and other organisations. By stimulating research in the universities, the available funding for the recommended reservoir safety research projects would be increased. The champion's responsibilities could include:

1. Liaising with research councils to identify joint funding opportunities for research and training.
2. Identifying academics to conduct reservoir safety research and lead on grant applications.
3. Identifying organizations, e.g. dam owners, engineering consultancies, and individuals, e.g. panel engineers, to support research. Support can be direct by co-funding a project or PhD studentship, or indirect by contributing staff time, e.g. as a project advisor, or the use of facilities.
4. Introducing academics to reservoir safety professionals interested in collaborating on research grant proposals.
5. Identifying and encouraging partners to develop a proposal for an EPSRC Network Grant for Reservoir Safety, in particular, an appropriate academic champion to lead on the proposal.
6. Encouraging companies to collaborate with universities in training graduates as specialists in reservoir safety by supporting them as research students (through Industrial CASE Awards or on EngD projects) on company or university projects. The value here is in the succession training of experts to ensure the future safety of reservoirs.

Action 5: Defra/EA should consider publicising the list of recommended research projects and circulate it to UK universities conducting research in reservoir safety related areas. The list should be accompanied by a letter explaining the value of the projects and encouraging academics to develop proposals for research council funding for collaborative research projects. The value of initiative would be in stimulating greater activity in UK universities in reservoir safety research.

It must be recognised that any work undertaken with or in a UK university will probably attract a 3 year research period associated with the timescale of a PhD student for example.

I.4 UK Water Industry Research (UKWIR)

UKWIR was set up by the UK water industry in 1993 to provide a framework for the procurement of a common research programme for UK water operators on 'one voice' issues. UKWIR's members comprise 24 water and sewerage undertakers in England and Wales, Scotland and Northern Ireland. Its chairman is Paul Butler, Managing Director, South East Water.

The objectives of the organisation are to:

- Identify research requirements to meet the water industry's strategic business needs
- Procure the research competitively
- Work with the water industry regulators

- Provide value for money for the contributors
- Transfer the research outputs to contributors

Over the last 10 years, UKWIR subscribers have contributed some £32m with a further £19m of research coming from UKWIR collaborators, resulting in over 400 reports delivered to members.

Work is often carried out in collaboration with government departments and regulators including DEFRA; the Drinking Water Inspectorate and the Environment Agency. Some work is also done in collaboration with research organisations internationally.

The majority of work is put out to open tender to a wide range of companies, academic institutions and other organisations in the UK and overseas. Project management is undertaken by both the water industry's R&D departments as well as by individuals employed by UKWIR.

The research programme is currently divided into the following topic areas: drinking water quality and health; toxicology; water resources; climate change; wastewater treatment and sewerage; sewage sludge; water mains and services; sewerage; leakage and metering; as well as customer and regulatory issues.

For more information go to: http://www.ukwir.org/site/web/content/home

I.4.1 UK Water Industry Research (UKWIR) – Suggested Actions

Action 6: Defra/EA should identify research projects that cut across both dams safety and water resources issues and approach UKWIR with the view to jointly fund and project manage research in these areas.

I.5 European Commission

I.5.1 DG Research

The research directorate general of the European Commission (EC) funds a large number of research programmes, many of which may offer some relevance to reservoir safety and hence an opportunity for funding. The objectives of different research programmes vary significantly. For example, programmes may address basic technical research issues, or issues supporting the environment, climate change, uptake of new technologies, integration of regional areas, promotion of small businesses, regeneration etc. The key to a successful research proposal is to ensure that it meets the specific programme objectives; this may mean presenting the same case in slightly different ways. The current research programme is Framework 7 which has programmes on cooperation, ideas, people and capacities, see http://cordis.europa.eu/fp7/home_en.html .

Cooperation Programme

The EC DG Research commissions collaborative research by first publishing a ‘call’ or ‘work programme’ describing the areas of research on which proposals are sought. Typically, there is a period of about 3 months in which to develop the proposal and submit it to Brussels. Evaluation of the proposals is undertaken by independent experts commissioned by the EC. Selected proposals are then invited to ‘contract negotiation’ during which scope and costs are typically adjusted. The time period from initial call to the start of a project is often a year. With advance notice and preparation, larger projects may take as long as 2 years from concept to start.

