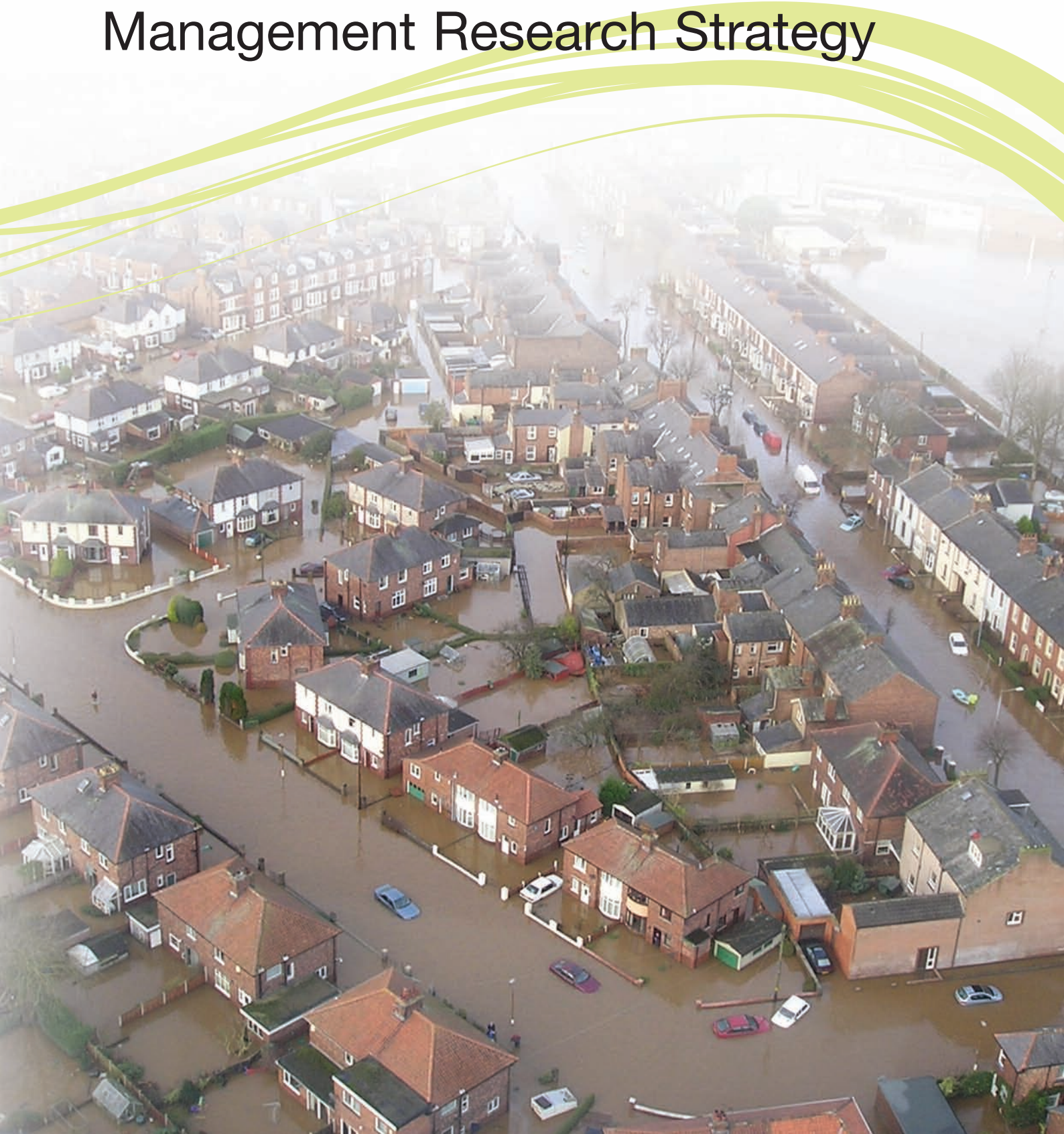
Living With Environmental Change

UK Flood and Coastal Erosion Risk Management Research Strategy



Foreword

In the UK, where 6 million properties are at risk from flooding, the devastating floods of 2007 cost the country a total of £3.2 billion, including £2 billion to homeowners and businesses. In that same year there were 200 major floods worldwide, affecting 180 million people, whilst over the course of this last year we have seen major floods in Australia, Brazil, China, Niger, Pakistan and the USA. Flooding has the potential to affect us all, and the indications are that the risks, both in the UK and globally, are likely to increase in the future.

The UK Flood and Coastal Erosion Risk Management (FCERM) Research Strategy sets out a framework to reduce the risks associated with flooding and coastal erosion. It has been produced following extensive consultation with leading academics and practitioners using reviews, workshops and survey outputs. The research to support flood and coastal erosion risk management calls on a wide range of disciplines from the natural, social, physical and engineering sciences. These include storm forecasting, flood modelling, catchment land use management, flood recovery and emergency response, and the adaptation of existing assets to climate change. That is why it is essential to have an overview of the research, to ensure that the research has practical application and is used to reduce flood risk and coastal erosion.

The Living With Environmental Change Partnership brings together those publically funded organisations that fund and use environmental research. In producing this strategy it aims to develop a common philosophy of approach, identify critical research questions and link practitioners more closely to the research base to ensure the dissemination, uptake and operational implementation of research. The aim is to make the case for investment in research and to reduce the risks associated with flooding and coastal erosion.

Lord Selborne (GBE FRS)
Chair of LWEC Partners' Board

LWEC Partner Organisations

Living With Environmental Change

Living With Environmental Change (LWEC) is an ambitious and innovative partnership of UK government departments and agencies, devolved administrations, local government and research councils. The LWEC partnership aims to ensure that decision makers in government, business and society have the knowledge, foresight and tools to mitigate, adapt to and benefit from environmental change.

To achieve this LWEC makes sure that:

- Research, observations and information-gathering are designed to meet the expressed needs of policy and practice partners;
- Partners sustain their engagement with LWEC activities so that they can shape and benefit from the outputs;
- Outputs are easy to find and well communicated to key business, government and other audiences;
- Funders align their efforts to get better return on investment and to avoid duplication.

Referencing this Document

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Introduction

This Flood and Coastal Erosion Risk Management (FCERM) Research Strategy outlines how the Living With Environmental Change (LWEC) Partnership will make a significant difference in meeting the scientific and practical challenges that FCERM presents. Within the UK at least 6 million properties are currently at risk from flooding and coastal erosion and this figure is set to rise due to climatic change and socio-economic pressures.

The strategy will facilitate the delivery of high-quality, outcome-focused research, to underpin UK-wide and local FCERM strategies, to enable evidence-based policy decisions, to improve operational efficiency and effectiveness and to develop new innovative tools and techniques to improve FCERM delivery. It aims to secure the finances and expertise to deliver the identified research needs, building upon a solid base of past experience and lessons learnt; and to develop and sustain this over the next 20 years through:

- fostering increased collaboration between funders, researchers and practitioners, through co-design, co-production and co-delivery of initiatives;
- improving the dissemination and uptake of research outputs, including making best use of the existing evidence base;
- building capacity, capability and knowledge exchange within all sectors;
- focusing on developing a line of sight between research and practice;
- maximising the economic, social and environmental benefits arising from research and FCERM policy and operational activities.

FCERM research is complex, involving numerous stakeholders and drawing upon expertise from a diverse range of disciplines. Integrating across organisational and traditional topic boundaries is critical to delivering research informed solutions to flooding and coastal erosion problems. However, this represents a major challenge which requires changes in organisational culture, skilled and trained personnel, alongside significant and sustained financial investment. To help achieve and facilitate this, the strategy identifies priorities within a risk-based thematic structure:

- Understanding Risk
- Managing Probability
- Managing Consequence.

Within each theme, research needs have been assessed according to the urgency of the agenda, the maturity of the research and the capacity to deliver it within different areas of the overall research spectrum. This provides a focus for future research effort and will help funding organisations develop their investment strategies to ensure the greatest impact. In addition to the Risk Themes, Sectoral Frameworks are introduced which cross-cut thematic areas and provide a mechanism for gathering expertise, information and addressing specific challenges within FCERM.

The strategy presents a coherent vision for future UK FCERM research and signposts the direction of travel towards a goal that can be shared by all stakeholders. It aims to place research and evidence at the heart of FCERM activities, via the effective translation of research findings into practical application and through promoting improved interactions among the research community, business, the public, policy makers and international partners.

A group of LWEC partners with responsibility for implementation of the Strategy will be operating from early in 2012. Progress with Strategy implementation may be followed via the LWEC website: **http://www.lwec.org.uk/activities/uk-first-flood-research-strategy**

1 Strategy Aims and Objectives

This strategy builds upon the foundations of UK Flood and Coastal Erosion Risk Management (hereafter referred to as FCERM) research that have been developed through individual and multi-organisational research programmes across the UK. These include the Flood Risk Management Research Consortium (FRMRC), which involves research councils and partners from across the UK, the Joint Defra/Environment Agency Research and Development Programme (which covers England and Wales), and programmes run by the Scotland and Northern Ireland Forum For Environmental Research (SNIFFER). Its implementation should propagate research agendas, cultures and behaviours that deliver genuine benefits for FCERM across the UK.

1.1 Aims

- To promote the development of research that, through its application, supports the aims of sustainable FCERM, namely:
  - o to manage the risks from flooding and coastal erosion.
  - o to facilitate decision making at the appropriate level by underpinning policy and operational activities.
  - o to increase and maximise the financial and societal benefits from investment, including exploiting opportunities for achieving multiple outcomes.
- To improve the coherency of UK FCERM research over the next 20 years, through co-design and co-delivery of initiatives.

1.2 Objectives

- To develop a simple but robust framework to help foster improved links and early engagement between academics, industry researchers, service providers, end-users and beneficiaries both nationally and internationally.
- To identify key FCERM research priorities in light of political, economic, social, legal and environmental drivers via an overview of existing activities and analysis of gaps.
- To outline how UK FCERM research capacity and capability may be enhanced and maintained.

1.3 Principles

The strategy will:

- Complement and inform emerging wider strategies and related agendas by placing FCERM research in the wider context of ecosystem services approach, catchment land-use, water availability, climate modelling and marine issues. This should facilitate sharing of capabilities, data and observations between future programmes.
- Ensure a line of sight from research through to end-user delivery in order to ensure the benefits of UK research investment are realised.
- Encourage innovation and research excellence, as well as the onward development and usage of appropriate best practice methods in operational flood risk management.
- Consider the needs of stakeholders and involve them in the development and implementation of the strategy.
- Build upon existing investment and appropriate good practice in the coordination of UK FCERM research, learning lessons from past experience and drawing upon international knowledge to improve UK FCERM delivery over the next 20 years.
- Seek to embed the principles of active benefits management, via acknowledging the provenance of methods, tools and software derived from research, in order that the benefits of research investment are more widely recognised.

2 Why do we need a UK FCERM Research Strategy?

To address flood risk and coastal erosion, funding is directed towards a portfolio of intervention measures, which are delivered by a range of institutions from Devolved Administrations, Government Departments, their Agencies, Local Authorities, Internal Drainage Boards, Water Companies and land owners. In addition, a range of responders including those defined under the Civil Contingencies Act[1] and a range of third sector organisations provide incident and post-incident services including emergency, health and military services. Collectively, these comprise a holistic risk management approach, with effort focused upon where greatest benefit will be yielded and usually involving a bespoke combination of social, economic, environmental and engineering activities, including:

- developing policy and legislation to manage flood risk and coastal erosion
- mapping risk in a variety of forms
- effectively managing floodplain development
- raising public awareness of risk and encouraging preparedness
- monitoring, forecasting and warning in real time of flood risk
- developing natural flood management measures
- building flood alleviation and coastal protection schemes
- maintaining existing flood and coastal defences and associated structures.

This strategy sets out a framework within which the research to support FCERM activities can be co-ordinated. In this context, research includes addressing problems, exploiting opportunities and identifying needs and can be classified as aiming to achieve one or more of the five key benefits of research outlined in Table 1.

It is intended that the research strategy is not simply a vehicle to achieve the coordination of funders pursuing research for the advancement of knowledge. Instead, it should primarily focus upon further changing the culture and mindset of researchers to ensure that research and development sees practical application and yields social, economic and environmental outcomes that are shared across all sectors of FCERM. The strategy also aims to encourage researchers from beyond the traditional boundaries of FCERM to apply their expertise within this area of research, recognising that knowledge and techniques from other disciplines may provide fresh insight into FCERM issues. The users of FCERM research outputs and the primary audience for this strategy therefore include:

Table 1: The 5 key benefits of research

- Enabling activities – allowing us to do things we cannot currently do
- Improving efficiency – allowing us to do things more economically
- Improving effectiveness – allowing us to achieve our goals in the right way
- Improving understanding – allowing us to better appreciate the scientific principles needed to address FCERM issues
- Providing evidence – allowing us to make and justify better decisions.

- Policy Makers – Devolved Administrations, Government Departments
- Operating Authorities - Government Agencies, Local Authorities, Coastal Authorities, Internal Drainage Boards
- Industry – including insurance sector, engineering and environmental consultancies, as well as innovative commercial enterprises
- Researchers – university academics, research funders, research and technology organisations, third sector organisations.
- The informed public.

2.1 LWEC and the FCERM Research Strategy

The Living With Environmental Change (LWEC)[2] initiative is a partnership of 22 major public sector research funders which aims to coordinate environmental research across the UK and to ensure that decision makers in government, business and society have the knowledge, foresight and tools to

mitigate, adapt to, and benefit from, environmental change. The LWEC partner organisations are listed at the front of this document. The issue of FCERM is relevant to most of these partners.

This FCERM research strategy represents the first topic-specific LWEC sponsored strategy and is thus both a pilot and a litmus test for the effectiveness of the LWEC partnership in delivering added value through partnership. A number of the LWEC partners have a critical interest in FCERM research; however, the research strategy aims to allow collaboration with parties beyond the LWEC partnership, including independent research institutions, private sector consultancies, other government departments and agencies, and other businesses. FCERM research cross-cuts the LWEC Strategic Challenges (Table 2):

Table 2: Living With Environmental Change Strategic Challenges

- Climate Challenge: To understand the risks of climate change and assess options for avoiding or managing such risks.
- Ecosystem challenge: To ensure that decision-making takes full account of impacts on the natural environment and their consequences for ecosystem sustainability, human well-being and economic prosperity.
- Resources challenge: To promote human well-being, alleviate poverty and minimise waste by ensuring a sustainable supply of water, food and other biological resources.
- Health challenge: To understand and protect human health in a changing environment.
- Infrastructure challenge: To make infrastructure, the built environment and transport systems resilient to environmental change, less carbon intensive and more socially acceptable.
- Societal challenge: To understand the role of government, business and society in enabling all to live with environmental change.

Intuitively, improving the coordination of the FCERM research landscape makes sound sense. The LWEC FCERM Research Strategy should deliver benefits through increased future collaboration between research funders and FCERM practitioners, yielding efficiencies in a number of areas (see Table 3):

Past experience has shown that the greatest value from research investment has been achieved when there has been a common vision, coordination of stakeholders and a strong linkage between researchers and practitioners. In contrast, where this has not existed, there has been lack of research problem definition, poorly targeted research effort, lack of practitioner buy-in to research activities and the successful uptake and realisation of benefits has been variable.

Table 3: The key benefits of the LWEC FCERM Research Strategy

- avoiding duplication of effort
- defining the critical research questions and identifying the issues
- developing a common philosophy of approach
- links researchers to practitioners and those affected by flooding and coastal erosion
- improving dissemination and access to knowledge
- improving national capability (data/facilities/skills) to meet observation, data collation, synthesis, interpretation and translation needs
- ensuring the dissemination, uptake and operational implementation of research.

There are also potential disbenefits and risks to multi-organisational collaboration, which need to be actively managed and mitigated. These include:

- more complex and slower decision making
- dilution of individual organisational goals due to the need to compromise
- a tendency towards larger and harder to deliver research and development
- blurring of accountabilities
- the potential for innovation to be stifled.

Criteria and options for implementing this strategy and proposals to address any potential risks and disbenefits are outlined within Section 7.

2.2 Scope of the Strategy

This strategy covers the whole of the UK (England, Wales, Scotland and Northern Ireland) and is intended to cover the period from 2011-2030. It will need to be reviewed periodically to ensure its relevance to user needs, but it should be ambitious in attempting to initiate research which may see practical implementation several years from now. It is

vital that research councils continue to fund the basic research requirements and that policy and operational organisations exploit these outputs and translate these into the tools that FCERM practitioners require. As the strategy aims to facilitate a linkage between academic and end-user requirements, its scope includes basic research, applied research and experimental development as per the Frascati definitions[3].

