



Flood Risk from Extreme Events (FREE)

Implementation Plan

Dated: 25 January 2008

Part 1: Overview and description of the FREE Programme and its results

(to be maintained by the Project Co-ordinator)

NERC Programme:

Directed

Programme Title & Acronym:

Flood Risk from Extreme
Events (FREE)

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www.nerc.ac.uk/thematic/free

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1.1 Executive summary

(a) Research objectives

Broad objectives:

In carrying out research within the Earth system of specific relevance to flooding it will be necessary to,

- improve the estimation and prediction of flood risk from extreme events through considering the processes involved as an integrated system;
- seek ways to reduce uncertainty and improve the quantification of flood risk; and
- identify and articulate critical guidance on how flood risk is changing.

Specific objectives:

Objective 1: To develop and extend the science underpinning integrated modelling frameworks enabling models to work sensibly and more effectively together

Objective 2: To identify and spread scientific improvements in model initialisation, data assimilation and the processing of forecast ensemble outputs across modelling communities

Objective 3: To understand and quantify the propagation of uncertainty within a changing environment and within rapidly changing catchments

Objective 4: To develop techniques for uncertainty reduction at the output stage enabling the communication of risk assessment to the user community

Objective 5: To enable mitigation of, and adaptation to, floods by the provision of advice on flood risk management system development

Objective 6: To seek the use, or re-analysis and use, of existing datasets whilst organising and creating a methodology to enable specific data to be collected following any extreme event that might occur during the period of FREE

Objective 7: To engage with the national and international community and stimulate knowledge transfer and user engagement

Objective 8: To provide training opportunities through research studentships including CASE awards, and to encourage the involvement of students funded via other means in FREE activities

(b) Expected deliverables

Objective 1

- Joint research to be undertaken by an identifiable integration of science communities.
- Language integration across discipline boundaries leading to the training of a new generation of scientists having an integrated way of approaching environmental scientific research.
- Synergy between different models specifically demonstrated by a prototype complete integrated system or through its component parts

Objective 2

- Specifying techniques for data assimilation through coupled models from meteorological, hydrological, hydraulic to coastal models.
- Transfer of data handling, quality control and assimilation techniques between disciplines.
- Demonstrated complementarity with, but not duplication of, the FRMRC programme.

Objective 3

- Quantification of forecast uncertainty across disciplines and within data and models.
- Specifying and managing the propagation of uncertainty across discipline and model boundaries.
- Estimating and utilising uncertainty in the physical processes represented in models.
- Analysis of factors impacting changes in frequency and intensity of storms and extreme flood events.
- Preparing a scientific approach to the development of risk assessment tools.
- New approaches for forecasting extreme events in rapid response catchments.
- New approaches for forecasting extreme pluvial events in urban and built up areas.
- Analysis of the relative contributions to flooding from natural variability and human forcing of climate change.

Objective 4

- Achieve a better understanding of the sensitivity of fluvial, surge and total water levels to uncertainties in model inputs.
- Development of procedures for constraining and presenting risk and uncertainty to end users, and the impact of this uncertainty on the environment.

- Consider the relationship of meteorological indices in global models to the likelihood of catchment flooding and coastal surges.

Objective 5

- Identifying the implications of uncertainty across disciplines for policy development e.g. within the framework of the EU Water Framework Directive.
- Identifying consequent changes in engineering design risk in both fluvial and coastal zones arising from the impact of sediment transport and geomorphologic change caused by extreme events.
- Development of a national network of world class scientists and professionals in this multi-disciplinary field.

Objective 6

- To develop for this programme a methodology for gathering new data and collating existing data for extreme events shortly after they occur.
- Archiving within the Research Council Data Centres using the e-science Data Grid, data sets derived from research studies and extreme events occurring during FREE.

Objective 7

- Quarterly updates describing activity and new opportunities presented by research outputs.
- Identification of specific routes to user involvement and early adoption of science by operational agencies.
- Demonstrations of outputs at appropriate events or workplaces.
- Transfer of research outcomes to policy makers.

Objective 8

- Research degrees awarded from FREE supported research.
- Involvement of a mix of cross-disciplinary students in FREE and related international activities.

(c) Actual outputs at *date*

(d) Expected outcomes

- success in training scientists to think in an inter-disciplinary way (in making future research bids)
- scientists working across disciplinary boundaries
- the emergence of new research groups developing in a multi-disciplinary way e.g. Environmental System Science Centre (ESSC) and the National Centre for Oceanographic Forecasting (NCOF)

- the adoption of research outputs in activities of operational agencies and advisory services that improve the civil contingency response to flooding from extreme events
- an increased understanding amongst user communities of the capabilities and limitations of predicting and assessing flood risk from extreme events and vice versa with research
- influence on future policy making in the mitigation of, and adaption to, flood risk

(e) **Actual outcomes at *date***

(f) **Broad dissemination and use intentions for the expected outcomes**

1.2 Overview of main programme objectives at October 2006

No.	Descriptive <u>short</u> title of the objective	Participant(s) (PIs only) owning the result and involvement in the exploitation
1	Science underpinning integrated modelling frameworks	Illingworth; Zou; Dance; Osborn; Beven; McGregor; Wheater; Reynard; Williams; O'Connell; Toumi
2	Scientific improvements in model initialisation, data assimilation and processing ensemble outputs	Illingworth; Dance; Beven; McSharry; McGreger; Williams
3	Understanding and quantifying the propagation of uncertainty	Illingworth; Zou; Dance; Osborn; Beven; Wheater; Reynard; O'Connell
4	Techniques for uncertainty reduction and the communication of risk	Illingworth; Beven; McSharry; Svensson; Toumi
5	Mitigation and adaptation to floods through provision of advice on structural design	Dance; Beven; McGregor; Reynard; Williams; Svensson
6	Methodology to enable specific data to be collected following extreme events	Illingworth; Dance; Wheater; Lane
7	Stimulating Knowledge Transfer and user engagement	Illingworth; Dance; Zou; Osborn; Beven; Wheater; Reynard; Williams; Svensson; Toumi
8	Training opportunities and student involvement	Zou; Illingworth; Dance; Osborn; Wheater; Reynard; Williams

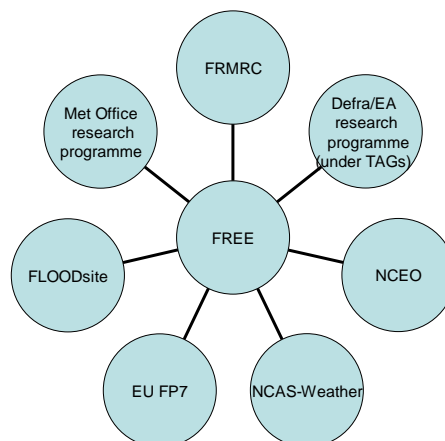
1.2.1 Programme coherence

The broad programme objectives are framed around improving the estimation, prediction and reduction in uncertainty of flood risk from extreme events through considering the meteorological, hydrological and coastal oceanographic processes involved. Such processes include floods arising, either through the occurrence of rainfall and subsequent flows underground, overland and in river channels to the sea, or within sea areas generated from storm surges around our coasts.