Funding of EC research is rarely at 100% of real costs. The funding structure varies significantly between programmes. A reasonable assumption under the Seventh Framework Programme is funding of 75% of total costs for universities, SMEs and research organisations, with the other 25%

expected to come from matching sources. There are strict criteria on the rates that can be applied to EC research contracts, for example, contractors cannot charge rates that make any form of profit.

Whilst the EC offers potential for significant financial support, it presents a complex programme of research calls and contract terms and conditions. The timing of EC research programmes cannot be modified, hence if participation in a programme is sought, it will be to the schedule of the EC rather than the UK that the work follows.

People Programme

The Marie-Curie actions support individuals in projects of training and research, some academic and some in collaboration with industry, with individuals funded for 12 to 36 months. The work is called in the same way as the cooperation programme but specific areas of science are not defined.

Ideas Programme

The new European Research Council is funded from this programme. The ERC funds high quality academic research from individual applications or small teams. The intention is to be the European equivalent of the US National Science Foundation. Topics are not defined in advance and the competition is on scientific merit.

Capacities programme

The capacities programme funds project which strengthen the European Research Area. Two type of activity possible relevant to the RSAG are the ERA-NET programme for networking nationally funded research on specific topics and the programme for access to large scale facilities.

I.5.2 Other EC Actions

Several other EC programmes from DG research and actions from other Directorates General could potentially finance research on reservoir safety – these include work in

- COST of the European Science Foundation: http://www.cost.esf.org/
- Interreg programme from DG Regions http://ec.europa.eu/regional_policy/index_en.htm
- GMES Global monitoring for environmental security see: http://ec.europa.eu/comm/space/gmes/index_en.htm
- Civil Protection, see http://europa.eu/scadplus/leg/en/s15007.htm
- Information Society see http://ec.europa.eu/information_society/newsroom/cf/news.cfm?redirection=1&item_type=fo

I.5.3 European Commission – Suggested Actions

Successful bidding for European research funding requires considerable advance planning and preparation. Participation in EC proposal evaluation and work programme development provides access to useful information on potential work programme content and EC direction. Being well prepared for a research call, to the extent of having an outline team structure and all internal (UK) collaboration arrangements sorted in advance, is a practical way to boost success rates. Searching for research opportunities at a specific time and to a specific UK timescale is unlikely to be effective. It is better to monitor and be aware of the content of calls as they are released from Brussels, and to be in a position to react quickly to opportunities. A further, long-term approach is to lobby Brussels to include specific text within calls to address specific research needs. This can be achieved through Defra links and through high profile projects such as FLOODsite (www.floodsite.net).

There may be assistance available from BERR (formerly Dti) for this area of development. See: http://www.berr.gov.uk/

It is recommended that:

Action 7a: If Defra/EA wish to be proactive in seeking European funding then in the short-term, they should fund a detailed assessment of current and near future (i.e. within 12 months) EC research work programme opportunities, and feed UK research priorities back to Defra, EA and FLOODsite contacts to establish whether opportunities exist for feeding these into later EC research programmes.

Action 7b: The EA (Reservoir Safety) should consider establish methods for participating with EC projects prior to any specific call, to enable prompt responses to opportunities as they arise. These should include links with any formal group or people within the EA who may be responsible for bidding for and managing EC projects.

Action 7c: Defra/EA should consider encouraging organisations familiar with EC research and reservoir safety issues to look for opportunities to develop EC research proposals in line with longer term R&D priorities.

Action 8: Defra/EA should consider contacting the Defra managed, but EC funded, CRUE project. CRUE aims to coordinate flood risk analysis and management research at a national level, by funding research of common interest to participating countries. CRUE may be open to suggestions on specific reservoir safety/flood risk research needs.