The strategy is intended to facilitate and help exploit links to international work, including EU funded frameworks (Framework Programmes and ERA-Net), Inter-regional Cooperation Programmes (Interreg) as well as further afield (e.g. United States Army Corps of Engineers, Chinese Foresight[4,*]).

For this strategy, flooding is defined as: a temporary covering by water of land not normally covered by water and is taken to include surface water, fluvial, tidal, coastal, groundwater and flooding from reservoir failure. The social, economic and health implications of flooding will be covered, together with a consideration of how flood risk management fits with other land use pressures and in delivering other ecosystem services. Within the scope of this strategy, flooding from sewers is considered where it is caused, at least in part, by an increase in the volume of rainwater entering the system. This is most likely to occur where sewers have a dual purpose, carrying both surface water run off and sewage, and the combined flow entering systems exceeds the capacity of the sewer. Coastal erosion is also covered by the Strategy due to the synergies between flooding and coastal erosion risk management agendas, and pre-existing linkages at both a policy and operational level. The coastal erosion agenda includes whole system coastal geomorphic change including: sediment accretion, and habitats under threat through sea level rise and lack of migratory opportunity.

Although the management of flood and coastal erosion risk, through the application of research, is the primary goal of this research strategy, it is recognised that within FCERM multi-objective benefits may be delivered alongside risk management; for example, improvements to habitats, and creating environments conducive to leisure and commercial activities. Likewise, risk management can and should be an objective when considering other activities; for example, in designing other public infrastructure and considering land use options. Therefore, in delivering FCERM research and consequent management activities, opportunities must be sought and maximised wherever possible.

Details of the development process of the strategy are contained in Appendix 3.

2.3 UK Flood and Coastal Erosion Risk

Across the UK, at least 6 million properties are at risk, with figures for each country dependent upon the sources of flooding which are included within national totals. In England 5.2 million properties are at risk from flooding from rivers, sea, surface water, groundwater or reservoir failure[5]. In Scotland 130,000 properties are at risk from fluvial, coastal and surface water flooding, and an unknown number from groundwater or reservoir failure. In Wales a total of 357,000 properties are at risk; (220,000 from the rivers and sea, and a further 137,000 from surface water alone[6)]. Within Northern Ireland[7] 46,000 properties are at risk from rivers and the sea. 20,000 properties are at risk from surface water and in excess of 60,000 people are at risk from a reservoir breach. Natural environmental hazards, and flooding in particular, have been cited by the National Security Review[8] as some of the key risks facing the UK. In England alone, approximately 200 properties are currently vulnerable to coastal erosion, with up to 2000 potentially at risk over the next 20 years[9]. Whilst these numbers are smaller, per-property damage figures are often far greater due to the terminal nature of coastal erosion effects on both properties and associated infrastructure.

A range of studies have examined scenarios related to future UK flood and coastal erosion risk. All have indicated that risk both in the UK and globally is likely to increase in the future[10,11,12] in the face of both climate change and socio-economic pressures. The potential societal impacts and economic damages

* In draft form, this strategy has already been used to help shape discussions with the Chinese Foresight project during a meeting in March 2011.

from flood and coastal erosion risk are significant[13]. The challenge for the UK FCERM community is how to adopt sustainable adaptation and development strategies in order to tackle this increased risk.

2.4 Legislation and Policy Context

The legislative framework for FCERM has been substantially revised in recent years with the passing of the Flood and Water Management Act: England and Wales[14], the Flood Risk Management (Scotland) Act[15], Water Environment (Floods Directive) Regulations Northern Ireland[16] and the Flood Risk Regulations which implement the EU Floods Directive[17] into UK law. In addition, the Flood and Water Management Act and recently passed Reservoirs (Scotland) Act[18] reinforces the provision for Reservoir Safety. Collectively, this legislation revises the accountabilities for delivery of FCERM within the UK and recognises the need for provision of detailed risk and real-time flooding information to the public. Coastal erosion legislation is defined in the Coast Protection Act[19] (excludes Northern Ireland) and erosion issues form a key part of the delivery of Shoreline Management Plans (SMPs) led by coastal authorities.

Within the UK, central and devolved administrations deal with FCERM strategy and policy at a local level. These above Acts also provide the framework for Operating and Responsible Authorities to develop, maintain, apply and monitor their own flood risk strategies either directly or within plans from the flood risk management process. Further detail of the legislation and policy that impacts FCERM in the UK is provided in Appendix 2.

The legal requirement to undertake research for both the Environment Agency (England and Wales) and Scottish Environment Protection Agency (SEPA) is mandated within the Environment Act[20]. This Act defines the requirement for research within the functions for which these agencies have authority, including FCERM.

Recent flood events have also had a large bearing upon FCERM policy direction, most notably the Pitt Review[21] which followed the summer 2007 floods in England and Wales. This review emphasised the role of community involvement in FCERM activities in terms of empowering individuals and groups to actively participate in measures to protect themselves and their homes, as well as response and recovery from flooding events. In addition, it stressed the importance of a clearly structured tiered approach to FCERM management, where roles and accountabilities are clear and coordination between organisations is improved.

2.5 A case for investment

FCERM research and development plays a major role in providing a robust evidence base and improved tools for both government policy and the activities of operating and responsible authorities throughout the UK. This has delivered improvements in FCERM across each of the benefit areas outlined in Table 1 and is illustrated further in Section 2.6.2. The drivers and needs for new or improved knowledge and tools are increasing and the culture of delivering real benefits to front-line users is in many cases well established.

Future funding for FCERM research is likely to be substantially reduced in the current economic climate. In common with all areas of public expenditure, funding will be subject to rigorous scrutiny, both to ensure research is likely to provide benefits to multiple organisations with different agendas, and to ensure that economic, societal or environmental benefits accrue from research investment. This culture is already manifest, and many researchers will be challenged to demonstrate the public value and 'real-world' impact of their work, through the proposed Research Excellence Framework which has recently reported on an implementation pilot study[22].

A challenging and changing FCERM funding environment may alter the balance of funding regimes in favour of areas where 'quick-wins' can be most readily achieved. It is important that strategic research and investigation of less-mature research areas is maintained to ensure continuity and long-term sustainability within FCERM research (see also Section 3.3 and Figure 11). Funding will also have a bearing on the capacity of user organisations to adopt and implement research. Therefore, a careful balance needs to be made between the pace and amount of research-led outputs. Furthermore, a consideration of the magnitude of change necessary to implement research should be made at the outset.

The linkage between investment in research, the implementation of research results, and the realisation of benefits in terms of social, economic and environmental improvement can be more difficult to precisely track and quantify in some areas (e.g. improving understanding) than others (e.g. enabling activities). For example, a research initiative to address a specific user need may require investigatory research over several years before the point is reached when sufficient knowledge and user engagement exists to specify and deliver the practical output. Also, several separate research initiatives may be combined during implementation, and research that results in an incremental improvement of service, which although providing a good return on investment, may be difficult to separate from the wider benefit. However, the tracking of research benefits is vital in order to recognise the provenance of activities grounded in research and to demonstrate the return on investment research and development provides.

While specific research initiatives require justifiable objectives and need to demonstrate their relationship to tangible benefits, a number of independent reviews have stated the macro case for substantial and sustained investment in FCERM research. The Pitt Review[23] into the summer 2007 floods stated: "Scientific and engineering techniques will play a crucial role in the adaptation strategy we put in place", thereby highlighting the importance of research and development in addressing FCERM. The review identified a number of specific goals in which evidence or tools had been found lacking. The Royal Academy of Engineering Review of Infrastructure, Engineering and Climate Change Adaptation[24] systematically cites flooding as a key risk to UK infrastructure and highlights the need for research and research integration across a range of sectors.

Successive independent reviews of Defra (previously the Ministry of Agriculture, Fisheries and Food; MAFF) and Environment Agency FCERM research and development, after considering the range of user needs, have concluded that, "budget allocation is too low to match the changing policy arena and the urgent need for greater FCERM implementation efficiencies"[25,26]. These reviews considered that the dedicated budget for the Joint Programme should be approximately £7m per annum. Since these reviews, UK investment in Flood Risk Management has increased to over £800m per annum (£765m Defra, circa £50m Scotland, supplemented by circa £50m European Regional Development Funding in Wales), while dedicated research investment remains a low proportion of this sum. The amount invested in FCERM research compared to other environmental sectors is also relatively low, as shown by the analysis the Environment Research Funders' Forum (ERFF) undertook in 2007, which shows how direct investment in FCERM R&D has compared to the wider funding of FCERM activities since 1998/9 (see Figure 1 on page 8). This allocation of funding to FCERM research contrasts with the consequences of flooding which can be very large, with damages from the Summer 2007 floods in England and Wales alone estimated at £3.2bn[27].

2.6 Research Contribution to Flood and Coastal Erosion Risk Management

2.6.1 Current Activities

FCERM research is currently undertaken within the university sector, government departments and agencies, research council sponsored centres, independent research organisations and within private sector consultancies and industry. A number of the most successful examples of research programmes involve partnership and cross-organisational working between these sectors; some examples are outlined in the case study boxes in Section 2.6.2.

Within the (mainly) academic sector, two major research council initiatives on FCERM have recently been completed or are about to end. The Flood Risk from Extreme Events (FREE)[29] programme, sponsored by NERC, and Flood Risk Management Research Consortium Phase 2 (FRMRC2),[30] sponsored principally by EPSRC, represent significant recent investment and collaboration between different research sectors (although with differing models of collaboration). There are numerous other responsive mode grants, research council strategic research programmes and UK and European sponsored programmes funding academic led FCERM research. It should be noted that FCERM research is rarely a discrete entity and draws upon research within multiple topic areas. One such area is the cross research council programme on Global Uncertainties[31]. Within this programme the 'Threats

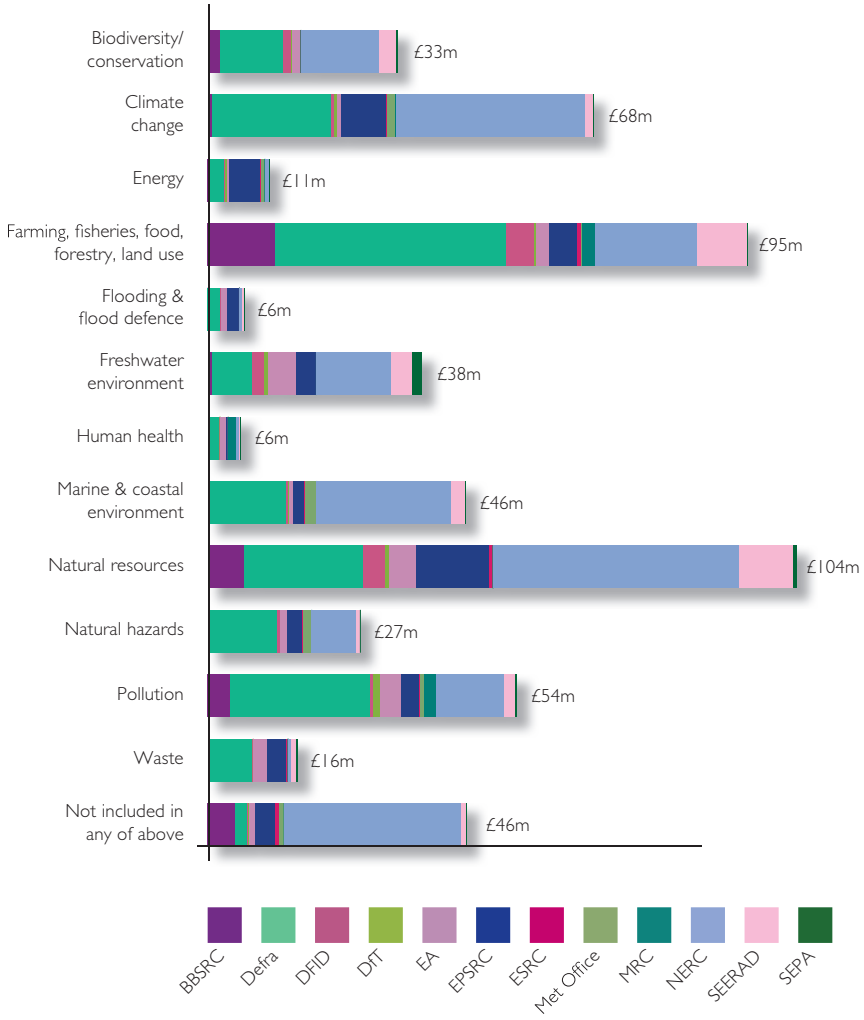


Figure 1: Analysis of research expenditure 2004-5 from ERFF Research Database Source: Strategic Analysis of UK Environmental Research Activity, ERFF 2007[28]

to Infrastructure' theme covers issues around resilience and preparedness, the work of responding organisations and also public recovery. Other areas where there are significant synergies include climate change, social science and engineering research which is applicable and relevant within FCERM.

Within the public sector, the Joint Programme[32] has accountability for research delivery to all England and Wales Operating Authorities including Internal Drainage Boards, Local and Maritime Authorities. This programme is approaching the end of its regular review cycle, having last been independently reviewed in 2005[33]. The Scotland and Northern Ireland Forum For Environmental Research (SNIFFER)[34] coordinates partnership working to support public sector organisations cooperating in multi-funder initiatives. The Scottish Government also provides funding through the Coordinated Agenda for Marine, Environment and Rural Affairs Science (CAMERAS) to the James Hutton Institute[35] to undertake flooding research as well as ecosystem services. The Scottish Environment Protection Agency (SEPA) also directly supports some FCERM research. The Met Office invests significantly in climate, meteorological and oceanographic research to support their forecasting services for FCERM, government and commercial purposes[36].

In the private sector, UKWIR (UK Water Industry Research)[37] works on behalf of the water companies to provide research and development relevant to a range of water and wastewater issues including sewer and surface water flooding, while British Water seeks to represent a range of commercial research and development interests within the water industry supply chain. The Association of British Insurers (ABI) sponsors research to support risk analysis and

spatial mapping. The Construction Industry Research and Information Association (CIRIA) also funds collaborative research and development for FCERM and plays a key role in ensuring dissemination and uptake amongst practitioners. The consultancy sector also conducts contract and commercially-led research principally to support the development of tools and models. The 'Third Sector' organisations, particularly charities, are also becoming a player in research and development, particularly at the societal impact end of flooding research (such as the work being undertaken currently by the Joseph Rowntree Foundation)[38].

Within Europe there have been a number of notable FCERM research programmes, including the ongoing CRUE[39] programme, initially funded as an ERA-Net under the Framework Programme (FP6) which involves partners from 13 member nations. Two research calls have taken place to date focusing on: risk assessment and risk management; and flood resilient communities. The Floodsite project[40], also EU funded under FP6, was designed to provide the research to support the implementation of the EU Floods Directive. Research focused on the application of methods across several international pilot sites, which in the UK centred on the Thames Estuary 2100 project[41]. The EU Interreg (phases III and IV) has also funded FCERM research focusing on trans–national co-operation to address common issues, for example; Managing Adaptive REsponses to changing flood risk (MARE)[42] Skills, Integration and New Technologies (SKINT)[43] and FloodResilienCity (FRC)[44] projects.

2.6.2 Research into Practice: examples from FCERM research

Four specific examples are detailed in the Case Study boxes, but other areas which have benefited from research investment include, but are not limited to:

Mapping and Modelling Flood and Coastal Erosion Risk: Risk Assessment for System Planning (RASP) tools include the National Flood Risk Assessment (NaFRA), which provides an overview of residual flood risk in light of current flood defences across England and Wales. This method underpins flood-risk related insurance provision for the majority of householders and businesses in England and Wales. Likewise, the Modelling and Decision Support Framework (MDSF) supports the implementation of Catchment Flood Management Plans. These take a holistic approach to flood risk management, defining strategic policy units within which management interventions are determined. Together, these tools have facilitated the shift to a risk-based approach to flood management, underpin planning legislation[45] and have allowed the analysis of future scenarios for climate change and socio-economic development[46].