The programme is bound together by the use of advanced mathematical techniques to represent physical understanding. However, the techniques being used are expressly formulated to cope with *extreme* events having annual probability of occurrence more infrequently than 0.01. It is these aspects of FREE which make it quite different from other coordinated programmes such as the EPSRC-led FRMRC. Figure 1 shows how FREE complements and fits together with on-going research programmes being undertaken by several agencies.

Figure 1

FREE interconnections to other research programmes



FRMRC: EPSRC-led Flood Risk Management Research Consortium; EU FP7: European Union Framework 7 research programme; NCEO: NERC National Centre for Earth Observation; NCAS-Weather: NERC National Centre for Atmospheric Science Weather Directorate; FLOODsite: EU FP6 research project

The Natural Environment Research Council (NERC) Strategy 2007-2012 ‘Next generation science for planet Earth’ articulates the science priorities to be supported by the Council during the next five years. The strategy is set out within seven themes, one of which is ‘Forecasting and mitigation of natural hazards’. It is within this theme that the FREE directed research programme fits addressing as it does the major natural hazard likely to impact the United Kingdom namely extreme flooding from rivers and the sea.

Figure 2 shows schematically the coherence of this cloud-to catchment-to-coast research effort set within the framework of the hydrological cycle, which is being addressed through thirteen linked individual projects. Hence, FREE is a leading edge environmental science research programme underpinned by data analysis, numerical modelling at a range of complexities and scales, methods aimed at developing numerical representations of physical processes describing how water flows overland, underground and as it approaches our coastline and statistical procedures examining the frequency of occurrence of extreme events. Ultimately this research is expected to lead to significant improvements in our understanding of extreme flood events, the approach to planning flood defence and the ability to provide timely and accurate operational flood warnings, a fact anticipated by the involvement of stakeholders as discussed later.

Figure 2
(courtesy M. Bramley)



Whilst data are being used extensively in FREE specific data collection is not a feature of this programme. Research is largely being undertaken using existing data sets, although it is recognised that data on major extreme floods occurring during the lifetime of FREE will need to be acquired for use by FREE researchers. Data sets generated as part of FREE will be archived as outlined in the Programme data management policy set out by the British National Data Centre (BADC).

1.2.2 Taking the science forward

Process innovation:

Flooding is the consequence of the interaction of a number of different physical processes. To forecast flooding, be it fluvial, pluvial or coastal, requires numerical representations (models) of these processes to be linked together. Such models are

driven by quality controlled data inputs, but the way in which data are assimilated requires mathematical structures which enable models to be initialised, and then integrated forward in time in ways which retain numerical stability yet allow changes to occur in ways which are physically realistic.

The FREE Programme is addressing the initialisation of Numerical Weather Prediction (NWP) forecast models by assimilating new types of weather radar data. This will lead to the generation of probabilistic rainfall forecasts using ensembles of forecasts achieved through multiple model runs based upon slightly different initial conditions. These forecasts will then be inserted into a hydrological model to produce probabilistic river flow forecasts (PI: Illingworth). An alternative approach to improving the quality of predictions of the probability of rainfall is to combine advanced methods of statistics, the output from NWP models and an archive of extreme rainfall events (PI: McSharry).

A similar, albeit novel, approach is being adopted for coastal sediment models. Future bathymetry is predicted to achieve model initialisation via a computational assimilation structure (PI: Dance). An attempt to link meteorological, hydrological and coastal inundation models will be made to investigate uncertainties in forecasts using ensemble techniques (PI: Zou).

However, more detailed investigation of uncertainties, and how to constrain them, in the assimilation of data into hydraulic routing models is needed (PI: Beven). In addition, floods do not always arise from rivers overtopping, they may result from groundwater sources reaching the surface, particularly in Chalk catchments. Extreme floods of this type require new approaches to groundwater modelling as their occurrence is rare and difficult to forecast. (PI: Wheater). Although Chalk catchments have a specific type of land use associated with them, other catchments attract different types of land use which may have impacts on the occurrence and behaviour of floods. This too is being investigated in FREE (PI: O'Connell). Pluvial floods (overland flows) in both urban and rural areas also present challenges for modelling, which will be examined through knowledge transfer activities.

Forecasting extreme floods using the outcome of FREE research as articulated above takes no account of climatic change. Our climate is changing due to human activity. Research on how this impacts the occurrence of rainfall (PI: Osborn), hydrological and hydraulic flows (PI: McGregor), the whole of the fluvial flooding chain from rainfall to river inundation (PI: Reynard) and coastal flooding (PI: Williams) are being investigated in FREE. Finally, the mathematical recurrence of extreme fluvial or estuarine flooding, important for the engineering design of mitigation measures, requires statistical analytical approaches such as joint probability analysis which incorporate seasonality and geographical variation. This work will concentrate on floods with return periods of up to 1000 years and beyond (PI: Svensson). In addition the use of the Met Office Numerical Weather Prediction model offers a basis for investigating the recurrence of extreme rainfall events (PI: Toumi).

In order to test models and procedures for any extreme events occurring during the lifetime of FREE, a Flood Action Team (FLoAT) has been established with the remit to assemble the wide range of data sets needed to fully describe major flood events. The Team will ensure that the data are archived at the BADC, and therefore be

available to FREE researchers and others. A preliminary FLoAT has already begun work to assemble data sets from the June and July 2007 flood events.

New methods:

The FREE Programme is underpinned by the deployment of numerical methods to seek further understanding of extreme flooding as it affects the United Kingdom. The numerical methods may not be novel in themselves, but in combination, or modified in ways to deal with specific data types, they will provide new ways of tackling problems. For example, variational analysis is a method of estimating a set of model

FREE Programme at a glance

<i>Improved modelling and forecasts through new data assimilation methods</i>	<i>New approaches to modelling uncertainty in an integrated modelling environment</i>	<i>The statistics of extremes and their use</i>	<i>The Impacts of a changing climate on the occurrence of flooding</i>
Illingworth – NWP and new remote sensing observations	Zou – linking meteorological, hydrological and coastal models using ensemble methods	Svensson – joint probability analysis of fluvial and estuarine floods	Osborne – changing occurrence of rainfall
Dance – initialisation of coastal sediment models	Beven – constraining uncertainty in hydrologic modelling	McSharry – quantifying flood risk using density forecasts based on a new digital archive and weather ensemble predictions	McGregor – changes in hydrological and hydraulic flows
TBC – reducing the risk of pluvial flooding	Wheater – groundwater modelling of rare events	Toumi – a hybrid model for predicting the probability of very extreme rainfall	Reynard – changes in fluvial flooding and inundation
	O’Connell – impact of land use on behaviour of floods		Williams – changes in characteristics of coastal floods

parameters by optimizing the fit between the solution of the model and a set of observations which the model is meant to predict. It has been used to assimilate

conventional meteorological observations into NWP models, and in a simple form is used to calibrate hydrological models. However, the assimilation of new types of data or parameters derived from data such as information on air motions and humidity from radar will require different methodologies. Likewise the assimilation of bathymetry from satellite data in coastal sediment models will demand different mathematics.

In dealing with uncertainty in model forecasts produced from perturbations in initial conditions, statistical procedures need to address the description and selection of the most likely outcome with measures of uncertainty associated with that outcome. Similarly extreme event statistics needs to go beyond conventional joint probability analyses if we are to produce meaningful approaches to understanding the factors leading to the recurrence of extremes.

