Chapter 1

# Introduction and methodology

This chapter introduces the methodology and metrics that have been used to assess a wide range of possible responses to the future flood risks identified in Volume I. These risks cover the whole of the UK and relate to four scenarios – each of which encompasses differing amounts of climate change, and different socioeconomic futures.



## 1.1 The Foresight project

The Foresight Flood and Coastal Defence project set out to produce a long-term vision for the future of flood and coastal defence in the UK. This vision, while taking account of the many uncertainties, such as the future extent of climate change, aims to provide a robust analysis to inform policy development.

The Office of Science and Technology (OST) initiated the Flood and Coastal Defence (FCD) project because of growing awareness that flooding poses an increasing threat to economic and social activity in the UK. Rising values of buildings and their contents mean that even current flooding severity could impose greater financial burdens in the future. Climate change will exacerbate the risk still further. The project set out to provide a firm and rigorously researched basis for consideration of the responses that the UK should use in managing those increasing risks.

The objectives of the project are to:

- Identify and assess the relative importance of the threats that need to be addressed in long-term planning on flood and coastal defence.
- Construct a set of risk-based scenarios over a 30-100 year timescale and addressing social, economic and environmental issues.
- Provide an overview of the responses that are available for use and the key issues that determine those responses.
- Inform policy and its delivery.

In addition, the work seeks to:

- Identify implications for the future skills base.
- Identify knowledge and technologies that might transfer from other sectors.
- Inform long-term needs for research in floods and coastal defence.
- Inform public understanding and the debate on flood and coastal defence.

- Promote an effective and enduring dialogue between the science base and stakeholders, and between those with an interest in flood and coastal defence.

The project is broad in scope. Geographically, it covers all of the UK: England, Scotland, Wales and Northern Ireland. It considers river, coastal and estuarial flooding, local flooding due to heavy rainfall and coastal erosion. Finally, it takes a holistic view of future flood risk by considering economic, social and environmental impacts.

The project proceeded in three phases:

**Phase 1** – scoped the problems of flooding and coastal erosion and developed a methodology for the analysis in subsequent phases.

**Phase 2** – analysed drivers and potential impacts of future flood risk under a simple baseline assumption that existing flood-management policies continue unchanged. This assumption enabled existing policies to be assessed against future risks, and so identify where changes could usefully be made.

**Phase 3** – analysed a range of possible responses and flood management policies that could be used to improve the management of future flood risk. However, while Phase 2 assessed the drivers and the impacts of future flood risks for England, Scotland, Wales and Northern Ireland both together and individually, the analysis of responses in Phase 3 considered the United Kingdom as a whole.

This report describes Phase 3 of the project. Phase 2 is reported in Volume I.

The main tasks of Phase 3 and their coverage in this report are to:

- Identify and review a wide range of conventional and radical responses to flood risk.

- Evaluate the potential effectiveness, costs and impacts of the responses, using a combination of expert judgement, quantified risk-analysis tools, and a range of sustainability metrics. This evaluation is performed against four scenarios of socioeconomic and climate change and considers the responses in two stages: individually and as part of a possible integrated portfolio.
- Review potential constraints to and opportunities for the implementation of the various responses. In particular, the analysis reviews the broader institutional and governance issues surrounding alternative approaches to flood and coastal management.
- Identify and comment on the strategic choices that policy-makers in the public and private sectors should consider now in order to better manage long-term risks from flooding and coastal erosion.

The remainder of this chapter introduces the concepts and terminology that are used in Phase 3, and outlines the analysis methodology.

## 1.2 The analytical framework and models used in Volume II

This section outlines the key concepts and models that have been used in the work reported in this volume. These have previously been employed in the analysis described in Volume I, but are briefly reviewed here for completeness. The metrics used to assess the responses are also described.

### 1.2.1 The position of responses within the analytical framework

The analysis of responses to flooding and coastal erosion uses an analytical framework which embodies the following concepts:

- The flooding system is defined as encompassing all physical and organisational systems that influence or are influenced by flooding (Hall *et al*. 2003b).