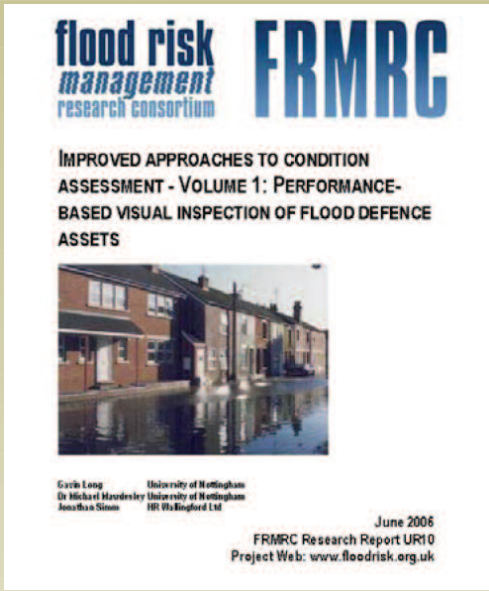
Flood Incident Management: Research investment has played a key role in improving rainfall, wind, wave and surge monitoring and prediction. This has led to greater skill in real time forecasting and the development of probabilistic forecasting methods. Improved predictions, and assessments of uncertainty associated with those predictions, have allowed improved real-time management decisions which have protected people and properties through the operation of defences and the dissemination of warning messages. In addition, research has aided the understanding of individual and collective responses to flooding, risk awareness and preparedness and the effects of flooding upon communities. This has allowed better targeting and messaging of flood warning communications and an increased understanding of the societal effects, rather than simply the financial costs, of flood events.

Flood and Coastal Defence Asset Management: Asset management research has allowed risk-based methods to target investment on critical components of asset systems, extending their design life and maintaining standards of service. A range of international best-practice design manuals have also been produced in collaboration with industry partners, to ensure both new-build and maintenance is based on sound science. Concepts of sustainability, whole-life strategies, and the important interface with environmental management, have also been developed. This has enabled a shift away from pure engineering solutions to techniques which provide multiple benefits and comply with requirements of environmental legislation.

The following case studies illustrate success stories where the transition of research across the spectrum from academic-led basic research into operational practice has occurred. They demonstrate the value of researchers and practitioners working together throughout the development of research initiatives.

Case study 1: Maintaining Flood Risk Management Assets

The UK has an extensive FCERM infrastructure base, comprising raised embankments, walls, associated structures and controls. However, river channels, beaches and natural features also form a crucial part of the FCERM asset base. Within the EPSRC led Flood Risk Management Research Consortium (FRMRC) the concept of fragility curves was applied to flood risk management assets[47]. These fragility curves describe how assets perform under loading and how the likelihood of failure (asset performance) is affected by the condition of the asset. An assessment of asset performance can thus be made through a simple visual inspection process of asset features (e.g. embankment toe, crest) to derive an overall condition index. This condition index gives a scientifically-grounded view of performance and has been used in the production of the Environment Agency Condition Assessment Manual, a guide used by operational staff to visually grade asset condition and determine necessary interventions - a simple tool for the end user supported by robust science.



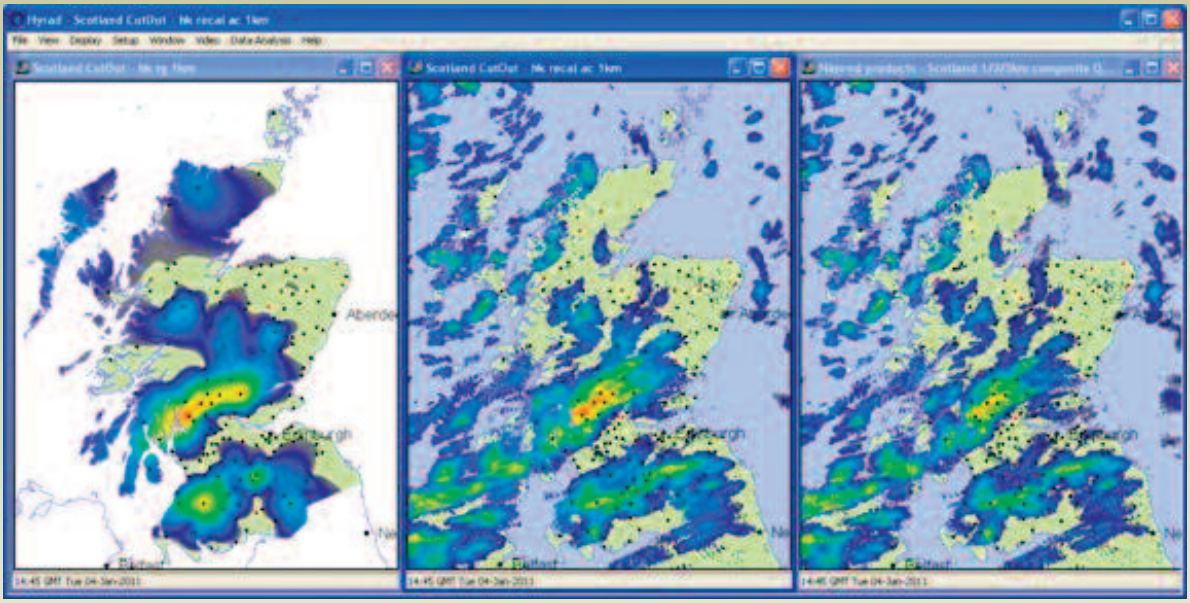
Case Study

Case Study 2: Improving the Resolution of Weather Radar Data

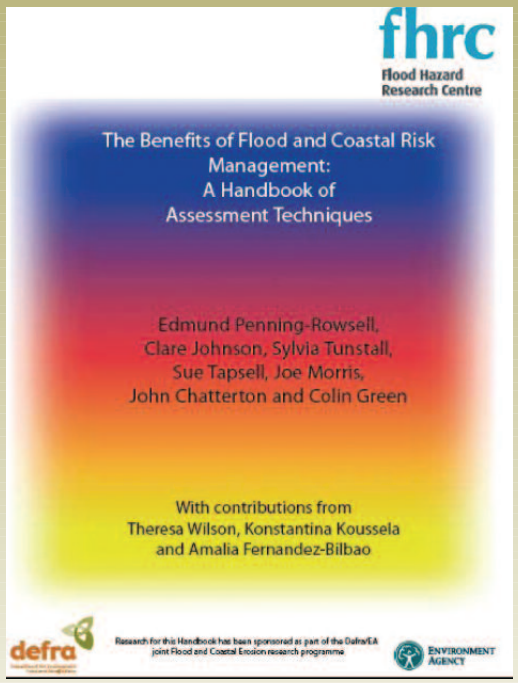
The Scottish Flood Forecasting Service is a partnership between the Met Office and the Scottish Environment Protection Agency. This service aims to make best use of the weather and river forecasting expertise of these organisations, to provide improved flood resilience and vigilance for emergency responders in Scotland.

Flood guidance is determined using a blend of experience, professional assessment and input from meteorological and hydrological models[48]. For countrywide forecasts the Centre for Ecology and Hydrology Grid-to-Grid model, currently under development, will be the key forecasting tool. This tool has its origins in Defra, NERC and Met Office funded research projects and is now seeing practical user application. The model employs radar and rain-gauge estimates of rainfall together with weather model predictions to produce forecast river flows, as gridded time-series with a full coverage of the Scottish mainland, at a resolution of 1km and for up to 5 days ahead. Following the introduction of deterministic forecasting using the G2G model, capabilities will be developed to incorporate probabilistic flood forecasts using ensemble predictions of rainfall from the Met Office Global and Regional Ensemble Prediction System (MOGREPS)[49].

The provision of rainfall data from radar and numerical weather prediction into hydrological models is a challenge in Scotland, especially given the terrain and sparse radar network coverage. This makes forecasting uncertain; however, the merged hydrological and meteorological capabilities developed through the service provide tangible benefits for improved flood prediction.



Case Study 3: Evaluating the Benefits of Flood and Coastal Risk Management



The Flood Hazard Research Centre at Middlesex University has been involved in research underpinning the economic appraisal of flood risk management interventions for many years, with the successive development of several manuals (Red, Blue and Yellow Manuals). These manuals have incrementally built-up on research and empirical evidence of flood damages. The latest Multi-Coloured Manual, underpins the appraisal and economic justification of all flood risk management capital works across England and Wales. The Defra/Environment Agency joint programme has an ongoing project which is seeking to update the datasets, methods, post event data, the latest science and other related information within the existing Multi-Coloured Manual[50]. This will provide the cornerstone for the economic appraisal of flood alleviation schemes and play a key role in how the future of funding for flood risk management is delivered.

Case Study 4: Coordinating, Observing and Utilising Coastal Data

Coastal Authorities and the Environment Agency have progressively taken up a new more strategic approach to the management of flood and erosion risk on the coast over the past 20 years. New Coastal Groups now contribute to and utilise a shared understanding of the coastal environment - waves, currents, sea level, sediment and coastal geology - which underpins the Flood and Coastal Risk Manager's requirement to '*work with natural processes*'. The six English Coastal Observatories that support this are a recognised model for sharing environmental data and information across multiple partners. Shoreline Management Plans - based on coastal cells and spanning more than one authority - now set a framework for the long-term management of the coastline in the face of pressures from economic and social development, sea level rise and the need to protect the natural environment. The on-going development of 'soft' engineering measures, such as beach management and set back, is supported by scientifically-based tools and guidance. All these advances are acknowledged as a success and represent a major step forward from the culture of piecemeal measures and traditional engineering practice that they replace. All these changes are underpinned by science funded through Defra and the Environment Agency (and their predecessors) along with the research councils, notably NERC.

3 A Thematic Approach to FCERM Research

FCERM is widely recognised as a multidisciplinary challenge and the paradigm of flood and coastal erosion defence has now evolved towards one of flood and coastal erosion risk management. With this has come a rebalancing of research focus from that supporting the delivery of pure engineering solutions towards FCERM options that more fully incorporate working with natural processes and understanding of societal and individual behaviours. This strategy continues to build a thematic approach for research and development based upon holistic, multidisciplinary principles.

3.1 A Spectrum of Research Needs

The term Research and Development covers a range of activities from research on fundamental processes to operational piloting and implementation. These activities are commonly defined using the Frascati system[51].

- **Basic research** is experimental or theoretical work undertaken primarily to acquire new knowledge about materials, structures and environmental processes, without any particular application or use in view.
- **Applied research** is also original investigation to acquire new knowledge. It is, however, directed primarily towards specific practical aims or objectives.

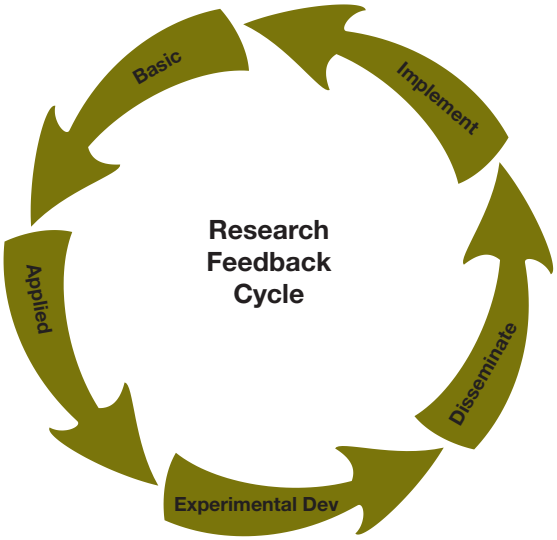


Figure 2: Research Feedback Cycle

- **Experimental development** is systematic work, drawing on existing knowledge gained from research and/or practical experience. It is commonly directed to: producing new materials, products or devices; to installing new processes, systems and services; or to substantially improving those already produced or installed.

A key aim of the strategy is to ensure a continuous linkage between basic research and operational activity through the co-design and co-delivery of initiatives. This is facilitated by the fostering and maintenance of dialogue and knowledge exchange between researchers and the user community throughout the research process. It is also reliant on continuous practitioner feedback to spawn the basic and applied research needed to address real-world problems in a responsive way and should not be regarded as a one way flow of information (see Figure 2). The cultural and organisational barriers to achieving this should not be underestimated and are considered in Section 8.2.2.

This strategy covers the needs of many institutions and funders, the collective remit of which spans the full breadth of the research spectrum. Figure 3 describes how different research funders and users have interests in particular parts of the spectrum. This figure also highlights the need for piloting of research outputs in making the transition between research outputs and practical application.

It is important to highlight the areas where novel cutting-edge research can most effectively inform practical problems and to encourage users to rapidly uptake the latest research outputs. Indeed, in the delivery of research, it is important that outputs are continuously checked to ensure they are meeting needs and allow the delivery of real benefits to people and property at risk from flooding and coastal erosion. It is also important that the cost to uptake and embed research-led changes is factored into robust assessments of net benefit. In some cases, research-led quality improvements may be theoretically achievable, but (particularly in large organisations) the costs to implement incremental changes may be large and prohibitive in terms of changes to, for example, training, systems and processes. Research, particularly within the applied spectrum, should therefore target areas where the benefits are realisable and define a route to adoption.

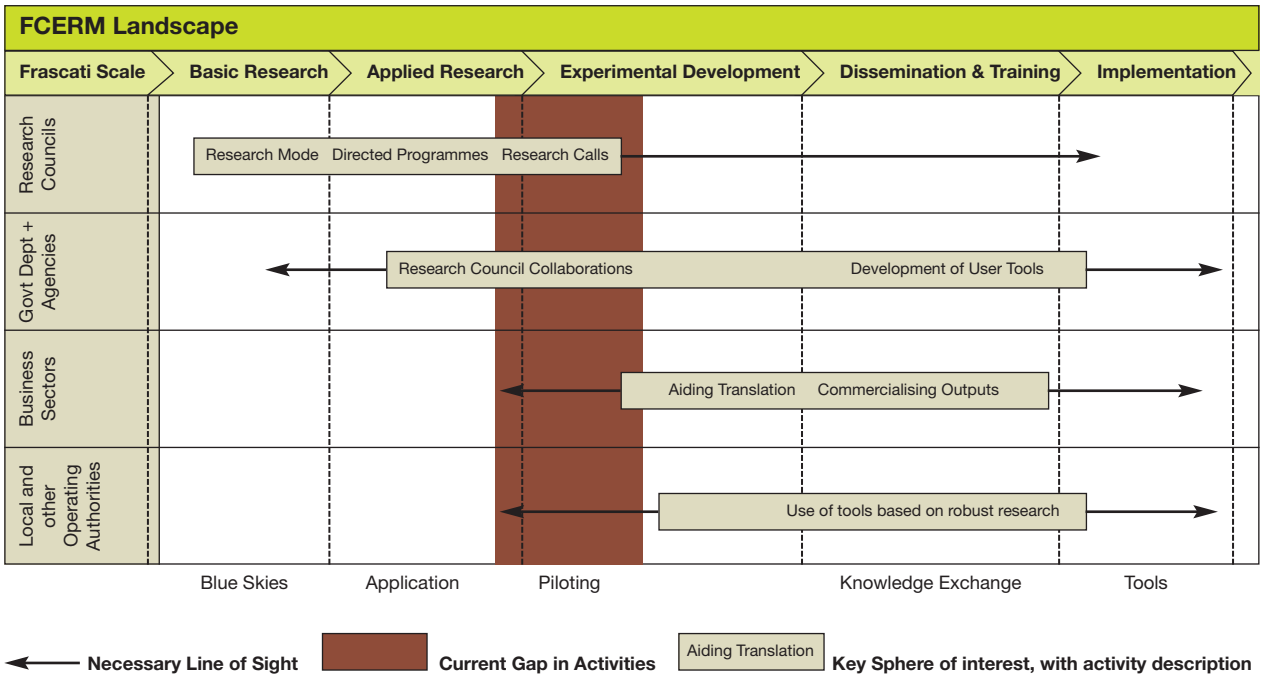


Figure 3: FCERM Research Landscape. The relationship between research spectrum and key stakeholder groups

3.2 The Thematic Approach to Flood Risk Management Research

The multidisciplinary nature of FCERM research makes the aggregation of issues into simple discrete challenges areas difficult. The Environmental Risk Assessment and Management (ERAM) guidelines published by Defra in 2000[52] outline a common risk framework to address environmental issues. Thus, a straightforward thematic framework has been adopted to describe FCERM research needs, which aligns to the ERAM guidelines. This is based upon the constituents of managing risk, where risk is a function of probability (likelihood) and consequence (impact). As such it may be considered a generic framework, applicable across other environmental topic areas (for instance within LWEC). It contains three key Risk Themes:

- Understanding risk
- Managing probability
- Managing consequence

This strategy describes high-level research priority areas within these three Risk Themes. It is intended that these, based on clearly identified needs, will inform further more detailed consideration of key knowledge gaps and provide a signpost for funding future research work. Collectively it is intended that they form a crucial first part of the components that need to be addressed by FCERM research over the next 20 years.

Each of these Risk Themes cannot, and should not, operate in isolation; many issues, researchers and user interests cross-cut the thematic areas. Figure 4 below shows some of the topic areas which are not easily categorised into a single theme and demonstrates the need to understand the interfaces between the Risk Themes.