In summary new methods likely to arise from FREE research will be mathematical and statistical in nature offering methodologies and modelling tools which can be used in a variety of future environmental science research.

Contributions to new products and services for stakeholders:

Overall the aim of many of the FREE Projects is to develop validated modelling methodologies to form the basis of useful tools for weather and flood forecasters, managers concerned with putting in place warning procedures and civil engineers concerned with designing and building flood mitigation measures. However FREE is a NERC programme and its principle focus is on the development of the natural sciences. However, FREE views the relevance of its research outputs to the stakeholder community as extremely important. FREE is therefore investing in early engagement with the stakeholders, and will be guided by them on its Knowledge Transfer activities. In recognition of the potential for improving the design of flood defences and operational flood forecasting, a number of stakeholders are supporting the research through the provision of data, models and advice.

Already it is possible to envisage the incorporation of new procedures in the Met Office high resolution NWP model, and in the Environmental Agency warning systems. Also should the research on statistical analysis of extremes be successful it is likely that developments of the Flood Estimation Handbook for design engineers would be expected to follow.

Scientific breakthroughs:

FREE is a basic science research programme of the Natural Environment Research Council, and as such it is reasonable to expect the outcomes to be advances in our knowledge of how extreme floods occur, how we might forecast them and how climate change may impact their occurrence and recurrence. The work will lead to publication of results in scientific journals, as well as forging new collaborative programmes of work and offering several training and development opportunities for young scientists. All of which will look to build capacity in this important inter-disciplinary area. Whilst it is difficult to predict with any certainty the major scientific breakthroughs, it is possible to anticipate that major steps forward will be taken in data assimilation, the modelling of uncertainty and statistical analysis. Also it is likely

that understanding of why some floods are extreme, whereas others with similar initial conditions are not.

1.3 Quantified data on the dissemination and use of the programme results

Number of items on the dissemination and use of results	Currently achieved	Estimated future number
Product or process innovations	0	1
New contributions to services (public and commercial)	0	2
New methods (academic)	0	8
Scientific breakthroughs	0	4
Other investments attracted	0	3
Technical standards contributed to	0	2
Regulations/directives contributed to	0	2
International regulations contributed to	0	1
CASE studentships	0	4
PhDs generated by programme	0	6
Scientific papers published (refereed)	0	≥20
Conference papers	0	≥100
Influence on government policy	0	2
Influence on programmes & policies in operational agencies	0	2
Interfaces with other research initiatives	2	4

Note: Future means expected within the three years following the end of the programme.

1.4 Description of progress for each objective (one page per objective at *date*)

The following will be included against each FREE objective listed:

Description of resources used; scientific milestones; methods employed and developed; papers prepared; problems encountered; documentation; demonstrations; commercial applications; engagement with stakeholders; next stages in the research.

Number and title of objective

1. To develop and extend the science underpinning integrated modelling frameworks enabling models to work sensibly and more effectively together

Summary (200 words maximum)

Current stage of development (tick one category)

Scientific and/or technical knowledge (basic research)

Guidelines, methodologies

Software code

Experimental development stage (prototype)

Prototype/demonstrator available for testing

Result of demonstration trials available

Other (please specify)

Documentation and information on the developments

Documentation type

Details

Status: PU-public

CO-confidential

Intellectual property rights

Market application

Number and title of objective

2. To identify and spread scientific improvements in model initialisation, data assimilation and the processing of forecast ensemble outputs across modelling communities

Summary (*200 words maximum*)

Current stage of development

Scientific and/or technical knowledge (basic research)

Guidelines, methodologies

Software code

Experimental development stage (prototype)

Prototype/demonstrator available for testing

Results of demonstration trials available

Other (please specify)

Documentation and information on the results

Documentation type

Details

Status: PU-Public

CO-Confidential

Intellectual property rights

Market application

Number and title of objective

3. To understand and quantify the propagation of uncertainty within a changing environment and within rapidly changing catchments

Summary (*200 words maximum*)

Current stage of development

Scientific and/or technical knowledge (basic research)

Guidelines, methodologies

Software code

Experimental development stage (prototype)

Prototype/demonstrator available for testing

Results of demonstration trials available

Other (please specify)

Documentation and information on the results

Documentation type

Details

Status: PU-Public

CO-Confidential

Intellectual property rights

Market application

Number and title of objective

4. To develop techniques for uncertainty reduction at the output stage enabling the communication to, and management of, risk by the user community

Summary (200 words)

Current stage of development

Scientific and/or technical knowledge (basic research)

Guidelines, methodologies

Software code

Experimental development stage (prototype)

Prototype/demonstrator available for testing

Results of demonstration trials available

Other (please specify)

Documentation and information on the results

Documentation type

Details

Status: PU-Public

CO-Confidential

Intellectual property rights

Market application

Number and title of objective

5. To enable mitigation of, and adaptation to, floods by the provision of advice on structural design

Summary (200 words)

Current stage of development

Scientific and/or technical knowledge (basic research)

Guidelines, methodologies

Software code

Experimental development stage (prototype)

Prototype/demonstrator available for testing

Results of demonstration trials available

Other (please specify)

Documentation and information on the results

Documentation type

Details

Status: PU-Public

CO-Confidential

Intellectual property rights

Market application

Number and title of objective

6. To seek the use, or re-analysis and use, of existing data sets whilst organising and creating a methodology to enable specific data to be collected following any extreme event that might occur during the period of FREE

Summary (200 words)

Current stage of development (tick one category)

Scientific and/or technical knowledge (basic research)

Guidelines, methodologies

Software code

Experimental development (prototype)

Prototype/demonstrator available for testing

Results of demonstration trials available

Other (please specify)

Documentation and information on the results

Documentation type

Details

Status: PU-Public

CO-Confidential

Intellectual property rights

Market application

Number and title of objective

7. To engage with the national and international community and stimulate knowledge transfer and user engagement

Summary (200 words)

Current stage of development

Scientific and/or technical knowledge (basic research)

Guidelines, methodologies

Software code

Experimental development stage (prototype)

Prototype/demonstrator available for testing

Results of demonstration trials available

Other (please specify)

Documentation and information on the results

Documentation type

Details

Status: PU-Public

CO-Confidential

Intellectual property rights

Market application

Number and title of objective

8. To provide training opportunities through research studentships including CASE awards, and to encourage the involvement of students funded via other means in FREE activities

Summary (200 words)

Current stage of development

Scientific and/or technical knowledge (basic research)

Guidelines, methodologies

Software code

Experimental development stage (prototype)

Prototype/demonstrator available for testing

Results of demonstration trials available

Other (please specify)

Documentation and information on the results

Documentation type

Details

Status: PU-Public

CO-Confidential

Intellectual property rights

Market application

Number and title of objective

9. To provide training opportunities through research studentships including CASE awards, and to encourage the involvement of students funded via other means in FREE activities

Summary (200 words)

1.5 Quantified data about the output at date

Items about the outputs	Current quantity	Estimated future quantity
1. Time to application/market		
2. No. of public or private entities involved in the implementation of the results		
- SMEs		
- Outside UK		
3. Targeted user audience of reachable people		
4. Scientific and technical refereed publications		
5. Publications for public awareness of science		
6. Contributions to policy		
7. Visibility for the general public		

Part 2: Description of the intentions of each participant at the start of FREE

This part has been completed by the Principal Investigator of each participating project. The contents comprise the summary Science Case of each project plus the foreseen collaborations with other bodies.