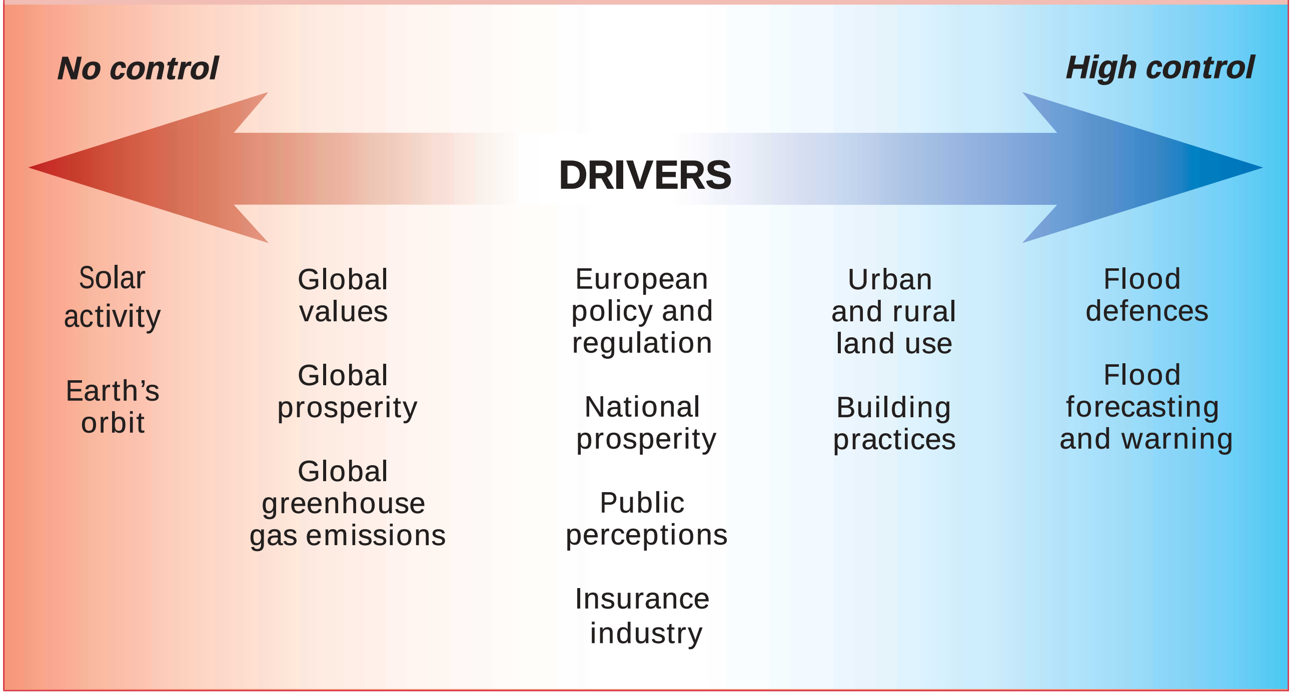
- A driver is any phenomenon that may change the state of the flooding system (see Volume I).
- Responses are changes to the flooding system that can be implemented to reduce flood risk.

Figure 1.1 shows that responses may be considered to be drivers that can be controlled – the degree of control affecting the ease with which a given response can be implemented. However, it should also be recognised that certain responses that are difficult to control, may nevertheless have a large influence on flood risk – for example, global emission of greenhouse gases. Changes to this driver could, if achieved, make a substantial contribution to managing future flood risk.

In this volume we also introduce the idea that responses may be considered at different levels:

- Direct measures, which are examined in Chapters 2 and 3 of this report. These include flood forecasting and flood defences.
- Governance responses, which operate at a level above direct measures. They seek to provide an effective framework of institutions, funding, incentives and regulation, along with the necessary science and skills, to enable direct responses to work well.
- Radical responses, which for flood risk, may be divided into:
  - Evolutionary ideas such as further developing ‘soft’ solutions and working with nature – concepts that have, during the past two decades, become increasingly used in flood management worldwide.
  - Revolutionary ideas such as weather control, which may not have been used for flood management but may have considerable potential in future.

Figure 1.1 **The degree of control by Government over different drivers of flood risk. The most practical responses to flood risk lie towards the right-hand side.**




### 1.2.2 The Source-Pathway-Receptor model

We can characterise flood risks in terms of the Source-Pathway-Receptor (SPR) model.