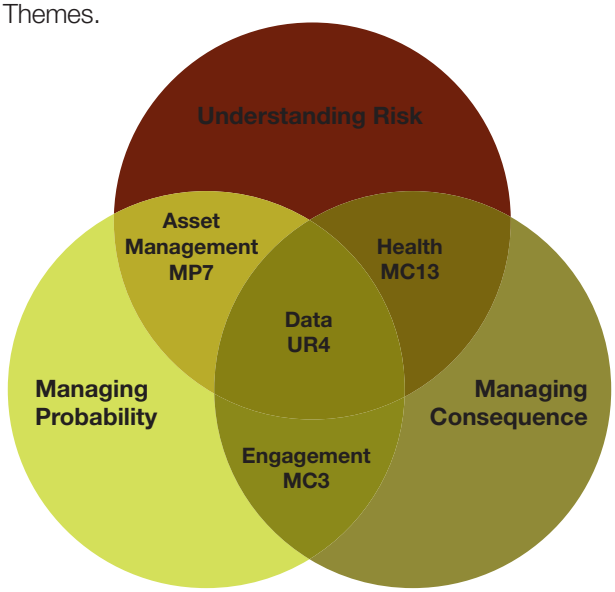


Figure 4: Relationship between Risk Themes (with examples of overlapping topic areas)
(*For a full explanation of topic areas and codes see Appendix 1*)

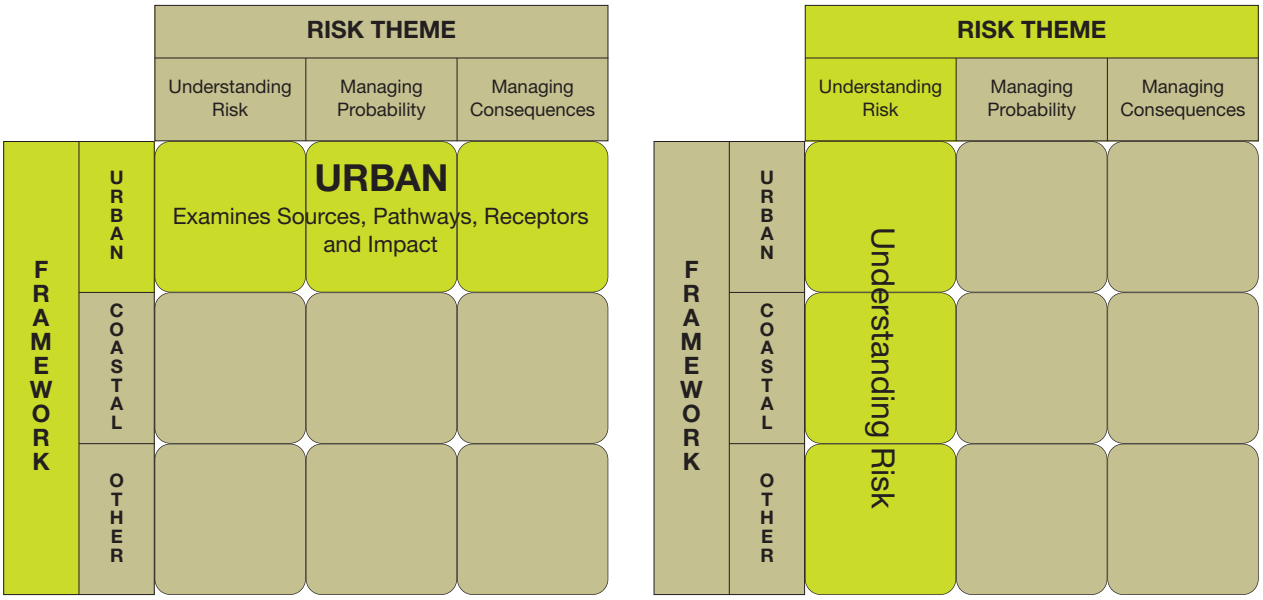


Figure 5: The use of Risk Themes and Sectoral Frameworks to analyse the FCERM research landscape

Where significant cross-cutting areas exist, the use of Sectoral Frameworks will allow and encourage further multi-disciplinary working. These frameworks are described within Section 7.2.1 of this strategy but may be set up to examine specific environmental domains (e.g. urban or coastal) or topical domains (e.g. economics or social science). It is envisaged that use of Sectoral Frameworks will provide a flexible model which will evolve as any subsequent programmes are developed and provide a useful vehicle for sharing research needs and outputs across stakeholder groups. In addition, Sectoral Frameworks will assist in guiding projects and initiatives across different partner bodies. In combination, the use of the Risk Themes and Sectoral Frameworks approach allows the examination of research issues from a number of perspectives as illustrated in Figure 5.

A number of common elements influence each of the Risk Themes and Sectoral Frameworks, namely Political, Economic, Social, Technological, Legal and Environmental (PESTLE) considerations. It is widely accepted that fundamental research is required to understand these elements, but that greater value, particularly in application, can be achieved when they are integrated into other research areas as part of the approach.

Implicit within the ERAM guidelines is the concept of the Source-Pathway-Receptor model, which has been widely adopted by researchers and practitioners as a useful approach to the FCERM system (Figure 6). The concepts within this model should be inherent within both the Risk Themes and the Sectoral Frameworks.

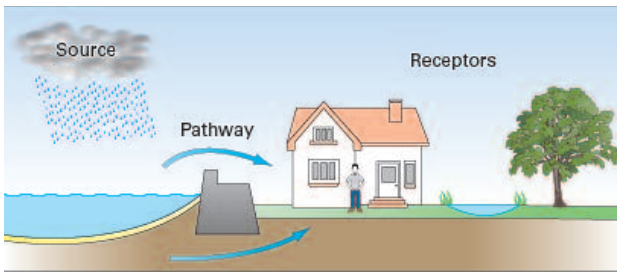


Figure 6: Source, Pathway, Receptor model

3.3 Research Maturity

Research maturity is used to describe the current status of knowledge within a topic area. This is based on the extent to which research has progressed across the research spectrum, from basic research to operational implementation. This strategy advocates targeting investment within the research spectrum to where it will be most effective, whether filling gaps in basic knowledge or promoting the transition of research into common application.

Identification of the areas of research that are likely to be most responsive in terms of yielding benefits from additional investment is crucial. A high level of existing research maturity does not necessarily suggest that investment should be redirected to

topics exhibiting a lower level of maturity; mature areas of research may yield significant benefits through their effective transition into user application via limited, but crucial research investments. There is frequently a large gulf between the knowledge base and what constitutes common practice.

Similarly, a low level of maturity within a topic area does not indicate that it should be de-prioritised on the basis that benefits in terms of social, economic or environmental outcomes are unlikely to materialise for several years. Important areas of research exist at currently low levels of maturity, where there is a need to undertake basic research to improve the fundamental knowledge of the topic. Indeed, low maturity areas may present an opportunity to develop the paradigm of thought via a more inclusive approach to multiple stakeholder groups. Appreciating that benefits progressively accrue as research extends across the research spectrum is taken-up by users, is useful when considering research maturity and prioritisation[53].

In translating this strategy into a work programme that is appropriately targeted to achieve specific outcomes, focusing and balancing research across the spectrum is desirable in order to:

- ensure a continuous pipeline of research aligned to meet critical FCERM outcomes
- recognise the corporate aims of different funders
- balance researcher and user effort, and to work within capacity constraints

Research delivery across the spectrum through to FCERM practitioners should be via progressive, incremental and logical steps in order that research can be readily assimilated and used to manage flood and coastal erosion risk.

3.4 Application of research in a local context

This strategy advocates the increased use of locally based studies, particularly where research has reached a reasonable level of maturity. A focus on communities, specific catchments, or coastal cells is supported within emerging FCERM strategies and is aligned with the recommendations of the Pitt Review[54]. Approaches may comprise either research pilot studies or the application of research methods to deliver local strategies – both of which may bring numerous benefits. For example:

- research is tested and applied in a 'real-world' context where local factors create unique conditions
- local user buy-in to the research effort is encouraged, aiding embedding of practices
- shift the perception of research in the local community from that of an abstract exercise to a pragmatic application of science to practically solve specific problems; this increases the likelihood that research and development will be adopted into the local management cycle.

A good example of this is the Thames Estuary 2100 project[55]. Here, research methods developed by the Joint Defra/Environment Agency Programme were built upon within the EU funded Floodsite Programme and piloted in the Thames Estuary. Here research has helped to develop local management strategies to minimise risks associated with climatic and socio-economic changes. Scaling up the methods piloted in the TE2100 project across England and Wales has proved challenging due to capacity constraints.

Image courtesy of the Environment Agency

4 Understanding Risk Theme: research priorities

Understanding risk is fundamental to effective FCERM. Research within this Risk Theme will provide the data, knowledge, and tools to support robust, risk-based, FCERM decision-making. Flood and Coastal Erosion Risk Managers must predict and plan for environmental change and events that may not have happened before - on the basis of a good understanding of processes and the provision of reliable and fit for purpose data and models that span physical, social, environmental and economic domains. Research is required to assess current and future risks, by detecting and predicting changes and trends to ensure FCERM approaches are economically, socially and environmentally sound. The many contributors to FCERM, be they natural driver or socio-economic vulnerability components, mean that risk has to be assessed in a multidisciplinary context, in which most environmental and socio-economic drivers are changing, where uncertainty is pervasive and decision-making is complex. Throughout this theme, there is a need for basic research to better understand sources, pathways and receptors (Figure 6), including physical processes, environmental extremes, system responses, vulnerabilities and uncertainties. Applied research into how these may be parameterised and modelled, as well as developed into practical tools for use in decision support, is required.

The Understanding Risk Theme has been sub-divided into four thematic priority areas. The key anticipated outcomes from these are outlined below. Further detail on the specific research priorities is detailed in Appendix 1.1.

4.1 Understanding Risk Theme Priority 1: Uncertainty, complexity and decision making

This thematic priority will improve our understanding of the complex inter-related environmental, social and economic systems that comprise FCERM and examine how associated uncertainties impact upon, and may be managed within, decision making. This includes adequately characterising natural variability, the complexities of how individuals and communities respond, ways in which we can communicate the level of confidence in our evidence and justify decisions. Research supporting the optimal use of decision pathways under multiple uncertainties and scenarios are important and should facilitate consistent, informed, flexible and risk-based decision-making based upon the best available information.

4.2 Understanding Risk Theme Priority 2: Data and observations

This thematic priority will effectively collect, process and utilise data and ensure that these are sufficient to support and calibrate models with event information and take FCERM decisions with an appropriate degree of confidence. This includes full consideration of operational and research data and observational data requirements, raising awareness of the data available, understanding the quality constraints it may contain, translating data into useful information and sharing this between users. Data requirements should be objective-led, informed by multiple users[56], and considered within the wider UK Environmental Observation Framework[57] to ensure consistency and maximise re-use of data and observations.

Image © ABPmer

4.3 Understanding Risk Theme Priority 3: Sources and processes

This thematic priority will identify, characterise and predict FCERM sources and processes in order to accurately evaluate the risk that they pose from both the built and natural environment, particularly the effect that they have on FCERM activities on a range of spatial scales. This includes improved broad scale evaluations of risk from surface water and groundwater sources and how these may be impacted by climate change and socio-economic pressures. It also includes improved understanding of how we might work with natural catchment, land management and morphological processes to deliver improved and sustainable FCERM techniques.

4.4 Understanding Risk Theme Priority 4: Understanding the costs and benefits of risk management

This thematic priority will improve our understanding of the true costs and benefits of FCERM activities, over many spatial and temporal scales, in order to better inform funding strategies and yield the greatest return on investment. This includes comprehensive quantification of costs of flooding and coastal erosion, the valuation of goods and services, including those of the environment and communities, in order to build a robust business case for continued investment. This should allow an evaluation of the effectiveness of different FCERM interventions and demonstrate the relative value of FCERM in comparison with competing funding agendas.

Image by kind permission: John Connor, Press Association

Image © SEPA 2011

5 Managing Probability: research priorities

Research to reduce the probability of flooding or coastal erosion will lessen the threat to people and their property whilst providing environmental, social and economic benefits. It should support the design, construction, maintenance, renewal, adaptation, removal or replacement of built FCERM assets, such as embankments, barriers and pumping stations. Increasingly research should also focus on utilisation of natural features such as river channels, dunes and beaches, taking into account non-FCERM pressures on their usage, for instance in food security and leisure activities. Asset management currently accounts for by far the greatest expenditure in FCERM and thus small incremental improvements from research investment may yield large benefits for the UK. In the face of significant future climatic and socio-economic changes there is a need to continue research into FCERM assets and associated risk management systems, but also to provide more sustainable, cost-effective and environmentally acceptable solutions. The Foresight Future Flooding study highlights that under 3 of the 4 future scenarios, the provision and maintenance of flood and coastal defence structures ranks amongst the most significant contributory responses to risk reduction[58,59]. This Risk Theme draws upon two recent reviews of research needs within the fields of Reservoir Safety[60] and Integrated Urban Drainage[61] conducted by the Defra/Environment Agency Joint Programme and also the review - Engineering to Live within Planetary Boundaries: Research Needs for Civil Engineering[62].

The Reducing Probability Risk Theme has been sub-divided into three thematic priority areas. The key anticipated outcomes from these are outlined below, with further detail on the specific research priorities detailed in Appendix 1.2.

5.1 Managing Probability Theme Priority 1: FCERM Asset System Assessment and Design

This thematic priority will ensure that FCERM asset design is conducted according to evidence-based good practice, in order that we build and are able to maintain an effective asset infrastructure base. This will allow us to understand the effects of climate change upon assets, that assets have the ability to perform multiple functions for little additional investment, ensure that assets are resilient to future usage scenarios and how safety can be designed into systems from the outset.

5.2 Managing Probability Theme Priority 2: FCERM Whole Life Asset Management

This thematic priority will improve our understanding of asset condition (components and systems) and performance, in order that it effectively informs decision-making within the asset management life cycle. Research should consider asset deterioration and how this is affected by different maintenance regimes. It should include: provision of the scientific basis for interventions in non-routine maintenance or major refurbishment; understanding how lack of maintenance affects performance, risk and future costs; and when design life is exceeded, knowing how to most effectively replace assets under a range of future climatic or socio-economic scenarios. The key principle is to optimise investment to ensure assets are exploited as much as possible without exposing them to unacceptable levels of risk.

5.3 Managing Probability Theme Priority 3: Environmental Management and Sustainability

This thematic priority will help to better understand the interaction between human intervention and natural processes in asset management to ensure that FCERM activities are undertaken in an environmentally sensitive and sustainable way. The benefits, usage and effectiveness of natural flood management measures as mechanisms for reducing risk need to be better understood. Research should include developing sediment and vegetation management techniques, and maintaining compliance with legislation regarding fauna, flora and ecosystem condition.

6 Managing Consequence: research priorities

Research within this Risk Theme supports the establishment of flood or coastal erosion resilient communities and properties. It will never be technically, economically or environmentally possible to prevent flooding or coastal erosion entirely, but it is possible to manage the consequences. Much of the research will focus on how to develop awareness of flood risk and establish how this may be effectively translated into real time response to flood events via forecasting and warning regimes and emergency planning. These actions forewarn the emergency services and responding bodies involved in flood incident management and provide people with time to evacuate or protect their property. Building the resilience of individuals and communities, including improving their ability to recover quickly from events, is very important. A number of the priorities identified draw upon those identified in the Defra/Environment Agency Joint Programme Incident Management and Community Engagement Theme work plan 2010-2015[63]. The recently developed Social Science Strategy[64] for the Joint Programme calls for the embedding of the social sciences within all aspects of FCERM research and development.

Image courtesy of Environment Agency

The Reducing Consequence Risk Theme has been sub-divided into four priority areas, all of which are generically important in hazard management. The key anticipated outcomes of which are outlined below, with further detail on the specific research priorities detailed in Appendix 1.3.

6.1 Managing Consequence Theme Priority 1: Risk awareness and preparedness

This thematic priority aims to understand how concepts of risk can be more effectively communicated to individuals, communities and professional partner organisations in order to raise awareness, gain acceptance of the risk and elicit an appropriate response in terms of both pre-event preparedness and action during an event. This will address key social and psychological barriers, better targeting of public engagement activities, and recognise inherent diversities within groups. This will enable stakeholders to produce their own plans, and to take responsibility for themselves during flood events. Through this approach there should be increasingly wide community identification, understanding, participation and ownership of, the issues within FCERM.