1. **Coastal Flooding by Extreme Events (CoFEE) (Plymouth, Liverpool, Edge Hill, POL): NE/E002471/1**

PI: Dr J. Williams, University of Plymouth
jon.j.williams@plymouth.ac.uk

Award period; 25 Apr 07 – 24 Apr 10

- Summary

Over the next 100 years sea level will rise and there may be more severe storms. This will increase the coastal flooding risk to property, businesses, industry, roads and rail at great cost to us all. We must now face the consequences of climate change and either invest in sustainable defences or develop new ways to live with more flooding. The first option will cost a great deal of money and the second option may mean we need to change radically the way we currently occupy and use the coastal environment. The Coastal Flooding by Extreme Events (CoFEE) project will use our present knowledge of the eastern Irish Sea coastline in computer models to investigate the speed and extent of coastal flooding during storms and to determine how sensitive our coasts are to extreme events. CoFEE will attempt to answer 4 questions (a) how big will coastal floods be in the future; (b) which types of coast can we leave to flood and which must we defend; (c) what might the coast look like in the future; (d) what are the risks of allowing coastal flooding to occur? CoFEE will look at different natural coastlines that include, estuaries, beaches and sand dunes and coastlines that are defended by a range of man-made structures. The results will be applicable to coastal areas elsewhere in Britain and more widely. By bringing together scientists, engineers and the people who plan flood defences, CoFEE will provide the basis for predicting the threat of coastal floods in a changing climate so that resources can better targeted to deliver more effective, better informed sustainable strategies offer managing the flood risk to our coastlines in the future.

- Collaborations: Defra, EA, EPIRUS Project

2. **Ensemble prediction of inundation risk and uncertainty arising from scour (EPIRUS) (Plymouth, Bristol, Liverpool): NE/E002129/1**

PI: Dr Q. Zou, University of Plymouth qingping.zou@plymouth.ac.uk

Award period: 1 May 07 – 30 Apr 10

- Summary

Sea level rise is now acknowledged as a real threat to our coastal towns and cities. In addition, global climate changes may lead to increasingly frequency and severity of storms. As a result the value of the UK's assets at risk from flooding by the sea have significantly increased. The current UK coastal flood defences, which have typically been designed to cope with severe storm events with a return period of 50-100 years, may be now inadequate to protect the coastal areas under threat. To improve the design of future coastal defences requires a better understanding of the linkages between atmosphere, ocean and seabed; as well as improved quantification of the inherent uncertainties in the predictions. This joint research proposal between the Universities of Plymouth, Bristol and Liverpool, aims to develop a robust and integrated "Cloud-to-Coast" modelling framework which will include the complex interactions between atmosphere, ocean and coastal flood and erosion, so that the flood risk in the coastal areas from the extreme events, such as severe storms, can be accurately predicted and assessed. The project will use various existing proven computer programmes together with necessary further developments to provide information on meteorological conditions under severe storms, the associated surge and wave conditions, as well as detailed transformation of wind and waves from the offshore to areas close to shoreline in order to predict coastal flood and erosion due to wave overtopping and scour. The main work of the project includes: 1) development of an integrated modelling methodology for a "Cloud-to-Coast" prediction of coastal flooding and erosion; 2) linkage of the large-scale high-resolution weather models for prediction of the atmospheric pressure and wind field, the regional and local scale process models for wave transformation from offshore to near-shore, and the local coastal models for predicting wave overtopping and scour near coastal defence structures; 3) validation of the modelling methodology and specific model system with field datasets; and 4) application of the modelling system to investigate uncertainties by creating ensembles of possible future storm events. The major output of the project will be a well-developed modelling methodology and a validated modelling system which can be used as a useful tool for coastal engineers and coastal zone managers to assess the possible flood risk in coastal areas.

- Collaborators: FRMRC, Defra

3. **Identification of changing precipitation extremes and attribution to atmospheric, oceanic and climatic changes (UEA): NE/E002412/1**

PI: Dr T. Osborn, University of East Anglia t.osborn@uea.ac.uk

Award period: 1 Feb 07 – 31 Jan 09

- Summary

Some of the most critical changes due to climate change will probably occur due to changes in the extremes of the hydrological cycle (droughts and floods), yet the expected changes in future precipitation and its extremes are currently quite uncertain. Scenarios of future change are derived from simulations with global and regional climate models, and our confidence in scenarios of future precipitation extremes rests on our assessment of the reliability of those models. We propose to evaluate these models by careful comparison of their simulations with observed variations in extreme precipitation events. Our comparisons will go far beyond simple comparisons of the statistics of simulated and observed events, but will in addition assess the linkages between atmospheric circulation variability (wind speeds and directions, stability, convergence and uplift), atmospheric humidity, and resulting precipitation extremes in both models and the real world. We will then extend the assessment to consider whether including changes in greenhouse gases (and other external climate influences) in the model simulations improves the agreement with changes detected in the observational data.

- Collaborators: Hadley Centre, EA

4. **Quantifying flood risk of extreme events using density forecasts based on a new digital archive and weather ensemble predictions (Oxford):NE/E002013/1**

PI: Dr P. E. McSharry, University of Oxford mcsarry@robots.ox.ac.uk

Award period: 1 Jan 07 – 31 Dec 08

- Summary

Floods in the UK are often caused by heavy rainfall lasting from minutes to weeks. Houses in flat areas are particularly at risk: meeting the demand for houses in the south-east requires building of these areas. To estimate the flood hazard risk in order to try to protect these buildings, accurate rainfall predictions are needed. However, the connection between rainfall and flooding is complicated, so that rainfall predictions must also say how likely rainfall is at any time – calculating the probability of rainfall. Extreme rainfalls caused devastating floods in Boscastle in 2004 and Lynmouth in 1952, but the causes and pattern of rainfall was different. Therefore, scientists also need to know what pattern of rainfall caused the flooding. This research aims to get good quality predictions of the probability of rainfall by combining advanced methods from statistics, the output from a new supercomputer model of the weather, and a new computer archive of extreme rainfalls going back to 1860, provided by a specialist company Hydro-GIS Ltd. It also aims to produce an automatic system for discovering the most likely pattern in the predicted rainfalls. The new prediction system and data will be freely available over the internet for use by the government and universities.

- Collaborations: ECMWF, Met Office, Hydro-GIS Ltd

5. **Exploitation of new data sources, data assimilation and ensemble techniques for storm and flood forecasting (Reading, CEH): NE/E002137/1**

PI: Professor A. J. Illingworth, University of Reading
<a.jillingworth@reading.ac.uk>

Award period; 1 May – 30 Apr 10

- Summary

Floods in the UK are often caused by extreme rainfall events. At present, weather forecasts can give an indication of a threat of severe storms which might cause flash floods, but are unable to say precisely when and where the downpours will occur, due to the complex range of processes and space-time scales involved. The first stage is to predict the air motions leading to convergence and ascent at a certain location where the precipitation will be initiated, then the development of the precipitation needs to be forecast, and hydrological models used to produce accurate, quantitative, probabilistic flood predictions.