I.6 FEMA Dam Safety Programme

FEMA and other US federal agencies operate a large (partially) integrated programme of research addressing dam safety issues. The magnitude and range of research projects being implemented is considerably larger than in the UK, with budgets of millions of dollars. In addition to the Dam Safety Programme, individual agencies (e.g. USBR, USACE) undertake their own dam safety research.

The opportunity presented here is one of collaborative research rather than a funding source. Discussions are ongoing regarding increased collaboration between US and European researchers, but this is may take some time to resolve any financial arrangements. In the meantime, the most productive mechanism is to identify research projects of common interest and establish whether schedules and budgets permit collaboration on research.

I.6.1 FEMA Dam Safety Programme – Suggested Actions

Whilst some details of the Dam Safety Programme can found on the Internet, the best approach to establish details of the programme and common areas for potential alignment or collaboration of research is to meet directly with agency representatives. This could be achieved through a visit to the US or opportunistic use of US representative visits to Europe.

Action 9: EA/Defra should support an initial investigation to establish full details of research programmes of other countries active in dams safety research (such as the US , Canada and China), identifying areas of potential short and long term collaboration and funding opportunities.

I.7 Industry Supported Research

I.7.1 Dam Safety Interest Group (DSIG)

The DSIG manages a programme of research addressing reservoir safety issues, and is facilitated by CEATI International, in Canada (see http://www.ceatech.ca/DSIG.php). The concept adopted is that group members are all dam owning or operating companies. Research needs are identified by members, and research funds established through member contributions. Administration of the group, and project research, are performed by CEATI who charge an annual membership fee for the service. Group membership currently costs around £4,000 p.a., with participation in any research projects requiring additional direct cash or in-kind contributions. Research results are shared between group members, and later sold to industry via CEATI.

As an owner and regulator of dams, the EA qualifies as a potential member of DSIG. Initial discussions with DSIG have confirmed their interest in EA participation, and an open invitation exists for a UK representative(s) to attend a DSIG meeting to observe how the group operates. Scottish and Southern Energy have been a member for a number of years and successfully participated in a range of projects.

I.7.2 Dam Safety Interest Group (DSIG) – Suggested Actions

The DSIG approach offers an interesting approach to funding and undertaking research. From the UK perspective, it offers an existing international research structure that could return value for money on R&D, and an approach that could be adopted by UK organisations to address specific UK issues.

I.7.3 CIRIA

CIRIA is a member-based research and information organisation dedicated to improvement in the construction industry. Members include representatives from all parts of the supply chains of the modern built environment, covering building and civil engineering as well as transport and utilities infrastructure. CIRIA's work is recognised as being independent, objective and authoritative.

CIRIA's research is member-driven, and spans the separate market sectors of buildings and facilities, water and utilities and transportation infrastructure. Working both within and across these market sectors, the themes of work cover wide remits topical to construction, such as technical issues, legislation and regulation, training, management and economics. While much of the work benefits from competitively-won public sector funding, CIRIA maintains its provision of 'club-funded' projects aimed at building understanding between contributors in key areas of concern, such as Knowledge Management and Performance Indicators of Design. In addition to a published output (in the form of design guides, training manuals, etc in both hard copy and electronic format), CIRIA also provides training seminars and workshops based on the results of its project work. Typically, each project is funded by a number of stakeholders which often include core members and government as well as other private sector companies. A steering group comprising key industry individuals, including funders.

CIRIA have funded many of the guides relating to dams and reservoirs and should be examined as a source for further funding, particularly for updating some of the guides.

For more information go to: http://www.ciria.org.uk/

I.7.4 Industry Collaboration – UK Partners

A similar concept to the DSIG could be adopted in the UK, with industrial partners collaborating by directly and jointly financing R&D projects of mutual interest and relevance to their business. The concept could be expanded to include industry partners who are not dam owners, for example, large consultancies that implement in-house R&D programmes. There may be situations where collaborative funding of work by consultancies, dam owners and EA/Defra is possible.