6.2 Managing Consequence Theme Priority 2: Forecasting

This thematic priority will utilise the best available data, information and models to forecast the spatial extent, depth, velocity, duration, contaminant and debris loadings of floods, as well as their wider impacts, over many temporal and spatial scales and from multiple potential sources. To do this there is a need for greater integration of prediction models for the different components of the water cycle – specifically atmosphere, ocean, ocean waves, surface and sub-surface hydrology and inundation. This will allow us to predict the effects of flooding in real-time through provision of better warning and response services. It will more effectively protect people and properties, allow prioritisation of resources between responding organisations and estimation of the scale of the impact of flooding. There is a need to identify how to best make forecasting information accessible to different recipients, such as emergency responders or the public, who require it.

6.3 Managing Consequence Theme Priority 3: Warning and response

This thematic priority will aim to understand how the content, mode of delivery or improved targeting of warning messages may be tailored to most effectively produce a response which reduces risk to people and property. This includes establishing how we might exploit new and future technologies and media channels, utilise existing community dynamics (particularly in culturally diverse areas), use individuals as agents of change and shape warnings to make the messages relevant and effective to different groups. Additionally, research on information sharing between organisations, in terms of the priorities of what to share and how to share it, and the effects of information sharing would also be useful.

6.4 Managing Consequence Theme Priority 4: Social Effects

This thematic priority aims to understand the social effects of being at risk from flooding and coastal erosion and the effects of being directly affected by an event in order to better reflect the true impacts beyond economic damages. This will allow us to incorporate measures of what are often cited to be the most devastating (but often least understood) impacts of flood and coastal erosion more accurately within consideration of FCERM approaches. Understanding the characteristics of societies that most influence flooding and coastal erosion impacts, such as barriers to accepting advice, is important. Research should include how positive impacts of flooding or coastal erosion, such as increased social cohesion, may be used in resilience building. The shift in the character of impacts caused by both climate change and socio-economic pressures is also important as it has the potential to increase social inequalities.

Image courtesy of the Environment Agency

7 Making the UK FCERM Research Strategy work

7.1 Phases of delivery

Delivery of the UK FCERM Research Strategy is envisaged as a three phase process (Figure 7):

1. Strategy development: The development of this document describing the high level priority areas for research and the method for developing a governance structure for delivery.
2. Implementation: to consider detailed mechanisms that ensure effective delivery of the strategy, via the set up of governance arrangements and the transition of existing programmes. This phase will also consider success metrics and how the success of the strategy may be measured.
3. Adoption of revised ways of working: Full 'go live' of new arrangements, with scope for fine-tuning working arrangements and encouraging a culture of continuous improvement.

Risk Management Research and Development Programme Board have agreed that implementation of the LWEC FCERM Research Strategy should build upon the strengths of the existing Joint Programme, whilst recognising the interests of all LWEC partners[65]. This reflects the fact that devolution has altered the landscape of government since the Joint Programme was initiated and the emerging need for research councils to focus upon societal, economic and environmental impact, in addition to academic excellence when determining funding awards[66]. This Strategy sets out the initial high-level research priorities that require attention from the LWEC community, but also outlines the mechanism by which more higher-resolution priorities might be identified and research initiatives are instigated. It is intended that the research priorities should be subject to thorough and regular review by a wide range of stakeholders.

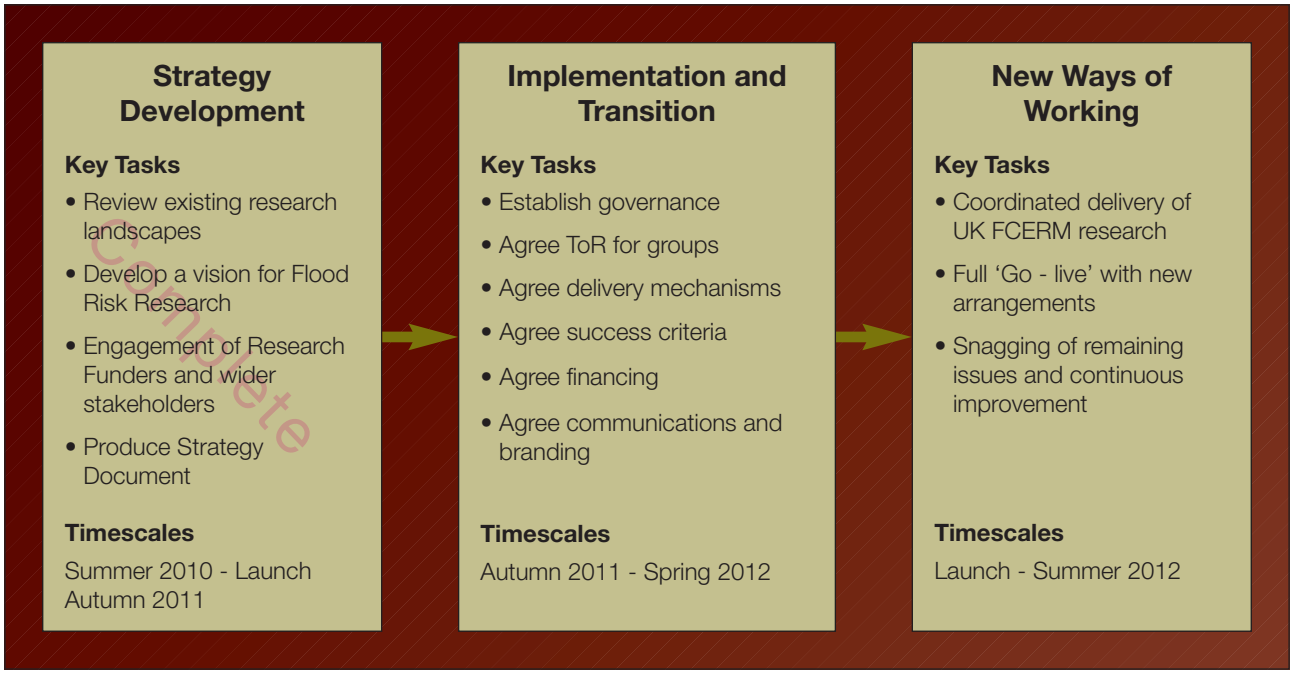


Figure 7: Phases of Delivery with key activities

7.2 Governance

This research strategy is bold and ambitious in attempting to secure greater collaboration across the FCERM community and success is dependent on strong leadership, strategic level coordination and the commitment of partners to make it happen. The LWEC Partners Board and the existing Defra/ Environment Agency Joint Flood and Coastal Erosion

As part of implementation, the options for longer-term governance and delivery will be examined and assessed against the aims and objectives of the strategy. In order to oversee this and gain agreement, it is proposed that a time-limited, LWEC sponsored **FCERM Research Steering Group** be put in place. Part of the remit will be to review existing delivery mechanisms and consider the extent to which these need to be modified to address the aims of the strategy.

7.2.1 Key Delivery Elements

It is proposed that Themes and Sectoral Frameworks form the key building blocks for delivery of the strategy (Figure 8). **The Thematic Structure** identified above is based around the 3 Risk Themes: Understanding Risk; Reducing Probability; and Reducing Consequence. Each Risk Theme forms the basis for describing research priorities and will be considered by the Steering Group in the context of future governance arrangements. It is anticipated that themes will draw upon expertise from across academia, industry and user sectors through a **Thematic Advisory Group**, as this model has proved successful in both the existing Joint Programme and through the Scottish Expert Advisory Groups.

It is proposed that cross-cutting **Sectoral Framework Working Groups** should be established to provide a flexible means for examining specific topic areas. Generally temporary in nature, they involve gathering expertise into working groups from across all sectors and themes to scope needs, facilitate cross-organisational collaboration, deliver work and oversee implementation. In common with the Thematic Advisory Group they may also generate and peer review proposals for projects and programmes, contribute to the delivery of projects and programmes and assist in the dissemination and uptake of research, as well as tracking of benefits accrued. Crucially, where required, these Sectoral Frameworks will allow continuity across disciplinary boundaries, providing a truly integrated approach to addressing FCERM problems.

Research **Delivery** will be achieved through commissioning and collaboration on a series of projects and programmes that exploit UK and International expertise and good practice across all research sectors. In addition to commissioned work, the portfolio will also provide shorter term gathering of evidence to meet operational and policy needs. All delivery will consider needs across the whole research spectrum, with work focused where it may most effectively deliver knowledge and tools that can be used to realise economic, societal or environmental benefits in relation to FCERM.

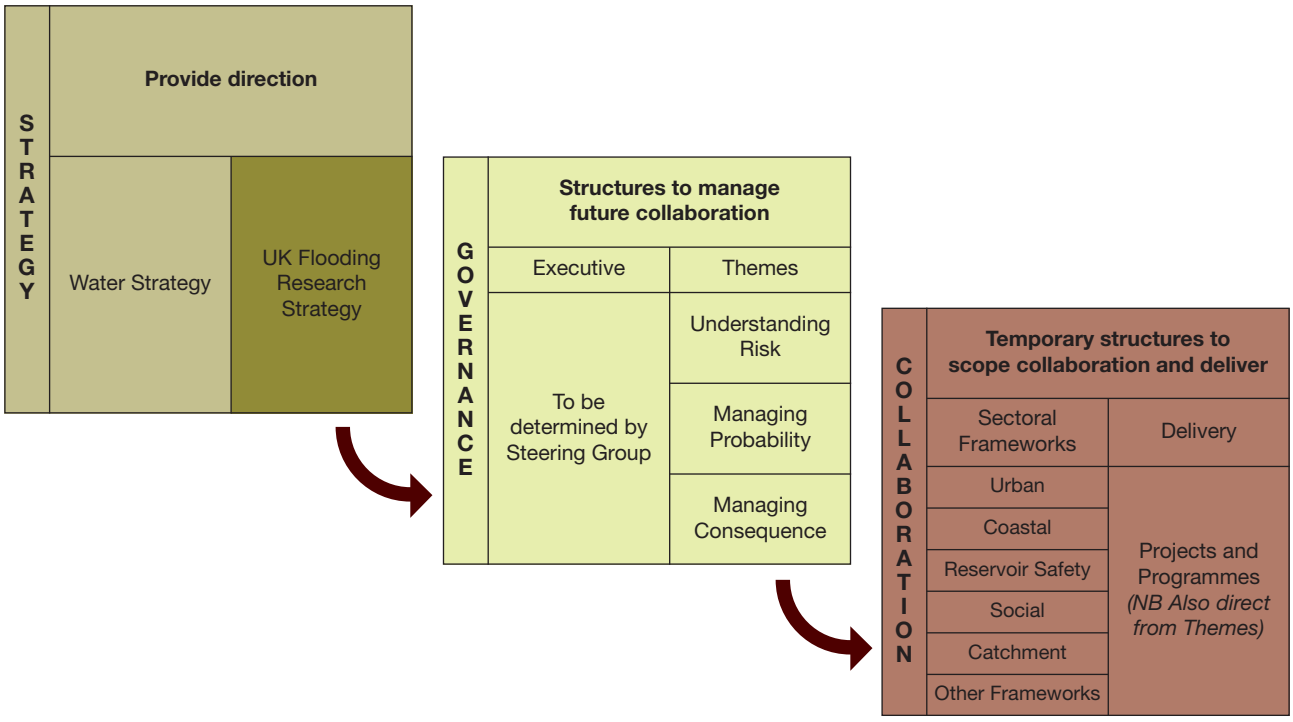


Figure 8: Relationship between Strategy, Governance and Frameworks

7.3 Ways of Working

7.3.1 Funding

The provision of funding to resource the FCERM research emerging from this strategy and its implementation is crucial to its success. Investment needs to be both sufficient to address the increasing risk posed by climatic and socio-economic changes and sustained to allow for long-term planning, capacity building and a follow through of research into policy and operational implementation. Renewed emphasis upon ensuring knowledge transfer and exploitation of existing high-quality research including explicitly funding this activity is needed. The findings of the 2005 review[67] remain valid, calling for a £7m per annum investment in user led research, with more recent sector reviews such as the Integrated Urban Drainage Research Framework[68] calling for investment of £30m over the next 10 years for this sector alone.

The allocation of funding between the priorities outlined within the three Risk-based research themes is anticipated to fluctuate during the lifetime of this strategy according to how priorities are tackled and the opportunities that emerge for leveraging funds between institutions (including those that may be beneficiaries from the research outputs). However, two factors should be considered in funding the research agendas, which may cause both conflict and complementarities.

- A shift towards working with both the natural environment and affected communities in delivering sustainable FCERM; this will entail some migration away from traditional engineering approaches.

- The relative contribution of different FCERM activities in reducing the risk to people and properties, which indicates that the provision and maintenance of assets provides some of the best return on investment in terms of damages avoided[69].

The future collaborative funding of FCERM research will be complex, due to the different organisational goals of partners, lack of synchronicity of funding cycles and the absence of centralised accounting systems. LWEC partners have agreed that they will each remain autonomous in terms of control of

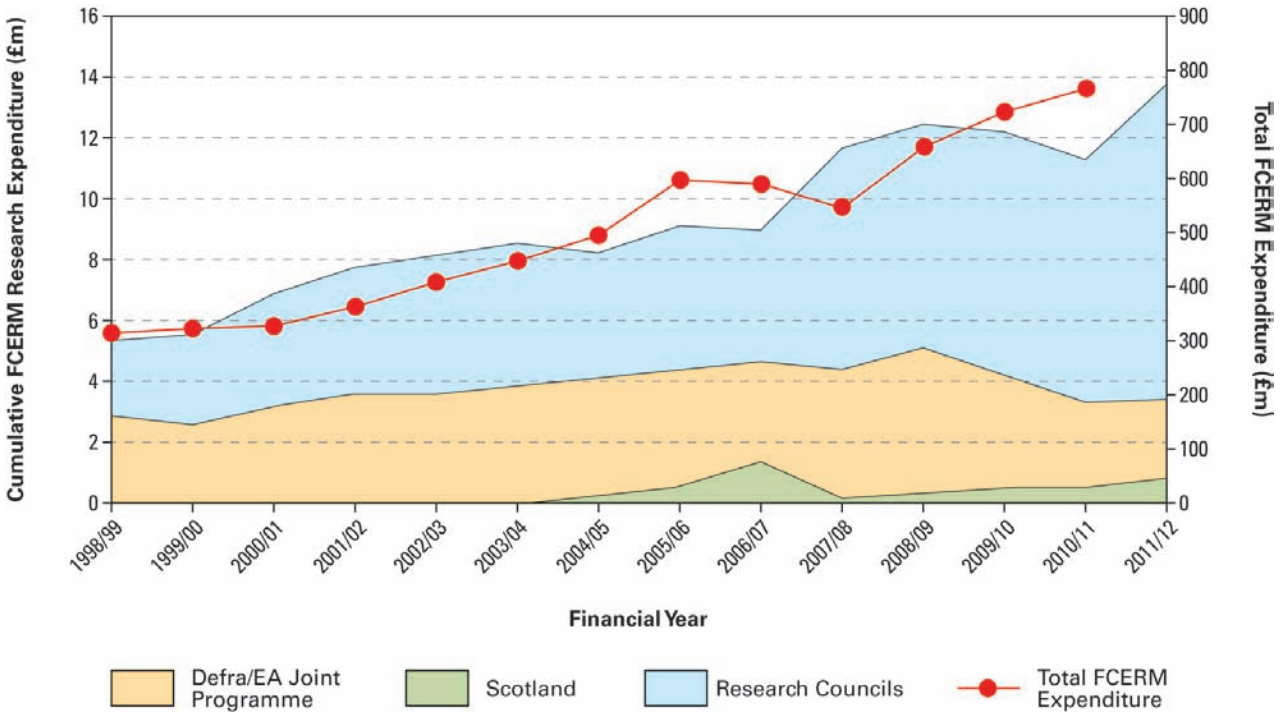


Figure 9: FCERM Research Expenditure as a proportion of overall FCERM
Note research council figures are a 3 year moving average to avoid peaks related to year of grant award – increases in research council funds in 07/08 relate to large EPSRC awards for FRMRC phase 2, increases in 11/12 relate to NERC budget secured through Natural Hazards Programme

Increasing Degree of Partnership					
	Coexistence	**Cooperation**	**Coordination**	**Collaboration**	**Co-ownership**
Description	"We understand how our work inter relates"	"I'll lend you a hand when my work is done"	"We need to adjust what we do to avoid overlap and confusion"	"Let's work on this together"	"We feel totally responsible"
Activity	Improved understanding of remits and boundaries between organisations Greater transparency of work being undertaken	Partners work to help each other achieve aims	Partners accept the need for an oversight of activities to avoid overlap and duplication	Partners identify opportunities for the development of collaborative initiatives	Development of a shared vision and commitment to deliver the vision

Figure 10: Five degrees of partnership

individual organisational expenditure. It is envisaged that approaches to funding will evolve as future governance arrangements mature and opportunities for shared initiatives arise. The governance structure should ultimately facilitate the joint funding of initiatives, the pooling of resources (skills, money and facilities), where appropriate, and the alignment of effort to meet shared priorities. Seed-corn money from a lead organisation to address an identified priority should promote collaborative contributions from others. Collective agreement on scope, time, costs and quality and how the work should be subdivided should be finalised before awarding contracts. Innovative approaches in this regard are encouraged and examples, such as those adopted within the Coastal and Estuarine System Tools (CoaEST) project, already exist. In CoaEST, NERC and the Defra/EA Joint programme have agreed a set of shared objectives, with NERC funding the basic research elements through academic grant award and the Joint Programme funding the subsequent translation of these outputs into user tools. Additionally, lessons from past multi-funder collaborations should be learnt, with key stakeholders involved in helping to define the goals of initiatives and the governance arrangements by which they are delivered.