Data assimilation is a sophisticated mathematical technique that combines observation with model prediction to give an analysis of the current state of the atmosphere. This analysis may be used to initialise a weather forecast. Although precipitation is well observed by weather radar, attempts to assimilate radar data had little success; by the time the rain develops the forecast model state is too far from the truth and the air motions are inconsistent with the position of the first radar precipitation echo. We propose to overcome this problem by assimilating the new types of data from weather radars. These provide information of the evolving humidity fields and air motions in the lower atmosphere so that the model can accurately track the developing storm before precipitation appears. The model used will be a new Met Office model that can be run with a resolution (i.e., grid spacing) of order 1-4km. this enables storm-cloud motions to be explicitly calculated, rather than treated as a sub-grid-scale effect. Furthermore, current operational forecast models are only updated with observations every few hours; in the new approach the model will be updated much more frequently. This should yield weather forecasts with improved locations (in space-time) for rainfall events.

Initialisation errors are not the only case of inaccuracies in storm-scale weather forecasts. Models are often run only for a small region of the world, and the data on the boundaries of this area provided from a larger-scale model. These data are known as lateral boundary conditions. Errors in these lateral boundary conditions and modelling errors also contribute to the errors in the forecast. Even if these errors were reduced, the nonlinear nature of the storm dynamics ensures that there is a limit, beyond which the value of deterministic forecasts become questionable. After that point it becomes important to determine the uncertainties in the forecast precipitation, so an ensemble approach is required. (An ensemble is a collection of perturbed forecasts that may be considered as a statistical sample of the forecast probability distribution.) The appropriate construction of a storm-scale ensemble is an open

question. We propose a structured approach where perturbations will be designed on the basis of physical insight of the convective forcing mechanisms.

The resulting probabilistic rainfall forecasts can be interfaced to hydrological models used for flood forecasting. For the first time, this project will allow different scales of application of these methods to be supported: ranging from localised flash flooding of small catchments, through to indicative first-alert forecasting with UK-coverage and forecasting of river discharges to the sea. The project will also assess the impacts of improvements in numerical weather prediction on flood forecast performance.

In this project we anticipate fruitful interactions between different disciplines of observations and measurement, meteorology and hydrology. Radar assimilation software development and ensemble forecasts will take place using Met Office models, so improvements can be implemented operationally very easily. The use of operational radars makes this project well placed to take advantage of data from any extreme events occurring during the period of the study.

- Collaborations: Met Office, EA

6. **Uncertainty assessments of flood inundation impacts: using spatial climate change scenarios to derive ensembles of distributed models of extremes (King's College, Lancaster and Exeter): NE/E002242/1**

PI: Professor G. McGregor, Kings College, London
glenn.mcgregor@kcl.ac.uk

Award period: 1 Sep 07 – 31 Aug 10

- Summary

Exploratory climate change studies for the UK indicate that an increase in the frequency of extreme events and associated flood risk is likely. Given that floods cause damage of over £1bn per year under present climatic conditions, climate change bears significant consequences for flood risk management. In order to evaluate these consequences, hydrological and flood inundation models are forced with projections of prediction from atmospheric models for a range of greenhouse gas emission scenarios to produce future flood predictions. However the validity and uncertainty of these model-based input precipitation fields are a key concern, as they potentially constitute a major source of ambiguity for hydrological and hydraulic modelling. Additionally, uncertainty is associated with the hydrological and inundation models themselves, such as for example the models ability to represent the dominating physical processes and to uniquely identify effective model factors (parameters and any other model variables) that will shape future forecasts. As the non-linear interaction of all model components will influence the total uncertainty associated with hydrological impact assessments these need to be comprehensively assessed.

Therefore, a key and exciting challenge is to describe and quantify the origin and propagation of uncertainty from climate to hydrological to flood inundation models. This project aims to develop a novel holistic modelling approach for doing this. Our region of focus will be the River Severn catchment because of concerns about current and future flood risk.

Specifically we will:

1. Quantify the “top-end” uncertainties associated with climate change hydrological impact assessments by analyzing precipitation fields produced by two contrasting methods and assess how these affect the nature of flood and inundation predictions.
2. Evaluate all uncertainties between and within a cascade modelling framework for flood inundation predictions in a fully coupled and dynamic way.
3. Use novel techniques of uncertainty analysis including global sensitivity analysis and a new efficient functional similarity sampling approach to enable an effective evaluation of the uncertainties in the modelling cascade.
4. Assess the likely flood hazard change for the River Severn catchment over the next 100 years for various climate, land use and soil moisture scenarios.

This project will deliver an insightful scientific methodology which can be used in future research assessments and catapult UK science to the forefront of an exciting, socially, and politically important international research area.

- Collaborations: Met Office

7. **FRACAS: a next generation national Flood Risk Assessment under climate Change Scenarios (CEH, Newcastle):NE/E002420/1**

PI: N. Reynard, CEH nsr@ceh.ac.uk

Award period: 1 Jan 07 – 30 Sep 10

- Summary

This proposed research will develop the new methodology required to make a step-change in our ability to quantify fluvial flood risk at large scales, incorporating climate change.

This will combine existing and emerging technologies, to provide national and regional estimates of flood risk based on models for improved assessment of flood risk for recurrence intervals in excess of 50 years. Linking gridded rainfall, runoff, flood defence performance and flood inundation models will significantly improve our ability to assess flood risk from extreme events and explore the potential impacts of climate change, including new scenarios, as they become available from

UKCIPnext. This will include a partially and temporally consistent gridded rainfall model operating over large spatial domains, a high resolution gridded runoff and flow routing model capable of modelling at the national scale and a continuous system analysis of flood inundation, taking account of defence performance. As each of these models will run continuously, a linked flood risk analysis system will be developed for the first time. Each model will also be able to derive future changes in climate to produce predictions of future flood risk. Moreover there will be an assessment of the model and data uncertainties, as well as estimates of uncertainty due to climate change. These uncertainty assessments will include the propagation of uncertainty through the linked modelling system.

The research will utilise many existing sources of data and build upon some established models and techniques, such as the Neyman-Scott Rectangular Pulses (NSRP) stochastic rainfall model at the University of Newcastle, the CEH Grid-to-Grid (G2g) model, the RASP system models, and the use ensemble scenario sets to represent uncertainty. At the regional or large basin-scale analyses will include a grid-based (5km) rainfall model linked to a (1km) gridded runoff and routing model and associated knowledge of defence systems and new routines developed to translate rainfall to river levels. Such a modelling system is ultimately applicable at a national scale and this will be demonstrated for river flows. The precipitation for this demonstration will be sourced for observed rainfall datasets, modelled time series, such as those available from RCMs driven will re-analysis data. The impact of future changes in rainfall, runoff and river levels on flood risk will be assessed within an enhanced version of the HR Wallingford RASP HLMplus model. Scenarios of climate change will be derived from a range of both global (GCMs) and regional climate models (RCMs). There will also be an analysis of the application of multi-ensemble climate scenarios and the generation of probabilistic scenarios of change in future flood risk.