I.8 Effective Communication and Dissemination

Many actions outlined above involve collaboration with organisations in the UK or abroad. Encouraging collaboration and funding through these routes may be supported through the provision of clear, effective and direct communication and dissemination of the R&D programme. Awareness of the R&D programme, and easy access to R&D outputs would encourage wider participation from groups in industry and academia.

I.8.1 Effective Communication and Dissemination – Suggested Actions

Recently, the most common route for R&D dissemination has been via the Internet. EA and Defra post details and deliverables from R&D work online, however this is not targeted specifically at the dam community.

Action 10: Defra/EA should consider supporting the development of a specific area on the Defra/EA website and perhaps asking BDS if it was possible to develop a specific area on the BDS website to facilitate communication and dissemination of reservoir safety R&D directly to the dam community. The Defra/EA website and if acceptable the BDS email system, in conjunction with new web content, would enable updates on progress, key initiatives and opportunities to be communicated directly to the majority of the profession.

I.9 Making it happen

A variety of ways in which reservoir safety research work can be funded and advanced, other than through direct and individual funding from Defra/EA, has been presented. In order to benefit from these additional sources of funding, Defra/EA must recognise and address a number of issues in advance, so that when an opportunity arises, it is not missed through an inability to proceed quickly.

Specific issues that should be considered:

- Policy and procedure for collaborating on European funded projects
- Methods of working in parallel with US or other national agencies
- Ability to integrate research with other organisations or programmes on a match fund or industry contribution basis
- Ability to react and work to other organisation deadlines or schedules
- Flexibility and ability to negotiate on Intellectual Property Rights
- The availability of a specific dam site suitable for research use

Defra/EA should ensure that a clear policy exists and wherever possible, flexibility in approach is permitted, ahead of any specific opportunity arising. This is particularly relevant for reacting to European research and international collaborative research opportunities.

I.9.1 EA/Defra – Suggested Actions

Action 11: In order to facilitate Actions 2, 4 and 7 above, EA/Defra should review policy, approach and procedures to better enable collaborative R&D between different UK institutions as well as international organisations involved in research relevant to dams safety.

I.10 Summary of Recommended Actions

A total of 11 suggested actions have been identified in this document. Their implementation will enhance R&D and funding opportunities in support of reservoir safety R&D in England and Wales.

It is recognised that resources are finite, so a prioritisation of actions has been conducted. Table 1 summarises the actions with an assessment of indicative duration, difficulty, cost and potential cost benefit. The final column indicates an order of priority and quick wins (QWs) are identified.

A review of priorities reveals that many of the recommended actions are short term and easy to implement and relatively low cost. This suggests that the majority of the actions could be undertaken within 6-12 months following this review and at minimal cost to Defra and the EA. This would have a positive effect on the launch of the new reservoir safety R&D programme, and present it as a truly integrated programme of research, recognised worldwide.

Action	Duration	Difficulty	Indicative Cost	Indicative Cost Benefit	Priority
Action 1: The case for reservoir safety research must be presented in the appropriate EA format (ROAME) and that relevant forms/templates are provided stating specific project specifications.	**QW**	**QW**	**QW**	**QW**	**QW**
Action 2: Defra/EA should consider exploring the development of a Strategic Partnership with EPSRC and other partners to fund a collaborative centre for multidisciplinary reservoir safety research and training. A Strategic Partnership would increase the available funding for the Defra/EA portfolio of recommended research. Partners could include dam owners, engineering consultancies specialising in reservoir safety, and the sister research councils NERC and ESRC, to cover the cross-disciplinary nature of the research. There are few UK universities currently conducting reservoir safety research, but some are working in closely related areas. The aim of the centre should be twofold: to bring university researchers together to apply their knowledge to reservoir safety research; to train graduates on the research in associated specialist areas, thus contributing in part to the succession training of reservoir safety experts.	**Long**	**Med**	**High**	**High**	**4**
Action 3: Defra/EA should review proposed reservoir safety R&D needs against the current FRMRCII (joint EPSRC/EA funded) research programme to identify any areas where common interests might be addressed. Immediate action is needed to benefit from FRMRCII which started in Spring 2008**.**	**QW**	**QW**	**QW**	**QW**	**QW**
Action 4: Defra/EA should consider identifying/employing/procuring a champion to proactively encourage the development of joint proposals for research council funding for research collaborations and networks between universities and other organisations. By stimulating research in the universities, the available funding for the recommended reservoir safety research projects would be increased.	**Short**	**Easy**	**Med**	**High**	**2**
Action 5: Defra/EA should consider publicising the list of recommended research projects and circulate it to UK universities conducting research in reservoir safety related areas. The list should be accompanied by a letter explaining the value of the projects and encouraging academics to develop proposals for research council funding for collaborative research projects. The value of initiative would be in stimulating greater activity in UK universities in reservoir safety research.	**QW**	**QW**	**QW**	**QW**	**QW**
Action 6: Defra/EA should identify research projects that cut across both dams safety and water resources issues and approach UKWIR with the view to jointly fund and project manage research in these areas.	**QW**	**Easy**	**Low**	**High**	**2**
Action 7a: If Defra/EA wish to be proactive in seeking European funding then in the short-term, they	**Short**	**Easy**	**Low-**	**High**	**1**