- Sources are weather events or sequences of events – such as heavy or sustained rainfall and marine storms – that may lead to flooding.
- Pathways are the mechanisms that convey flood waters that originate as extreme weather events to places where they may affect receptors. Pathways, therefore, include fluvial flows in or out of river channels, overland urban water flows, coastal processes and the failure of fluvial and sea defences or urban drainage systems.
- Receptors are the people, industries and built and natural environments that flooding may affect.

Most responses to flood risk addressed in this report aim to modify the pathways or receptors of flooding. However, we also consider the potential reduction in risk in decoupling global greenhouse emissions from the socioeconomic scenarios and reducing their amount.

The SPR model has been used in this work to consider both catchment-scale and intra-urban flooding. At the catchment scale, urban areas are considered as featureless components of the landscape. At the more detailed scale of individual urban areas, a different set of flooding mechanisms and issues must be considered. For example, intra-urban flooding is usually caused by intense rainfall that overwhelms the urban drainage system. Developing and implementing responses to these intra-urban floods, which we address in Chapter 3, offers challenges that are quite distinct from the management of catchment-scale flooding.

### 1.2.3 The use of scenarios

Scenarios of climate and socioeconomic change (as discussed in Volume I) have been used to assess the potential effectiveness of responses in a range of contrasting situations that may occur in the future. In this way they can be used to develop policies that can cope with a range of possibilities in an uncertain future.

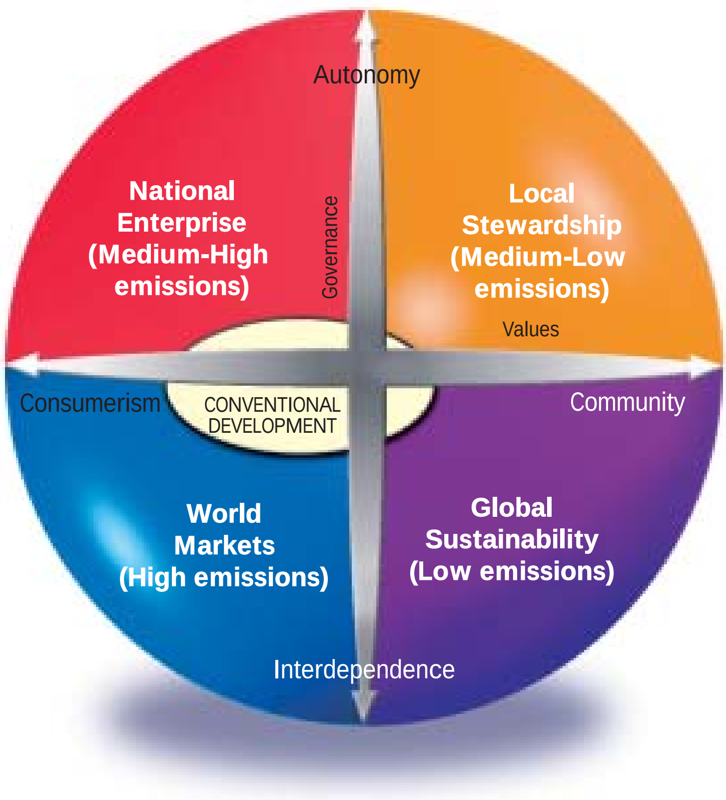
The socioeconomic scenarios used in this work are the Foresight Futures scenarios (SPRU *et al*. 1999; OST 2002):

- World Markets.
- National Enterprise.
- Local Stewardship.
- Global Sustainability.

Each scenario represents one of many possible societies that could prevail in the future. These societies will reflect economic growth, technological change and societal values, for example, regarding the environment. Thus they will embody economic and technological influences on greenhouse gas emissions and government/multilateral commitments to reduce emissions.

Figure 1.2 **Combined Foresight Futures and UKCIP climate-change scenarios**

In its assessment of flood risk, the FCD project used the Foresight Futures socioeconomic scenarios. The vertical dimension shows the system of governance, ranging from autonomy, where power remains at the national level, to interdependence, where power increasingly moves to other institutions, for example, the European Union. The horizontal dimension shows social values, ranging from consumerist values to community-oriented values. (SPRU *et al*. 1999; OST 2002). UKCIP02 climate-change scenarios have been associated with each of these and are also marked in the figure.