- Collaborations: HR Wallingford

8. **Local flood forecasting capability for fluvial and estuarine floods: Use of GridStix for constructing uncertainty in predictive models (Lancaster, Bristol, POL):NE/E002439/1**

PI: Professor K. Beven, University of Lancaster k.beven@lancaster.ac.uk

Award period: 1 Oct 07 – 31 Mar 09

- Summary

This project aims to make use of lots of networked GridStix depth sensors to improve predictions of flood inundation and water level elevation at important locations with a new improved flood warning capabilities. The project involves improving the software that links the sensors and distributed computing resources. This will allow distributed hydraulic routing models to be run, with the possibility of reducing the uncertainty in their predictions by using the sensor information in real-time. Since the

GridStix also have on-board computing capabilities there is also a possibility of building a cheap local forecasting system for specific points at risk of flooding. The science questions involved include how best to make the networking robust, how best to constrain the uncertainty in flood routing models and improve their predictions, and how best to implement the local flood forecasting models. The research will be implemented through the collaboration between Lancaster and Bristol Universities, the Proudman Oceanographic Laboratory and the Environment Agency.

- Collaborators: EA

9. **Changing coastline: data assimilation for morphodynamic prediction and predictability (Reading, POL):NE/E002048/1**

PI: Dr S. L. Dance, University of Reading s.l.dance@reading.ac.uk

Award period: 8 Jan 07 – 7 Jan 10

- Summary

In 2005, severe flooding in the aftermath of Hurricane Katrina focussed the world's attention on the importance of accurate knowledge of the topography of the coastal zone in natural disaster management and prediction. The topography of the sea floor, generally known as the bathymetry itself changes the motion of the water, which is also influenced by tides and weather patterns, such as storm surges. An accurate, up-to-date knowledge of coastal bathymetry would allow improved flood forecasting. Improved prediction of future bathymetry, and knowledge of the uncertainty in that prediction, would allow construction of better sea defences, better management of coastal habitats, and better understanding of the effects of changes in land use near the coast. It may provide better understanding of the effects of climate change (e.g. sea level rise, and increased numbers of extreme storm events) on the longer-term evolution of an estuary.

Coastal sediment transport models are becoming increasingly sophisticated. However, observed bathymetric samples typically only provide partial coverage of the domain of such a model. Hence, initialisation of such models using only a set of recent observations is not feasible. The effective and efficient use of limited data, such as these, require state-of-the-art mathematical, statistical and computational methods, known as data assimilation techniques. Data assimilation combines empirical observations with model prediction to give more accurate and well-calibrated forecasts and enables the uncertainties in the forecast to be calculated. Whilst data assimilation has been used in the context of atmospheric and oceanic prediction for some years, its use in the context of coastal sediment modelling is novel.

This project will use data assimilation techniques with a coastal sediment transport model to maintain up-to-date near-shore bathymetry, predict future bathymetry, and answer statistical questions regarding uncertainty and predictability, gain insight into physical processes taking place during intense storm events and to design an optimal observation strategy for coastal monitoring. Three coastal sites have been identified

for numerical experiments. Methodologies will be developed and tested using data from the first site and validated using independent data from the other sites, demonstrating the wider applicability of ideas. The novel use of data assimilation will allow improved estimates of the current bathymetry, and improved predictions of future bathymetry via better initialisation, error estimates for the improved bathymetry, and a means to estimate model parameters from indirect observations. The direct involvement of the Environment Agency in the project will ensure that the resulting benefits are transferred into operational practice.

- Collaborators: EA

10. Modelling groundwater flood risk in the Chalk aquifer from future extreme rainfall events (Imperial College, BGS, CEH-Wallingford): NE/E002307/1

PI: Professor H. S. Wheater, Imperial College h.wheater@ic.ac.uk

Award period: 1 Apr 07 – 31 Mar 10

- Summary

Recent events have show that groundwater flooding is a serious risk to property, infrastructure and social disruption, and is a particular problem for the Chalk of South East England. The nature of this risk is poorly understood, and there is no adequate methodology to assess it. This proposal will use experimental data from the NERC Lowland Catchment Research Thematic Programme (LOCAR) and historical data from affected areas to investigate the observed response of chalk catchments to extreme flood conditions, such as those of 2000/2001. It will develop and integrate state-of-the-art models of the soil, unsaturated zone, groundwater and surface water to provide a new integrated surface water / groundwater modelling tool for assessment of risk. The models will be run for future climate status to assess current and future risk from extreme events using ensembles of climate models. The project will also investigate the extent to which simpler modelling methods can be used in the regional assessment of flood risk, and in forecasting groundwater floods.

The objectives are:

- To develop an improved conceptual model of the processes occurring in groundwater flooding in chalk catchments.
- To develop a methodology for linking existing and new models (including methodology for assessing uncertainty in predictions) within an integrated decision support system.
- To undertake case studies to test the conceptual model, investigate system response, and demonstrate the utility of model integration.

- To assess the potential for future changes in groundwater flooding frequency using the integrated modelling system and a range of GCM/RCM scenarios.
- To develop and evaluate simpler methods for forecasting and regional assessment of groundwater flood risk.
- To engage with other projects in FREE and with the national and international community to stimulate knowledge transfer and user engagement.
- Collaborations: Environment Agency

11. **A data-driven exploratory study of extreme events based on joint probability analysis:NE/F001037/1**

PI: Dr Cecilia Svensson, CEH Wallingford <CSVE@wpo.nerc.ac.uk>

Award period: 1 Oct 07 – 30 Sep 10

- Summary

The aim of this project is to examine records of past moderate and extreme flood events, and of associated environmental variables related to the causes of flooding, and to undertake an exploratory data analysis of these. This would avoid relying immediately on the assumptions built into existing methodology and provide an independent check on these. It would also allow the construction of a statistical methodology tailored both to the observed properties of the datasets and to the estimation of the relevant properties of extreme events that need to be extracted from the data. Joint probability analysis would be one of the main statistical approaches being used. As well as providing useful insight into the occurrence of flooding, this has the potential to lead to more statistically efficient estimation of floods. Further insights into flooding problems will be sought by directly considering the seasonality of flood events in all the analyses. The datasets available can realistically be expected to provide good estimates of floods with return periods of 10-20 years, but the statistical models used can be employed to extrapolate to return periods of 50, 100 or even 1000 years. For such extrapolation the uncertainties inherent in this estimation are likely to be large and an important aim of the project will be to provide a useful assessment of this uncertainty. Hourly datasets already held at CEH will be used for the project.

- Collaborations:

12. **Land use management effects in extreme floods:NE/F001134/1**

PI: Professor Enda O’Connell, University of Newcastle
<p.e.oconnell@ncl.ac.uk>

Award period: 1 Dec 07 – 30 Nov 10

- Summary

It is increasingly recognised in the UK (e.g. Making Space for Water, Defra, 2005), and internationally, that the management of land and water is strongly interdependent, and that integrated management approaches are needed. There are particular issues for floods, where there is evidence that agricultural land management can increase local flood risk, but no evidence-based quantification of downstream impacts at larger scales. If such effects exist, as the local evidence suggests, clearly there is potential for use of land management to mitigate flood risk. The basic scientific question to be addressed in this research is therefore: how do the effects of land use management propagate from the local scale (~ 1ha, and below) to that of mesoscale catchments (~ 100 km²) and affect extreme floods? If an answer can be found, it will be possible to make useful predictions for the effects of future land use management changes on extreme floods. Such predictions would have wide use, including in preparing catchment flood management plans. Research like this demands high-quality long-term data sets, but there are relatively few data sets available. Modelling is essential to make the best use of the available data and to encapsulate and explore the understanding of the processes involved in the link between changes in land use management and flooding. Unfortunately, our current rainfall/runoff models are simply inadequate for this task, because they cannot adequately represent the underlying complexity associated with the effects of land use management on runoff generation, or the propagation of these effects downstream.