7.3.2 Partnering

The strategy aims to facilitate a model of flexible partnering, which can be adapted according to the nature of the challenge presented. The strategy aims to achieve coordination of the FCERM research agenda and facilitate effective collaboration opportunities. Ultimately, it is expected that the FCERM portfolio of research will be co-owned by FCERM partners and that a culture of shared vision will be fostered. Figure 10 shows how working between organisations may comprise increasing degrees of partnership.

The characteristics of a collaborative research and development community have been described within the emerging CoRDDI Framework[70] and are shown in Figure 11 below and are discussed in further detail within Sections 7.3.1 and Section 8 of this document.

7.3.3 Prioritising Research Efforts

Establishing detailed research priorities across FCERM is complex due to the breadth of the topic, the diversity of approaches to minimise risk, the dynamism of policy, the range of operational activities, the multitude of related agendas and the number of different institutions engaging in FCERM research. As outlined in Appendix 3, the identification of research needs was undertaken through a series of workshops, expert reviews and online consultation. It is anticipated that these will be further considered and refined through the FCERM Executive Board, Thematic Advisory Groups and Sectoral Frameworks.

Within Appendix 1.1 - 1.3 the relative urgency of research areas has been assessed and combined with a view of maturity across the research spectrum. This is designed to indicate where effort may be concentrated by different research funders to provide either the underpinning basic research or using existing research outputs and transferring these into operational usage.

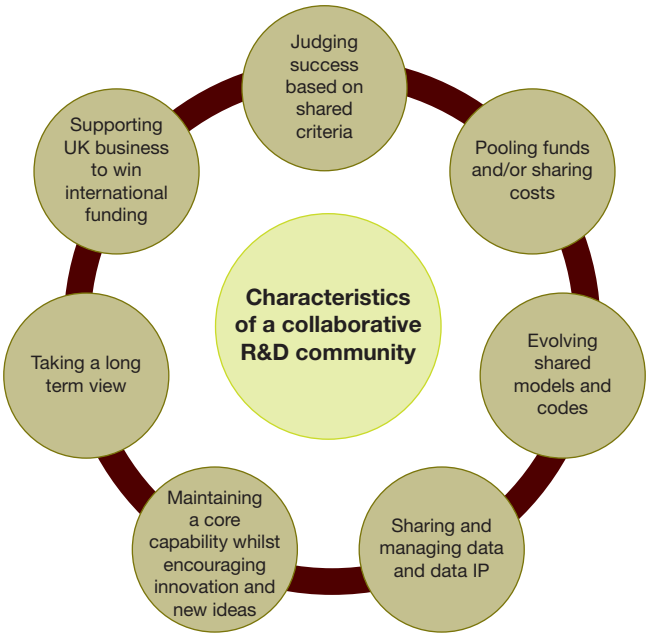


Figure 11: Characteristics of collaborative R&D (from CoRDDI Framework)

Image courtesy of The Environment Agency

8 FCERM Board Delivery Challenges

In delivering the FCERM Research Strategy, numerous barriers and challenges associated with cross organisational delivery will be faced. This document aims to identify these issues and highlight where the accountability for addressing them lies. Within the delivery structure outlined, it is anticipated that the Executive Board will take responsibility for sponsoring initiatives to fully investigate and resolve these delivery challenges. The Sectoral Framework approach, as previously outlined, may be useful in this regard, as temporary cross-cutting working groups may be initiated to scope problems, appraise options and deliver practical solutions to which all partners can agree.

Table 4: Key Challenges to the delivery of the Research Strategy

- Maintaining the relevance of the strategy
- Integration of individuals and organisations, including sharing data and information
- Maintaining and developing capacity & capability
- Embedding research into practice and demonstrating benefits

8.1 Maintaining the Strategy

The success of this strategy is dependent upon future governance arrangements and regularly refreshing research priorities into the future. To achieve this, it is intended that an online resource, detailing existing and future research priorities, is developed. This will allow researchers and users to contribute to and debate research priorities, facilitate the development of collaborative efforts through joint bids and aid the line of sight across the research spectrum. In this way, the strategy can remain responsive to emerging needs and maintain its policy and operational relevance. Existing models for active online collaboration do exist and could be adopted for FCERM purposes, through the use of online marketplaces or Ideagoras such as Innocentive[71], which actively challenge communities to solve specific problems. There is also a need to ensure access to completed environmental research, which is currently delivered through a range of databases including the Environmental Research Database: Envirobase[72].

8.2 Integrating Organisational Culture

Within FCERM Research there are three key elements to achieving integration:

- fostering true inter-disciplinarity
- bridging the research provider-user interface
- developing shared success criteria

8.2.1 Integrating disciplines

The thematic structure and research priorities outlined above emphasise the multi-disciplinary nature of FCERM research and how the combination of several disciplines is necessary to develop holistic flood risk management approaches. Such integrative approaches present challenges of culture, methodological practices and understanding, as research specialists working within niche fields need to consider the views of other researchers in fields which may be considered removed from their own. True collaboration is difficult to achieve and those who embrace the philosophy should be acknowledged for their efforts. Often, collaborative work of this nature does not mean cutting edge research in all contributory disciplines, but rather an application of accepted methods to a new topic. Should this be the case, it is desirable that funding bodies take account of this, and support research that is attempting to integrate across disciplinary boundaries.

FCERM research should also look beyond its traditional confines for research which may have applicability to the challenges that are being faced. Researchers may find that reviewing other engineering disciplines, non flood-risk hazards and the social and political sciences may all yield useful lessons for FCERM research.

8.2.2 Integrating providers and users of research

Bridging the gap between research providers and end-users of research is a well recognised problem across all areas of research[73]. Despite the FCERM research successes outlined in previous sections, there is an acknowledgement from both researchers and users that existing research effort across all areas of the research spectrum is not being fully exploited. This may occur for a number of reasons including issues of capacity and capability, inadequate problem definition, poor communication, misaligned scope and poor product specification. Within the Joint Programme, much recent effort has

focused upon improving the linkages between researchers and users, through improved governance and involvement throughout the delivery process. In addition, the use of industry in helping to bridge the gaps between researchers and practitioners has been successfully applied in the past, for instance within FRMRC[74]. This welcome trend, however, has been hampered by difficulties associated with the ability to fund and the potential loss of fee-earning time for the consultants themselves.

Organisationally, measures of success and drivers for different sectors are often unaligned and the organisational cultures in which individuals operate may deter collaboration. For instance, the drive for grant awards, research excellence and citation in the academic community contrasts with the need for practical user tools, benefits to people and property, required by many research users. Likewise, synchronisation of funding cycles, timescales to delivery and a lack of identification of long term needs, all add to the problem. The governance structures that are developed should facilitate a greater transparency of research agendas in order that they may be better aligned and useful synergies identified.

To encourage partnership working between research providers and users throughout the research delivery lifecycle, examples of effective collaboration should be recognised and rewarded to incentivise good practice[75]. This may be achieved through monitoring performance via interim outcomes, quality assuring outputs from a range of perspectives, evaluating track records of delivery into practice and weighting this in consideration of future funding awards. The forthcoming Research Excellence Framework[76] should help in this regard with greater emphasis to be placed upon science and engineering research that has a societal or environmental impact, rather than having to be solely an advance in science.

8.2.3 Developing shared success criteria

Organisations involved within FCERM research are driven by their own institutional outcomes and thus may have different criteria upon which to judge the success or otherwise of research and development projects and programmes. In developing collaborative multi-funder research initiatives such criteria can either become facilitators of integration between research and practice or indeed a divergent force or barrier to successful collaboration. These criteria should therefore be used to provide specific targets for the researchers to avoid ambiguity and to drive delivery in the intended direction. Targets may involve for example; academic papers, practitioner guides, knowledge exchange, awareness metrics or indeed the collaborative nature of the research itself. It is intended that progress towards the outcomes this strategy seeks to deliver are regularly monitored and evaluated and that the intended benefits that have been outlined within Table 3 are being realised.

8.3 Delivering Capability and Capacity

Maintaining and developing research capability and capacity is critical in addressing the challenges of UK flood risk management. A number of reviews have examined this across sectors which overlap the FCERM agenda. The Foresight Future Flooding[77], ERFF Skills Needs in the Environment Sector[78], Engineering Skills for Flood Risk Management[79] and the Infrastructure, Engineering and Climate Change Adaptation review[80] have identified the needs, impacts and potential solutions for identified shortages. Indeed, the FCERM Strategy for England[81] has identified the criticality of core skills and a commonly understood knowledge base in achieving sustainable FCERM into the future. These both help to enable the transition of research outputs into operational practice, discussed further in Section 8.4.

Enhancing research capability is not simply about promoting research excellence amongst universities and other research institutions. To achieve integrated research capability, transferable skills are needed to ensure researchers and users speak a common language, understand problems that exist across the research spectrum and are aware of user needs at the operational level. At a further/higher education level flood risk management research has relevance to engineering, geography, disaster management and social science courses. Including first hand user experience in these courses may help to ground learning outcomes by demonstrating real world relevance, assist in linking career pathways, inspire research questions and create synergy between teaching and operational activity. Such joint approaches have been adopted by several

universities#,[82]. Further promotion of FCERM and associated research agendas within course syllabi at all levels of the education system should be attempted.

FCERM research should also form a key component of within-job training, from inclusion within induction and foundation programmes for FCERM staff, through to training on specific research based tools and methods to ensure their application. In order to maintain user awareness and aid the embedding of the latest research into operational practice, Research and Technology Organisations (RTOs) and the wider consultancy industry have a key role to play[83]. Research projects should endeavour to include the need for knowledge exchange and training for users within their scope, and collaborative funding should assist the translation of research outputs into useable tools and good practice guidance. Whilst many users may not need to understand the detail of the research that underpins the operational tools they use, a lack of understanding is widely recognised as a key barrier to adoption of research outputs[84]. Users should be reassured that products are based on sound science and understand the principles upon which they are based.

Professional bodies also have a key role to play in the promotion of FCERM research and knowledge exchange to practitioner communities. This may be achieved through the attainment of chartered status of institutions such as the Chartered Institution of Water and Environmental Management (CIWEM), the Institution of Civil Engineers (ICE), the Royal Meteorological Society (RMetS), but also through other bodies such as the Emergency Planning Society (EPS), British Hydrological Society (BHS) and numerous others. The inclusion of representatives from professional institutions in any future governance arrangements and links to existing special interest groups should be considered.

Capacity is also a critical issue for flood risk management research as there is a need for sufficient skills to address current and future challenges[85]. This is not restricted to new skill requirements; there is also a need to better understand and exploit existing capacity in skills, data, methods and knowledge. Likewise, capacity should include the requirement for facilities and infrastructure to aid the delivery of research.

Opportunities for sharing and exploiting infrastructure capacity should be sought and a culture of more open access should be encouraged. Cross organisational secondments may also provide an excellent vehicle for capacity building and assist in building linkages between researchers and practitioners. This will aid the understanding of business cultures and expose participants to the challenges that others face. Research councils could play a key role in this through the existing mechanism of knowledge exchange fellowships. There is also a need to harvest informal knowledge through the systematic capture of knowledge held informally by individuals (both retiring practitioners and the informed public).

To optimise efforts in addressing both capability and capacity there is a need to address the culture of researchers and users alike and elicit behavioural change to develop collaboration and synergy between organisations. There is a need to encourage dialogue, mutual challenge and iterative checks throughout the research delivery lifecycle to ensure outputs are fit for purpose. This is especially relevant in the initial definition of problems and research questions and in defining the types of products users require to manage risk.

8.4 Dissemination, uptake and knowledge exchange

Knowledge exchange is an often overlooked and usually under funded component of research and development but is vital to the ultimate success or failure of any initiative. The challenges associated with effective delivery of research outputs and their translation into outcomes is complex but can be broadly classified into three areas[86].

- research systems and culture
- organisational and institutional systems
- individual learning and personal development issues

This includes the University of the West of England, Flood Risk Management Foundation degree sponsored by the Environment Agency[2], SEPA is also working in partnership with Stirling and Dundee University to provide a part-time degree course for flood risk scientists undertaken whilst employed by SEPA on the Flood Risk Science Programme

8.4.1 Research systems and culture

There is a need for effort to be focused upon the FCERM outcomes that may be derived from research; they should therefore be focused on being relevant to and applicable by the intended users. There is a need to raise awareness of research outputs by ensuring that they are readily accessible, for example, through online repositories and are highlighted via a range of media and adequately distributed amongst the user community.

8.4.2 Organisational and institutional systems

Many organisations do not allow sufficient time for users to remain abreast of the latest research and development and, where they do, there is little recognition of the effort that this takes. Organisations have a tendency to be risk-averse and stifle innovative approaches to problems that might arise through research. The use of pilot sites may overcome this and help to embed research and development within the specific local context, demonstrating the value of addressing specific issues. Centralised use of the outputs from research and development to change the guidance provided to operational practitioners can be an effective means of embedding research outputs.

8.4.3 Individual learning and personal development issues

Amongst individuals there may a reluctance to change to new approaches arising from research and development initiatives. This may be due to time, individual preference or a lack of scientific understanding of new approaches. Individual skills and capability can therefore have a major bearing on the ability to embed research and development into practice. Explicit recognition of the need for bespoke onward knowledge exchange to accompany the outputs of each phase of research development is crucial in ensuring that FCERM aims are achieved. This is particularly true in the transition from researcher to practitioner where training in implementing methods, using tools and maximising the potential of the research is necessary.

8.5 Delivering and demonstrating benefits

Effective integration as outlined above should enable more effective delivery of benefits from FCERM research as outlined within Table 3. However, attributing societal and environmental outcomes directly to investment in FCERM research is difficult, as these often occur significantly later than the initial research output. Tracking the usage of outputs should allow for the improved and consistent valuation of FCERM research, and dialogue between researchers and users will help to acknowledge the provenance from the original research in practical applications. It is crucial to avoid stymieing basic research (which may yield benefits some years later) by ensuring a longer term strategic view is taken.

Quantifying, monitoring and challenging benefit claims is crucial, as it provides the basis by which research funding may be justified. However, care should be taken that benefits are not overstated and that only the incremental value arising from the specific piece of research is identified, as spurious benefits claims may reduce the credibility of further cases for support.

Image © SEPA 2011

8.6 Joint Promotion of UK Expertise

The UK has already had considerable success in exporting expertise (e.g. Chinese Foresight, and investigations into the adoption of RASP methods in the USA) but consideration should be given over the lifetime of this strategy to formalising a Centre for FCERM research. In Scotland this approach has already been initiated through a Centre for Expertise for Water, within which FCERM is an important constituent element. The UK is relatively mature in how it approaches making maximum use of limited resources and delivering sustainable FCERM by balancing economic, social and environmental interests. There is the possibility that an FCERM Centre, whether real or virtual, could help to build on existing capability by providing an integrated, multi-disciplinary resource for FCERM research services of international standing. It would also provide foci for growing knowledge networks built upon individual and institutional relationships and aid effective use of capability, data, methods, knowledge and skills that already exist. The Centre could facilitate ongoing awareness and dialogue about FCERM research needs and delivery amongst diverse stakeholders and influence research prioritisation. It could form a cohort of advocates for communicating the relevance and impact of FCERM research at international, national and local scale. It may aid the quality assurance of research and promote the concept of science led policy, governance and operational activity. To this end, it may provide ready access to a wide evidence base of knowledge, which may be readily accessed to answer and provide advice upon policy and operational needs.