For the purpose of the project we have associated each of the Foresight Futures with one of the climate-change scenarios prepared by the UK Climate Impacts Programme (Hulme *et al.* 2002) (see Figure 1.2), referred to here as UKCIP02. There is no direct causal link between the socioeconomic and climate-change scenarios considered. However, it is not possible to evaluate all potential combinations. So, we have chosen four which allow us to explore a reasonable range of futures.

For reasons of simplicity, the above combinations of socioeconomic and emissions scenarios will be referred to as ‘the four scenarios’ throughout the rest of this report. A further sensitivity test was also analysed in Volume I, combining the high-growth World Markets socioeconomic scenario with Low emissions in order to assess the contribution of global emissions to future flooding risks. Data from this sensitivity test is reviewed later in this volume.

### 1.2.4 The use of quantified models

*Catchment and coastal models*

In recent years it has become possible to conduct national-scale analysis of the risks from fluvial and coastal flooding, making use of remotely sensed data and national databases of flood-defence assets and the domestic and commercial assets located in floodplains. We have therefore been able to use a newly developed risk-assessment tool (called RASP: Risk Assessment for Strategic Planning) in our analysis. RASP has been developed with Defra funding.

The RASP tool makes use of national databases of the location of river channels and coasts, the type of floodplain and the standard and condition of flood defences. This information is used to estimate the probability distributions of the depth of flooding, which, when combined with census data and commercial databases of the location of property and population, allows us to estimate the economic risk from flooding. The analysis therefore provides:

- An estimate of the flood risk associated with the failure of any flood defences, either alone or in combination.
- An estimate of the total flood risk for identified impact zones in the floodplain.
- An indication of the contribution that each defence makes to the total risk in the floodplain.

For this study the results have been aggregated for presentation purposes to 10km by 10km grid squares. Responses to flood risk have been implemented in this risk-assessment model by modifications to relevant parameters in the analysis, as described in more detail in Chapters 4 and 5.

The quantified risk-assessment methodology is based on the Environment Agency's National Flood and Coastal Defence Database for England and Wales. It has therefore only been possible to implement the quantified analysis of responses to flood risk at a catchment and coastal scale in England and Wales.

*Intra-urban models*

In the case of intra-urban flooding, there are considerable limitations in existing modelling tools – for example, in their capability to model above-ground flows when overflow occurs, and also in their geographical coverage. However, some modelling tools are available which we have used to investigate a small sample of urban areas. These have therefore been used where possible, to supplement expert opinion.

In particular, urban drainage models were used to test a range of possible response to flooding in urban areas, including measures to modify urban runoff, changes to urban drainage infrastructure implementation, maintenance and operation, and changes to the configuration of cities to modify flood pathways and the impacts of flooding. As in the catchment and coastal case, these models were used to assess responses for the four climate and socioeconomic scenarios. In so doing, they provide policy-makers with quantified examples of four very different urban drainage futures and insights into the effectiveness of specific measures.

### 1.2.5 Metrics used to measure sustainability and uncertainty

Individual responses and groups of responses have been evaluated against a range of metrics. These metrics relate to the three pillars of sustainability (environmental, social and economic). In so doing, we drew upon the government's guidance on sustainability (*http://www.sustainable-development.gov.uk/indicators/index.htm*). In addition, we used other metrics to assess the ability of a group of responses to cope with future uncertainty. These additional metrics are now described.

**Cost-effectiveness:** the cost-effectiveness of implementing the response option.

This appraisal is, for most responses, based on expert judgement. However, for river and coastal defences, some quantified assessment was conducted, making use of the quantified risk and cost analysis.

**Social justice:** the impact of action on different types of household, in particular, the differential impact of the response on households with a relatively low income.

Here the Government's Indicators of Sustainable Development include: Index of local deprivation (E2); Indicators of success in tackling poverty and social exclusion (H4); SDS indicators relating to social cohesion; Public understanding and awareness (T7); Number of local authorities with Local Agenda 21 strategies (L1); and Community spirit (L3).

**Environmental quality:** the impact on biodiversity, and the area and quality of habitats.

We considered, for example, the Government's Indicators of Sustainable Development for the UK, including the indicators on 'Biodiversity in coastal/marine areas' (R3), 'Rivers of good or fair quality' (H12), and 'Populations of wild birds' (H13).