The level of activity and interest in understanding and manipulating the link between land use management and flooding is very high, and recent mitigation works and investments in field research have resulted in new unique and important data sets being available to the investigators; the FRMRC field sites at Pontbren in the upper Severn catchment; the CHASM multi-scale monitoring for the Eden catchment; and the SCAMP large-scale land use management changes currently underway in the Ribble catchment. There are also new relevant developments in modelling, including local-scale runoff generation modelling developed at Imperial College and network routing modelling and information tracking methods developed at Newcastle University. This data and modelling will be brought together to tackle the basic scientific questions above, within the practical context of predicting the likely effects that given land use management mitigation and adaptation strategies would have in reducing flood risk in the Severn, Eden and Ribble catchments, for a range of specified extreme flood return periods.

This project will provide improved scientific understanding of the effects of land use management in extreme floods, and also provide results of the type required by those involved in decision-making, such as consultants and policy

makers looking for answers to some of the general questions raised in Defra's Making Space for Water consultation. The results will include maps showing the application areas for any management interventions achieving effective downstream hydrograph attenuation, for the present and possible future climates. The project also represents a major contribution to the next generation of whole-catchment continuous simulation modelling, which will help improve its capability and reliability for predicting the effect of land-use management change on extreme flooding.

The EA/Defra have agreed to fund a parallel programme of experimental research in the upper Ribble, to provide the necessary data for the effects of afforestation and blocking of moorland grips.

- Collaborations: EA, Defra

13. A hybrid model for predicting the probability of very extreme rainfall: NE/F011822/1

PI: Professor Ralf Toumi, Imperial College r.toumi@imperial.ac.uk

Award period:

- Summary

A hybrid physical-statistical model for very extreme rainfall statistics will be critically examined. This model will be tested against mesoscale model simulations and its limitations explored numerically. In particular two hypotheses will be examined. The first hypothesis is that regional simulations of very extreme rainfall are consistent with the proposed hybrid model. The second hypothesis is that the hybrid model is suitable for finite time periods and can be adjusted for non-stationary parameters. The objectives are,

1. To apply the methodology of probable maximum precipitation (PMP) to a mesoscale model simulation. We will test the concept of PMP and the methodology of maximising the water vapour column. The assumptions of the hybrid model will be tested for the case of the July 2007 UK event.
2. To examine the convergent properties of the hybrid model for very extreme events. Monte Carlo simulations of very long duration will be made to test for convergence of the hybrid model. The resultant or "penultimate" extreme value distribution will be determined.
3. To determine the sensitivity of the hybrid model to non-stationary parameters. We examine the impact of varying the scale and shape parameters of the parent distribution on the extreme value statistics.
4. To determine the sensitivity of the hybrid model to data record length. The sensitivity of parameter estimation to record length will be critically examined using bootstrapping and other techniques.

- Collaborations: Met Office

Part 3: Progress report from each participant at date

This part must be completed by the PI of each participating project on the following dates T+3, T+6, T+9, T+12, T+15, T+18, T+21, T+24, T+ 27, T+30, T+33, T+36.

Here T is the start date of each individual project. The report shall follow the following guideline headings:

Name of project

Start date

Participants in project

Progress in the previous reporting period (at T+36 this should not be included)

Relevance of output to the specific objectives of FREE

Problems arising and their impact on the research programme

Modifications to the original project plan and how they were overcome

Involvement with other bodies including other academic partners and Government Institutions

Research training (if appropriate)

Plans for the next reporting period (at T+36 this should be proposals for future work)

NB: The report at T+36 should be a project final report.

Part 4: Programme management

4.1 Workshops and Annual science meetings (two days)

Location	Type	Dates
Swindon	Workshop	7-12-06

4.2 Extended abstracts

Extended abstracts will be required from each participant at the annual science meetings.

4.3 Liaison visits by the Science Co-ordinator

Organisation	Location	Dates
European Union	Brussels	10-10-05
EU Floodsite Liaison meeting	London	15-11-05
FREE Launch	London	28-11-05
CEH	Wallingford	20-2-06
SNIFFER Conference	Dunfermline	21-2-06
Hazards Forum	London	7-3-06
BADC (RAL)	Didcot	8-3-06
Environment Agency Workshop	Daresbury	4-4-06
Manchester University (Prof I. White)	Manchester	28-4-06
Launch of Tyndall Centre	London	4-5-06
Defra/EA MAR TAG		
RMets Presidential Lecture (Flash Floods)	London	12/13-6-06
NCAS Meeting	Abington	22-6-06
Royal Society Summer Exhibition	London	6-7-06
'Sense about Weather'	London	3-8-06
-public awareness of science		

FREE Steering Committee and assessment	Swindon	7/8-9-06
‘Sense about weather’		
-public awareness of science	London	6-10-06
Meetings with Prof. Illingworth and Dr Dance	Reading	30-11-06
NCAS Conference	Cambridge	11/13-12-06
‘Sense about Weather’	London	9-1-07
-public awareness of science		
Meeting with Prof. Wheeler, Imp. Coll.	London	17-1-07
Meeting with Prof. McGregor, Kings Coll.	London	13-2-07
Meeting with Dr Zou and Dr Williams	Plymouth	7-3-07
‘Sense about weather’		
-public awareness of science symp.	Oxford	17-3-06
EU Linking Flood Policy & Research Workshop	The Hague, the Netherlands	17/18-4-07
Dinner, Chinese delegation, host Malcolm Wicks, Minister of Science & Innovation	London	23-4-07
RMetS Meeting ‘Data assimilation’	London	25-4-07
Meeting ‘Evaluating the impact of climate change upon rainfall’	CEH, Wallingford	2-5-07
Meeting with Dr Reynard	CEH, Wallingford	21-6-07
NCAS Weather Research Strategy Forum	Abingdon	26-6-07
FREE Steering Committee & 2nd Round Bid Assessment	Swindon	28/29-6-07
APPCCG Meeting, House of Commons	London	17-7-07
FREE sub-committee meeting	London	26-7-07
Am. Met. Soc. 33rd Radar Conf.	Cairns, Australia	6/10-8-07
NERC-funded National Centre for Earth Observation (NCEO) moderating panel	London	29/31-8-3-07
RMetS Biennial Conference at Heriot Watt University	Edinburgh	3/7-9-07.
Inter-Agency Committee for Hydrological Uses of Radar Data	London.	25-9-07
Workshop at Selex-Gematronik	Neuss, Germany.	15/19-10-07
Third European Water Association	Brussels	5-11-07
Inter-Agency Committee for Hydrological Uses of Radar Data.	London	7-12-07
NCAS Annual Meeting	York	10/11-12-07

Part 5: Knowledge transfer and the Small Business Research Initiative (SMRI)

Money has been set aside for the establishment of small inter-disciplinary networks and other activities including engagement with users, cooperation in training, people and knowledge flow, and the commercialisation of research outputs. Activities instigated by the Science Co-ordinator, and contained within a more detailed plan, will be described here.