8.7 Data Management and Intellectual Property

A more open exchange of data, information and code between stakeholders is desirable to achieve the aims of sustainable FCERM. This may facilitate the building of fully integrated models and to maximise the utility of available information according to the principles of “collect once, use many” - a philosophy present within numerous research strategies[87]. Currently, many data have dispersed, are inaccessible or their presence is forgotten. The challenges of achieving a coherent and coordinated approach to data and information management should not be under-estimated from both a technical and organisational standpoint.

Technical considerations include data architecture, platforms, storage and accessibility, although ongoing initiatives such as OpenMI[88] are enabling model inter-operability. Sharing does not necessarily imply free, open access and unfettered rights, but licence agreements need to be simple and transparent. Recent cross-government initiatives may assist in providing overarching principles and frameworks to achieve this. Consideration should also be given to both the process of procurement and grant award competition, as these may hinder cooperation and collaboration and may not be conducive to research excellence[89].

This challenge has been identified by LWEC as being critical to partnerships that may effectively deliver its aims. As this strategy has provided a pilot for further LWEC strategies, with adequate resourcing, so the field of FCERM research could be used as a test-bed for improving cross-organisational data management. Many of the challenges with data and intellectual property may be overcome through strong governance and changed cultures. In this respect, the implementation structure which this strategy proposes may provide a vehicle to achieve this. The emerging framework for Coastal Research, Development and Dissemination (CoRDDI)[90] has also highlighted this as a key need, describing a hosting platform for coastal research needs.

It is recommended that a FCERM data framework is initiated to examine data and observation requirements for FCERM in partnership with the UK Environmental Observation Framework (UK-EOF)[91]. This would have as a minimum four key objectives:

- To flag existing data and observations within the UK- EOF necessary for FCERM research purposes
- To highlight existing FCERM datasets not yet captured by the UK-EOF
- To identify gaps in data and observations necessary to deliver FCERM research needs
- To highlight the utility of the UK-EOF within the FCERM research community.

9 Continuing the journey

This strategy represents a major shift in how UK FCERM research providers and practitioners have prioritised and identified evidence needs. For the first time these have been considered jointly at a national scale with a view towards more efficient, collaborative delivery. Having been guided and produced by a wide-range of individuals and organisations that instigate, deliver and use FCERM research, the strategy provides a common vision that may be owned by the entire community.

The strategy therefore is an ambitious and important part of meeting the challenges the UK will face from the escalating flooding and coastal erosion risks associated with changing climates and socio-economic factors. Through the development of an inclusive partnership approach, the strategy should, in time, play a major role in enhancing the provision of sustainable FCERM to UK citizens. Given the importance of flooding and coastal erosion to the UK, there is no coincidence that it is the first research strategy developed by the LWEC partnership.

Nevertheless, the strategy is only the first phase in the journey towards a truly coherent UK FCERM research. There are many challenges ahead, not least the next phase of strategy implementation and transition.

Image courtesy of the Environment Agency

However, if the community is prepared to overcome these challenges, accept that mistakes will be made, and focus upon shared FCERM outcomes, then the delivery of FCERM research can be enhanced irrespective of future uncertainties. The next steps that are taken will determine whether in the future, this strategy is recognised less for the document itself but more for the further benefits that it started for UK FCERM research.

Image courtesy of the Environment Agency

Appendix 1: Research Priorities

This Appendix details identified research priorities with the three Risk Themes. The priorities have been assessed against two indices to attempt to aid the focus of effort between organisations and to provide a high level steer for future within-theme research prioritisation.

Maturity
The maturity measure is expressed across Basic, Applied and Experimental Development. This should help to determine, for example, if it is existing Basic research which needs turning into user focused tools or if there are fundamental knowledge gaps that require additional basic research.

Urgency
This measure is based on the relative status of the Political, Economic, Social, Technological, Legal and Environmental (PESTLE) drivers for the work and the extent to which there is a burning need for this research to be undertaken. N.B. technology is frequently an enabler rather than a driver.

1.1 Understanding Risk Theme: research priorities

1.1.1 Theme Priority 1: Uncertainty, complexity and decision making

UR1: Characterising and communicating uncertainty. Research is required to quantify and minimise uncertainty, through the understanding of joint probabilities and uncertainty propagation associated with all forms of flooding and coastal erosion. Research should provide practical methods and tools to support decision-making in light of uncertainties. This should encompass the identification of thresholds of uncertainty and aids to representing and communicating uncertainty to users.

UR2: Multi-scale modelling of all sources of flooding and coastal erosion for multiple users. Representation of the temporal and spatial variability in flooding and coastal erosion needs to be improved. Integrated models capable of analysis from multiple perspectives need to be developed. The consistent application of models within suitable user-focused formats is also important for FCERM. A specific example would be a linked national appraisal of flood risk and coastal erosion.

UR3: Recognising the complexity of receptor response. Many current risk management approaches assume that people and their assets are treated separately or remain stationary, where in reality people make adaptive responses in relation to their assets and risks associated with flooding and coastal erosion. This dynamism, including complexities of different forms of ownership, needs to be better, and more consistently characterised and modelled, to avoid exaggerated impact assessments that hinder the development of short and longer term adaptations to exposure, susceptibility and vulnerability. It is necessary to develop tools to support emergency planning and response.

1.1.2 Theme Priority 2: Data and observations

UR4: Data acquisition and assimilation. There is a need for more systematic collection of data for most aspects of FCERM, especially to build, test and validate models. This includes background data on the state of the environment, in addition to in-event and post-event data. There is a need to consider data needs across many spatial and temporal scales, including long-term monitoring, and gauging of small and urban catchments. Organisation and diagnosis of data requires development of appropriate models and assimilation into them of the observations. There is a need to understand the distribution, quality and format of data required before collection or collation and consider whether they will be adequate to understand floods and coastal change, as well as predict their impacts on people, communities, economies and environments. Research is required into optimal sampling, monitoring and data re-use strategies, and how smart monitoring methods, such as personal monitoring, innovative sensors or satellite technology, may be exploited in data gathering both for flood events and as part of systematic monitoring regimes such as for reservoir safety. There is also a need to improve the assimilation of data into models.

UR5: Flood and rainfall frequency models. A cornerstone of FCERM is the establishment of a functional relationship between flood magnitude and likelihood (a flood frequency curve) allowing estimation of extreme floods. Probabilistic models are required which fully utilise the observed evidence held in the national flood observation databases (e.g. HiFlows-UK[92]). New methods need to be developed that are capable of incorporating effects of non-stationarity resulting from environmental change.

1.1.3 Theme Priority 3: Sources and processes

UR6: Understanding of flooding and coastal erosion sources and trends in light of environmental change. A more in-depth understanding is required of how spatial and temporal patterns of rainfall, groundwater, sea-level, wave, surge, fluvial and pluvial flooding will respond to climate and land-use change, including robust methodologies for downscaling climate projections to the catchment and coastal zone scale. This will consider societal vulnerability in light of climate or land-use change, enabling the development of more resilient communities and infrastructure.

UR7: Surface Water Modelling. An enhanced understanding of the sources and pathways of surface water flooding is required to determine risk in both urban and rural areas. In urban areas, where features of the built environment coupled with the interface between above and below ground flow pathways modelling is complex. Research on the maintenance costs of Sustainable Urban Drainage Systems (SUDS), including 'blue corridors', is required for improved cost-benefit analysis. Advances in survey techniques and computing power will make the modelling of surface water increasingly sophisticated.

UR8: Extending the hydrological record. Prediction of flood risk is often hampered by lack of reliable observations. Methods are required for prediction of flood risk in un-gauged catchments, procedures for optimal transfer of information from gauged to un-gauged sites, and for use of historical information in combination with systematically gauged information. This may include using palaeo-flood techniques to extend the gauged record and better assess the likelihood of extremes.

UR9: Coastal morphology. Research is required to establish how coastal morphology is impacted by sequences of events, such as severe seasonal storms, persistent wave climates or storm surges, and sediment supply, particularly from near-shore sources. Research is required on all coastal types, including estuaries, over a wide range of temporal and spatial scales; it is fundamental for effective shoreline management, risk analysis and habitat creation. Better understanding of the processes, and the benefits associated with natural coastal systems, particularly in light of environmental and socio-economic change, is important.

UR10: Fluvial geomorphology. Understanding how sediment mobility impacts upon flood risk management in terms of changing river regime is important in flood risk management. There is a need to profile catchments with characteristics that make them especially vulnerable and sensitive to sediment dynamics or impacts that could either induce or could be induced by vertical and lateral channel mobility.

UR11: Understanding groundwater flood risk. Groundwater flooding has become a significant problem, particularly in parts of southern England. Developing an accurate and scientifically robust methodology to model groundwater flood risk at regional and national scales is important.

UR12: Catchment land use management. Evidence-based guidance on how to optimise land-use for flood mitigation requires examination of land-use impacts on flood sources and processes at a range of scales from plot to entire catchments. This requires a combination of modelling and experimental research efforts

1.1.4 Theme Priority 4: Understanding the costs and benefits of risk management

UR13: Valuing what we are considering defending: We need to know better how value can be measured in a holistic way, inclusive of the total value of communities, human health, economy, environment and cultural heritage, to establish where funding is best targeted to maximise return on investment from flood and coastal defence systems.

UR14: Understanding the true benefits of FCERM: We need a comprehensive assessment of the return on investment from FCERM actions. This should include the understanding of future scenarios of socio-economic development, including population change. It should address benefits to people, property and the environment across all flood risk and coastal erosion applications.

UR15: Economics of the health effects of flooding. We need to quantify the health costs to society of flooding. Research should not only consider direct impacts, for instance those associated with the increased burden on the National Health Service (NHS) and associated medical services, but also secondary effects, such as the reduced earning capacity of affected individuals and communities.

UR16: Understanding the secondary and tertiary economic effects of flooding and coastal erosion. Systematic research is required into the true costs of flooding and coastal erosion events. This should include costs of emergency response and the impact on government, business and domestic sectors - including property prices and the consequences of economic abandonment. The incorporation of these measures into appraisal techniques requires attention.

UR17: An ecosystem services approach to valuation in flood and coastal erosion risk management. Flooding and coastal erosion benefits need to be a part of a wider multi-objective environmental approach to land and water management. Applied research into how this can be valued against other goods and services in a market context including food, carbon accounting, and environmental value, is required.

UR 18: Incentivisation through policy/funding. Research is needed to assess how much individual or community behaviour may be influenced by incentives to change their activities and determine how we can best incentivise those activities that reduce flood and coastal erosion risk.

1.2 Managing Probability: research priorities

1.2.1 Theme Priority 1: Flood Risk Management Asset System Assessment and Design

MP1: Effects of climate change on flood risk management assets: Changing temperatures, rainfall regimes, soil moisture conditions, sea level rise and coastal climates, as well as secondary impacts such as channel change, will all have a significant effect upon the design and maintenance of natural and engineered assets. Basic process-based research into the effects of drivers and impacts on assets, including the geotechnical properties, material deterioration and defence resilience – performance under extreme loading – of these, is required to inform adaptation options.

MP2: Adaptation of existing assets to climate change: This includes retro-fitting and designing flexible, adaptable assets that may be altered, supplemented or developed to adjust to a range of projected flood risk scenarios. It encompasses the development of sustainable urban drainage systems (SUDS) and assets within floodplains that may perform multiple functions, such as roads - as flood pathways or flood storage areas. This key area is echoed in the recent Royal Academy for Engineering report[93]. Research will need to assess when the impacts and costs of existing assets are so unacceptable or unsustainable that retreat should be undertaken; revised schemes will need to consider the wider impacts, such as habitat loss resulting from coastal realignment.

MP3: Encouraging uptake through regulations and incentives: Building regulation reviews are required to identify barriers to the facilitation of flood source control measures, resilient practices and the sustainable use of urban drainage. Development of simple, practical evidence-based guidance of enforcement and incentivisation in differing scenarios is needed for practitioners.

MP4: Designing for use of the floodplain: As all development within flood risk areas may not be prevented, we need to encourage innovative design of resilient and flood resistant structures and develop good practice by both professionals and the public.

MP5: Passive Safety in FCERM. Research is required on the design of structures or systems that reduce the amount of manual intervention during floods. These include systems that: require no operation, such as those that use ramps instead of gates, have in-built redundancy, are resistant to vandalism, or are 'intelligent' and adapt to circumstances.

MP6: Temporary Flood Management. The design, application and effectiveness of temporary flood management measures such as temporary defences, building or community flood resistance and resilience, requires research.

1.2.2 Theme Priority 2: FCERM Whole Life Asset Management

MP7: Optimising asset management investment. As capital and revenue budgets are increasingly pressurised, investment in asset maintenance must be optimised to provide the greatest degree of flood protection for the least expenditure. It is important to understand the point at which reductions in risk

diminish disproportionately to investment, via understanding the relationship between asset condition and performance. This needs to consider whole life scenarios of assets, including reliability, cost of maintenance and the challenges presented by an ageing asset infrastructure base.

MP8: Asset Performance Reviews. There is a need to review how empirical periodic appraisals of assets are made in relation to their original design and standards of service. Areas of particular concern include, surface water management system performance, overtopping banks, reservoir spillways, mixed beaches and erosion protection. Knowledge of the physical response of assets under changing climatic and socio-economic scenarios, and following structure failure or removal, will improve the representation of assets within numerical models and allow their simulation within risk-based systems. It is necessary to develop guidance for the risk assessment of critical infrastructure to ensure its resilience and aid emergency planning.

MP9: Reservoir Safety. Research is needed on warning and response within incident management, the impacts of extreme rainfall and novel monitoring methods. Key asset management needs revolve around internal erosion, concrete deterioration of embankments performance, breach analyses and the performance and maintenance of structures such as spillways and sluice gates. This should allow the assignment of a risk designation to all reservoirs.

MP10: Withdrawing uneconomic defences. Research is required on the evaluation of uneconomic, ineffective or unsafe defences, development of good practice for their removal - including risks of system failures and compliance with waste directives - management of impacts, optimisation of replacement systems and appraising benefits.

1.2.3 Theme Priority 3: Environmental Management and Sustainability

MP11: Vegetation management. Vegetation plays a key role in determining asset performance, both positive, such as aiding the cohesiveness of earth embankments, and negative, such as blocking channels. Research is needed to ensure that vegetation maintenance is optimised from both a performance and cost perspective, particularly in light of potential changes in ecosystem composition, seasonality and growth rates as a result of climate change. The role of vegetation in flood defence, such as in saltmarshes, and in engineering design needs to be clarified and simple practical guidance provided.

MP12: Sediment management. Climate change also affects sediment flux through fluvial, estuarine and coastal systems. There is a need to improve understanding of sediment supply and dynamics to establish the sediment controls on rivers and coasts to long-term change, and the optimal strategies required to manage these.

MP13: Biodiversity management. The need to replace habitats lost in flood alleviation scheme design is a legal requirement. Understanding potential areas available for this, as well as the pathways of re-colonisation is important. Learning lessons from national and international experience here is vital, along with translating this into practical guides for users.

MP14: Fish and FCERM. Existing and future flood defence schemes will have to be adapted or designed to allow maximum fish and eel passage. Research is required on effective asset designs for fish passage where flood management interventions involve a barrier or impoundment across a watercourse.

MP15: Carbon accounting. Reducing the environmental impact of flood risk management interventions is vital for sustainable solutions. Whole-life carbon accounting models, which include embedded energy costs and consideration of alternative materials within schemes, are required to account for design, build, maintenance and decommissioning.

MP16: Natural FCERM Measures and 'green design': The application of Natural Flood Management techniques requires further research into their efficacy to provide more win-wins for flood risk-reduction and the natural environment. Likewise, although green design techniques exist there is little guidance for practitioners on how to apply these based on empirical studies of their use.