Action	Duration	Difficulty	Indicative Cost	Indicative Cost Benefit	Priority
should fund a detailed assessment of current and near future (i.e. within 12 months) EC research work programme opportunities, and feed UK research priorities back to Defra, EA and FLOODsite contacts to establish whether opportunities exist for feeding these into later EC research programmes.			**Med**		
Action 7b: The EA (Reservoir Safety) should consider establish methods for participating with EC projects prior to any specific call, to enable prompt responses to opportunities as they arise. These should include links with any formal group or people within the EA who may be responsible for bidding for and managing EC projects.	**Short**	**Easy**	**Low**	**Med**	**2**
Action 7c: Defra/EA should consider encouraging organisations familiar with EC research and reservoir safety issues to look for opportunities to develop EC research proposals in line with longer term R&D priorities.	**Short**	**Easy**	**Low**	**Med**	**2**
Action 8: Defra/EA should consider contacting the Defra managed, but EC funded, CRUE project. CRUE aims to coordinate flood risk analysis and management research at a national level, by funding research of common interest to participating countries. CRUE may be open to suggestions on specific reservoir safety/flood risk research needs.	**Short**	**Easy**	**Low**	**Med**	**2**
Action 9: EA/DEFRA should support an initial investigation to establish full details of the research programmes of other countries active in dams safety research (such as the US, Canada and China), identifying areas of potential short and long term collaboration and funding opportunities.	**Short**	**Easy**	**Med**	**Med**	**2**
Action 10: Defra/EA should consider supporting the development of a specific area on the Defra/EA website and perhaps asking BDS if it was possible to develop a specific area on the BDS website to facilitate communication and dissemination of reservoir safety R&D directly to the dam community. The Defra/EA website and if acceptable the BDS email system, in conjunction with new web content, would enable updates on progress, key initiatives and opportunities to be communicated directly to the majority of the profession.	**Short (Long)**	**Easy**	**Low**	**?**	**2**
Action 11: EA/Defra should review policy, approach and procedures for collaborative R&D to ensure prompt responses can be made to specific R&D opportunities as they arise.	**Short**	**Easy**	**Low**	**High**	**1**

Table I.1: Summary of Recommended Actions for Additional Sources of Funding

Descriptive terms:

Duration:	Short	< 6 months
	Med	6 – 12 months
	Long	> 12 months
Difficulty:	Easy	No or minimal technical challenge
	Hard	Significant technical/administration challenge
Priority:	Broad clustering/prioritisation based upon indicative (subjective) descriptions	

Indicative cost:	Low	< £10K
	Med	£10 – 50K
	High	>£50K
Cost benefit:	High	Good return on investment
	Low	Poor return on investment

defra
Department for Environment Food and Rural Affairs

Environment Agency

delivering benefits through science

fcerm.science@environment-agency.gov.uk