5.1 Basis of Knowledge Transfer

One of NERC's strategic objectives seeks to use NERC science to "identify and provide sustainable solutions to environmental problems". The FREE Programme will support high quality research and training which facilitates engagement with users of extreme flood forecasts, and the transfer of knowledge which will underpin improvements in generating forecasts of, and dealing with the consequences of, extreme floods.

Research proposals should therefore engage with stakeholders such as Government Agencies, research organisations and private sector organisations. Whilst research will focus on delivering the Science Programme, it is anticipated that outputs will influence policy development and add to our knowledge of how to address practical problems.

The FREE Steering Group includes representatives of stakeholder groups, which, with other members, will seek to develop a balanced portfolio of projects. These will include projects having user applications providing knowledge that can be used either directly via, for example, consultancy; through the application of patents or the development of new or improved operational services; or indirectly e.g. feeding into policy-making processes or through training young researchers.

5.2 Stakeholders

Key stakeholders who are already involved in FREE , or who will be consulted on the Knowledge Transfer aspects of the programme are listed in Table 1.

Table 5.1: Stakeholders and their roles

Stakeholder	They (stakeholder) Have/Steering Committee. want	We have/ they want	Source of power	Tactics	Status
Defra	Influence on policy: Complementary with Their R&D programme	Relevant science	Policymaker; Potential funder	Involvement in Programme through Steering Committee and Defra/EA TAGs; consult on all major activities	Steering Committee seek partnership
Environment Agency	Influence on policy; complementary with their R&D policy	Relevant science; application of some outputs	Policymaker ; potential funder	Defra/EA TAGs; consult on aspects of programme	Seek partnership
EU	Influence on policy particularly Floods Directive and FP7	Relevant science	Policymaker; potential funder	Involvement in discussion groups on programme development; establish bidding consortia	Seek programme involvement
Consultancies	Direct link to users	Relevant science	Influence on users and national policy development	Inform and consult especially on user relevance	Consult
Water PLCs through UKWIR (UK Water	User	Relevant science	Policymaker; influence on Government; potential	Inform and consult perhaps through	Seek programme involvement /partnership

Industry Research Ltd)			funder	UKWIR	
Met Office	Influence on policy; complementary with their R&D programme	Relevant science	Policymaker; user applications' potential involvement in data provision / training support	Consult on aspects of programme	Steering Group; seek partnerships
SEPA (Scottish Environment Protection Agency)	Influence on policy; R&D programme	Relevant science; research needs	Policy maker / potential funder	Involvement in discussion groups; inform and consult	Seek partnership
SNIFFER (Scotland & Northern Ireland Forum for Environmental Research)	Influence on policy; R&D programme	Relevant science; research needs	Potential funder	Participation in workshops; inform and consult	Seek partnerships
Northern Ireland Rivers Agency Department of Agriculture & Rural Development	Influence on policy; R&D programme	Relevant science; research needs	Potential funder	Participation in workshops; inform and consult	Seek partnerships
Maritime Coastal Agency	Influence on policy, R&D programme	Relevant science; research needs	Potential funder	Participation in workshops; inform and consult	Seek partnerships

5.3 Targets

Specific objectives of the FREE Programme are specified in the Science Plan. Associated with these objectives are the expected outputs and outcomes of the Programme. Some of these relate to aspects of Knowledge Transfer, the interpretation of which are developed further in what follows:

Table 5.2: Outputs and outcomes relating to Knowledge Transfer

Outputs

- Number of CASE awards.
- Number of publications involving stakeholders.
- Demonstration activities with stakeholder groups.

Outcomes

- The adoption of research outputs in activities of operational agencies and advisory services that improve the civil contingency response to flooding from extreme events.
- An increased understanding amongst user communities of the capabilities and limitations of predicting and assessing flood risk from extreme events and vice versa with research.
- Influence on future policy making in the management of, and adaptation to, flood risk.

5.4 Knowledge Transfer enabling actions

Whilst the targets associated with Knowledge Transfer will be underpinned through the FREE research it is anticipated that a number of enabling actions will be necessary to ensure success in this respect. It is our intention to instigate the following at the level of funding (budgetary only at this stage) shown:

- Gather stakeholder requirements and prepare and publish a report describing the FREE research programme and how it might influence stakeholder requirements (£20k).
- Workshops to bring together FREE researchers and stakeholders to identify key areas of operational utility, and seek funding for specific Knowledge Transfer extensions to the research (£10k).
- Establish a FREE Newsletter and researcher/stakeholder network to publish news updates to stakeholders and between researchers (£10k).
- Facilitate short-period (weeks) researcher placements in stakeholder units (£60k).
- Development of small demonstration projects targeted at transferring FREE research results to stakeholder applications (£100k).
- Publications of summaries of FREE research results (£10k).
- Aid the consideration of Intellectual Property Rights (IPR), and develop patents where appropriate (£15k).

5.5 Small Business Research Initiative (SBRI)

Part 6: Initiatives for further research

Networking collaboration with international groups including the preparation of activities leading to consortium bids to the EU Framework 7 programme (2007-2013), the European Science Foundation (annual call for exploratory workshops) and the British Council will be described here.

Part 7: Data Management Policy

A data management and protocol plan has been developed with the aid of the British Atmospheric Data Centre (BADC). This involves the BADC working with the FREE PIs. The project data will be archived in the Research Council Data Centres using the e-science Data Grid (NDG). The costs of this activity are to be included in the individual projects. Although the NDG Project comes to an end in September 2007 it is likely that a way will be found to continue its existence. There follows a summary of the data management plan:

The FREE web site will link to the following components,

- data from projects
- data feeding into projects
- how does the programme get access to the data
- What are the big data sets we want everyone to be able to access? Each data set will come with its own access limitations. There will be a two year embargo on public access which will start when each project ends.
- Outputs that might generate early wins for the programme will be identified.

Part 8: FREE science contribution to policy making

If FREE science is to have maximum impact and be used to protect or improve the environment, it needs to be communicated to policy makers. NERC recognises this, and articulates how this might be achieved in its booklet ‘Science into Policy. Taking part in the Process’, first published in 2005.

Of particular importance is the need to engage policy-makers in FREE science from its outset by communicating the science in an accessible form. This will enable policy-makers to recognise how this science fits into their political agenda. Government departments increasingly stress the need for evidence-based policy. However, all must recognise that policy may have to be decided in the absence of complete information. Hence, scientists may need to qualify the advice they give, but be ready to form opinions.

The FREE programme will communicate with government via

- * High level meetings with government departments;
- * Establish understandings with government departments and agencies;
- * Facilitate interactions between NERC’s Chief Executive and Government Chief Scientific Advisors;
- * Seek involvement with government and inter-governmental advisory committees, and provide input to government consultations;
- * Provide briefings and display FREE research output; and
- * Communicate with Parliamentary Select Committees and Groups, individual MPs and Peers and the Parliamentary Office of Science and Technology (POST).