Ref	Title	Maturity			Urgency
		Basic	Applied	Experimental Development	
UR1	Characterising and communicating uncertainty	2	3	2	2
UR2	Multi-scale modelling of all sources of flooding and coastal erosion for multiple users	2	2	2	1
UR3	Recognising the complexity of receptor response	1	1	1	2
UR4	Data acquisition and assimilation	3	3	3	1
UR5	Flood and rainfall frequency models	4	4	4	3
UR6	Understanding flooding sources and trends in light of environmental change	2	2	1	2
UR7	Surface Water Modelling	2	2	2	1
UR8	Extending the hydrological record	1	1	1	3
UR9	Coastal morphology	2	1	2	2
UR10	Fluvial geomorphology	3	2	1	2
UR11	Understanding groundwater flood risk	3	2	2	2
UR12	Catchment land use management	3	3	3	2
UR13	Valuing what we are considering defending	2	2	1	1
UR14	Understanding the true benefits of FCERM	1	2	2	2
UR15	Economics of the health effects of flooding	1	1	1	2
UR16	Understanding the secondary and tertiary economic effects of FCERM	1	1	1	3
UR17	An ecosystem services approach to valuation in flood risk management	2	1	1	2
UR18	Incentivisation through policy/funding	2	1	1	2

Maturity
1 – An immature area previously neglected within research agenda
3 – A less immature area, where significant gains could be made
5 – A more mature discipline where future work adds incremental value

Urgency
1 – Critical due to immediate policy or operational drivers
3 – Important work within the near future
5 – Useful, but no immediate demand

Ref	Title	Maturity			Urgency
		Basic	Applied	Experimental Development	
MP1	Effects of climate change on flood risk management assets	2	2	1	1
MP2	Adaptation of existing assets to climate change	3	2	2	2
MP3	Encouraging uptake through regulations and incentives	4	3	1	3
MP4	Designing for use of the floodplain	3	2	2	2
MP5	Passive safety in FCERM	3	2	2	2
MP6	Temporary flood management	4	3	3	1
MP7	Optimising asset management investment	3	3	3	2
MP8	Asset performance reviews	5	3	2	3
MP9	Reservoir Safety	3	3	2	2
MP10	Withdrawing uneconomic defences	3	2	2	1
MP11	Vegetation management	5	3	2	2
MP12	Sediment management	3	2	2	1
MP13	Biodiversity management	4	3	2	2
MP14	Fish and FCERM	4	3	3	3
MP15	Carbon accounting	3	2	2	4
MP16	Natural FCERM measures and ‘green design’	2	2	2	1

Maturity
1 – An immature area previously neglected within research agenda
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Urgency
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1.3 Managing Consequence: research priorities

1.3.1 Theme Priority 1: Risk awareness and preparedness

MC1: Attitudes and acceptance of risk: Important research needs include: understanding how people's response to risk is influenced by their view and understanding of it; determining how people form their views on flood risk; and ascertaining what level of risk they view as tolerable including during their consideration of insurance. There are major psychological barriers to acceptance of risk and simplistic modelling approaches will not produce the required changes in human behaviour. How can risk concepts, including flood probabilities at the individual property level, be best communicated and is there a consistent view on definition?

MC2: Ensuring awareness translates to action: Research to date has identified a significant gap between the flood risk awareness of individuals and the actions they take to protect themselves and property. There is a need to understand why this is, how behaviour may be influenced, and the role of community structures and coordination in supporting raising awareness and preparedness. How can people be best helped to realise that it is their responsibility to protect themselves and their homes, particularly where they are reluctant to accept this?

MC3: Community and individual engagement: Sustainability is aided by partnership and shared ownership of assets by those at risk. Evidence based guidance for practitioners to engage with individuals and communities is important to encourage involvement in schemes, to communicate risk, and plan for change.

1.3.2 Theme Priority 2: Forecasting

MC4: Improving flood modelling and forecasting: There is a need to develop more advanced real-time flood forecasting approaches giving improved coverage, timeliness and lead-time, accuracy and estimates of uncertainty. These should be able to exploit space-time information as input from weather radar and rain-gauge networks along with deterministic and probabilistic meteorological forecasts. Improving weather radar accuracy provides improved and more accurate spatial coverage and allows data from isolated storms to be analysed. Improved flood model formulations should be capable of utilising spatial datasets relating to terrain, soil, land-cover, geology and channel form as appropriate. Developments in data assimilation, particularly using river level/flow observations, are seen as important to increase forecast accuracy. Improving flood forecasting at a range of scales is a priority for research, encompassing flash floods resulting from high intensity rainfall in rapid response catchments, and flood inundation extent on floodplains of major rivers.

MC5: Improving storm forecasting: Major flooding damage is caused by extreme storm events. In order to improve prediction of these there is a need to understand the atmospheric pre-conditions of convective storms, to scale atmospheric models to sub 1km, and to understand the relationship between storm characteristics, antecedent conditions and urban drainage systems particularly for surface water flooding. This requires improved coupling of meteorological and hydrological models and improved modelling to better represent surface water flow pathways. Within the urban environment improving reliability of forecasts at lead times of 1-12 hours is crucial in allowing warning and response. Forecasting the likelihood of flooding within a 5 day time horizon is also critical in aiding preparedness.

MC6: Improving coastal forecasting: Improvements to coastal wind, wave and surge model accuracy require a better understanding of wave energy transfers, shallow water processes, windstorms and downscaling of global atmospheric models. Real time forecasting, aided by the assimilation of data from offshore installations, will allow wave dynamics to be considered directly within forecasting models, more frequently updated hydrography, and coastal sediment models.

MC7: Forecasting over a range of timescales: One of the key elements of preparedness is the ability to accurately forecast over a range of timescales. Research is required to improve forecasting skill over decadal, annual and seasonal timescales. This includes improving the credibility of predictions of within-period trends and the likelihood of extreme events. The development of sophisticated performance measures and improved observations is necessary to drive improved forecasting.

1.3.3 Theme Priority 3: Warning and response

MC8: Probabilistic Methods: The wider application of probabilistic methods in flood forecasting and flood warning application, as well as in coastal erosion risk, also requires further work. This includes tools to process probabilistic information, aid decision support, and assist individuals to interpret and communicate messages.

MC9: Harnessing technologies for flood warnings: Recent technologies have opened-up new channels for the dissemination of warnings, however, the effectiveness of these needs to be monitored to test whether they elicit greater response. They may also provide the potential for linking warning systems to automated property-level-responses, such as the automatic closure of airbrick covers. The development of bespoke flood warning applications by value-added-resellers for onward development[94] also has great potential for disseminating warning messages. Within all of these systems, the risk of failure, and responsibility for information provision, also requires research. The possibility of confusion due to different providers of information and the development of social inequalities resulting from unequal access to information or technology also need to be understood.

MC10: Warning systems and communities: Understanding the effectiveness of social mechanisms, for instance flood warning by word-of-mouth through key players such as the community leaders and police, requires research - particularly in light of the growing localism agenda. Likewise, the role of individuals as agents of change and the potential for dissemination and verification of warnings by the voluntary sector requires investigation.

MC11: Targeted flood warning messaging: Tailoring flood warning messages, both to the nature of the flood risk, (such as flood type and velocity,) as well as the individual needs of recipients (for instance appropriate language or format) is an important research need.

MC12: Behaviour change: People and communities lie at the heart of flood and coastal erosion risk management and understanding their barriers to change is crucial. Examination of the processes of behavioural change under different economic, climatic, social regimes - as part of a multi-hazard approach and according to different learning styles - is also an important research need. What measures do individuals perceive as being most effective to reduce risk and how does this influence behaviour?

1.3.4 Theme Priority 4: Social Effects

MC13: Understanding the health effects of flooding: An improved understanding of the health effects of flooding on individuals and communities is important. Research on psychological and mental health impacts - which can be long-lasting, health effects associated with the inundation of properties by contaminated floodwaters, the long term consequences of living within damp buildings and the consequences of evacuation, are priorities.

MC14: Inequalities and social justice: The correlation between socially deprived areas and those susceptible to flooding has been well demonstrated. Climate change and societal pressures are likely to accentuate this pattern; floods and interventions will commonly exacerbate social injustice. As risk increases in the future, research to deliver fairness and social equality in relation to flooding needs to be prioritised. How does insurance provision impact upon different social sectors and the ability of individuals to recover from events?

MC15: Revising flood risk management governance: Research is required to establish how the current shift towards localism will affect the delivery of flood risk management - away from the state towards local initiatives, and towards greater involvement of individuals and the private sector. How do local agendas reconcile with principles of whole catchment management? How can we create flood resilient communities; what are the barriers and how might these be overcome? How do we systematically include social choice and engagement within the decision making process?

MC16: Flood recovery and emergency response: The ability of individuals, communities and business to quickly and adequately recover from flood events is crucial to long term sustainability. The key elements which aid this process are poorly understood, but incorporate the cohesion of society, access to trades, insurance provision and many more factors. How we can both provide and speed recovery is crucial to holistic FCERM.

Ref	Title	Maturity			Urgency
		Basic	Applied	Experimental Development	
MC1	Attitudes and acceptance of risk	3	2	2	2
MC2	Ensuring awareness translates to action	3	2	2	2
MC3	Community and individual engagement	3	2	3	3
MC4	Improving flood modelling and forecasting	3	3	2	2
MC5	Improving storm forecasting	2	3	2	1
MC6	Improving coastal forecasting	3	2	2	2
MC7	Forecasting over a range of timescales	3	3	3	3
MC8	Probabilistic methods	3	2	2	2
MC9	Harnessing technologies for flood warnings	4	2	2	3
MC10	Warning systems and communities	3	2	2	2
MC11	Targeted flood warning messaging	2	2	2	3
MC12	Behaviour change	2	2	2	1
MC13	Understanding the health effects of flooding	1	1	1	2
MC14	Inequalities and social justice	2	2	2	3
MC15	Revising flood risk management governance	1	2	2	1
MC16	Flood recovery and emergency response	2	3	3	2

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Appendix 2: Legislation and Policy context - further details

Section 2.4 has provided an overview of the principal legislative drivers. Further details are below.

2.1.1 England and Wales

Making Space for Water[95] (Table 5) sets out the Government policy for flood risk management for the next 25 years and sits within the wider Future Water Strategy[96] which takes a holistic approach to managing water. An Environment Agency[97] and Welsh Assembly Government Flood Risk Management Strategy[98] are currently in development and should be complemented by local strategies developed by Local Authorities. Both England and Wales have made broad scale assessments of flood risk via the Flooding in England/Wales reports[99]. This work also aims to complement wider strategies and legislation such as the Climate Change Act[100], the Climate Change Strategy for Wales[101] and the Welsh Adaptation Action Plan (currently under development). In addition, private water companies have their own strategies, dealing with surface water. Planning and floodplain development are subject to their own policies, Planning Policy Statement 25[102] and Technical Advice Note 15[103] in England and Wales respectively. Aligned to the broad legislative framework for Flood Risk Management, is further legislation impacting on flood risk management activities including, but not limited to, the Civil Contingencies Act[104], Water Framework Directive[105], and Habitats Directive[106].

2.1.2 Scotland

'Delivering sustainable flood risk management'[107] sets out the Scottish Government policy for improving flood risk management across Scotland embodied in five outcomes (Table 6: Five outcomes for Sustainable Flood Risk Management in Scotland). Flooding and drainage planning policy is set out in Scottish Planning Policy 2010. Advice on good practice and other relevant information is set out in Planning Advice Notes (PANs). PAN 69 (Planning and Buildings Standards Advice on Flooding), PAN 61 (Sustainable Urban Drainage), and PAN 79 (Water and Drainage) are all currently under review[108].

Table 5: Making Space for Water a Vision for 2030

- Flood and coastal erosion risk management which contributes to sustainable development, combining the delivery of social and environmental benefits with the protection of economic assets.
- An understanding of the future risks of river and coastal flooding fully embedded into the spatial planning system, including planning for new settlements and other new developments.
- Consistent and holistic management of urban flood risk, with strategic planning, partnerships of responsible bodies, and clear understanding of various flood risk responsibilities.
- Public understanding of the risks we face and the actions we can take to help manage flood and coastal erosion risk.
- Community resilience to flooding from improved development planning, emergency planning and response, and resilience of homes, buildings, services and utilities.

2.1.3 Northern Ireland

Living with Rivers and the Sea (2008)[109] sets out the Northern Ireland strategic response to Flood Risk Management. An interim Flood Mapping Strategy[110] has been produced and Planning Policy Statement 15[111] deals with planning and flood risk, and policy FLD 4[112] deals with Flooding and Land Drainage.The Drainage Order 1973 enables the Rivers Agency to carry out maintenance to designated sea defences.

Table 6: Five outcomes for Sustainable Flood Risk Management in Scotland

- A reduction in the number of people, homes and property at risk of flooding as a result of public funds being invested in actions that protect the most vulnerable and those at greatest risk of flooding.
- Rural and urban landscapes with space to store water and slow down the progress of floods.
- Integrated drainage that decreases burdens on our sewer systems while also delivering reduced flood risk and an improved water environment.
- A well informed public who understand flood risk and adopt actions to protect themselves, their property or their businesses.
- Flood management actions undertaken that will stand the test of time and be adaptable to future changes in the climate.

Appendix 3: Development Process

Image © SEPA 2011

The need for a UK FCERM Research Strategy was identified by the Environment Research Funders' Forum (ERFF) Board in 2009 and a FCERM Research Review workshop occurred in October 2009. Following the merger of ERFF with LWEC, the development of the FCERM research strategy has been sponsored by the LWEC Partners' Board.

A Scottish Flooding Research Needs workshop was held in August 2010 hosted by SNIFFER[113]. This event brought together approximately 25 delegates to prioritise both generic research requirements and those most pertinent to Scotland. To understand the current state of the research landscape and highlight future priority areas, several reviews were undertaken by leading academics and practitioners within their field. The reviews identified 61 key topic areas, driven by a series of political, economic, social, technological, legal and environmental (PESTLE) drivers (N.B. technology considered an enabler rather than driver). The reviews, as well as outputs from the Scottish workshop were utilised as inputs into a UK wide consultation workshop in late September 2010. This brought together 120 stakeholders from the academic, policy, users, and business communities. The workshop appraised future research priorities and highlighted how LWEC might facilitate a more coordinated approach to UK FCERM Research. To supplement the workshop, an online survey was undertaken to capture the inputs of the wider Flood Risk Management community and seek views on research priorities.

Image courtesy of the Environment Agency

This draft strategy has been produced using the reviews, workshop and survey outputs as well as advice from the LWEC Partners' Board, Project Steering Group, Theme Advisory Groups of the Joint Defra/Environment Agency Research Programme and in consultation with the Chartered Institution of Water and Environmental Management (CIWEM) Rivers and Coastal Group, and the Maritime and Water Panels of the Institute of Civil Engineers. In addition, FCERM research was the topic for the first LWEC Citizens Advisory Forum, in October 2010[114]. The draft strategy has also been subject to an independent interim peer review. We welcome further comment on both the direction proposed and detailed content.

The UK FCERM Research Strategy is planned for publication in Autumn 2011 see Figure 7 on page 22. This will take into account comments received through the consultation process.

Appendix 4: Acknowledgements

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The following authors contributed to the expert reviews – thematic leads appear first, those in italics were 'sub-commissioned'.

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4.3 Other consultees

The following people attended the consultation workshops, responded to the post-workshop survey or commented on the draft strategy document. N.B. Dr Mervyn Bramley provided an independent peer review of the strategy.

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Jenny Forster - *BGS*
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Appendix 5: Glossary

ABI	Association of British Insurers
BHS	British Hydrological Society
CEH	Centre for Ecology and Hydrology
CIRIA	Construction Industry Research and Information Association
CIWEM	Chartered Institution of Water and Environment Management
CoaEST	Coastal and Estuarine System Tools
CRUE	Coordination de la Recherche sur la gestion des inondations financée dans l'Union Européenne" (Coordination of the research financed in the European Union on flood management)
EA	Environment Agency
EPS	Emergency Planning Society
EPSRC	Engineering and Physical Sciences Research Council
ERA-Net	European Research Area Network
ERFF	Environment Research Funders' Forum
ESRC	Economic and Social Research Council
FCERM	Flood and Coastal Erosion Risk Management
FRC	FloodResilienCity
FRMRC	Flood Risk Management Research Consortium
HEFCE	Higher Education Funding Council for England
ICE	Institution of Civil Engineers
IDB	Internal Drainage Board
IMC	Incident Management and Community Engagement
Interreg	Inter-regional research network
Joint Programme	Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management Research and Development Programme
LWEC	Living With Environmental Change
MAFF	Ministry of Agriculture, Food and Fisheries
MAR	Modelling and Risk
MARE	Managing Adaptive REsponses to changing flood risk
MDSF	Modelling and Decision Support Framework
NAFRA	National Flood Risk Assessment
NERC	Natural Environment Research Council
PAN	Planning Advice Note
PESTLE	Political, Economic, Social, Technological, Legal and Environmental
PPS	Planning Policy Statement
RASP	Risk Assessment for System Planning
RMetS	Royal Meteorological Society
RTO	Research and Technology Organisations
SAM	Sustainable Asset Management
SEPA	Scottish Environment Protection Agency
SMP	Shoreline Management Plan
SNIFFER	Scotland and Northern Ireland Forum For Environmental Research
SPD	Strategy and Policy Development
SPR	Source Pathway Receptor
TAN	Technical Advice Note
UK	United Kingdom – comprising England, Wales, Scotland and Northern Ireland
UK-EOF	UK Environmental Observation Framework

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