**Robustness:** the ability of the response actions to cope with uncertainty relating to socioeconomic factors and climatic change (as envisaged under the four scenarios).

In addition to dealing with the question, 'can a given response or group of responses be effective under all four scenarios?' there is additional uncertainty relating to unanticipated factors (including extreme events). Clearly, an option that is robust enough to be viable under different socioeconomic or climate scenarios would also accommodate some of this additional uncertainty. However, the appraisal of a response option's capacity to cope with unforeseen or catastrophic events also relates to the Precautionarity principle (see below).

**Precaution:** as well as the environmental and socioeconomic uncertainties already identified, this metric relates to the ability to cope with extreme events and operational uncertainty in implementing the responses.



Key factors for a response to achieve a good score for precaution are:

- The support of science relating to monitoring and early detection of hazards.
- The capacity for reversibility.
- Participatory involvement in policy-making by stakeholders that includes lay or local knowledge, as well as input from specialists, and which considers the different values and priorities of different social groups.

## 1.3 Overview of methodology

The overall structure of the Phase 3 analysis (i.e. the work reported in this volume) is summarised in Figure 1.3. The activities in this figure are now described in more detail in the sequence in which they were performed, though, as Figure 1.3 indicates, the process involved feedback cycles.

### 1.3.1 Scoping and clustering of responses

The analysis began by identifying a wide range of possible responses to future risks and classifying them. This was performed separately for catchment-scale and intra-urban flooding risks.

*Catchment-scale responses*

Literature review, consultation with a wide range of experts and stakeholders generated a comprehensive list of around 80 possible responses to future flood risk. These responses often addressed one or more of the drivers identified in Phase 2 of the research (Volume I). They included:

- Physical actions to reduce either the probability or consequence of flooding.
- Measures relating to the process of decision-making, financing and implementation of flood management (i.e. governance issues).

The responses included established methods of structural and non-structural flood management based on international practice – either implemented to a conventional or to a radical extent. They also included futuristic proposals that have yet to be implemented or even analysed in any detail.

The responses (80 in number for the catchment-scale responses) were clustered into around 25 groups of similar responses, taking account of previous classifications proposed in the literature. This grouping was necessary to simplify the subsequent analysis. The 25 response groups were also classified according to five broad themes:

- Managing the Rural Landscape.
- Managing the Urban Fabric.
- Managing Flood Events.
- Managing Flood Losses.
- River and Coastal Engineering and Realignment.

*Intra-urban responses*

A similar process was implemented to identify intra-urban responses and to group them into six themes. However, in this case the choice of themes largely reflected the scale at which the different responses operate:

- Building Development Operation and Form.
- Urban Area Development.
- Source Control.
- Groundwater Control.
- Storage Above and Below Ground.
- Main Drainage Operation and Form.



### 1.3.2 Understanding and comparing the responses

'Deep descriptions' of the various responses were produced. These included:

- The mechanism by which they reduce flood risk and interact.
- Constraints and limitations to implementation under the different scenarios.

The responses were then scored against a range of economic and sustainability metrics (see above). The purpose of the scoring process was to provide a consistent and concise means of reporting expert judgements of the potential effectiveness and impacts of responses to flood risk. An assessment of uncertainty was also made in the expert scoring.

Because consistent metrics were adopted for each response, the scoring provided a means to compare widely differing responses. It was not, however, possible to generate a precise ranking because of the uncertainties involved in scoring responses, and because the extent to which people value different criteria such as the environment, economics and equity, varies. Nevertheless, it was possible broadly to compare the responses and to identify those that are more desirable than others.

Two issues should be noted concerning the basis of the scoring:

- The potential for risk reduction of any given response will depend strongly on the scenario under which it is implemented, for example, due to regulatory or funding constraints implicit in the scenario. The responses were therefore scored in the context of each of the four scenarios.
- The scoring and ranking of responses was based on today's values and preferences – we did not attempt to interpret the preferences inherent within each socioeconomic scenario. This is because the analysis is intended to inform decisions today and in the near future.

### 1.3.3 Identification of portfolios of responses

Whilst the above analysis scored and clustered the responses individually, it was recognised that, in practice, responses are used as part of a portfolio of flood management measures. The next step was therefore to construct a portfolio of responses for evaluation in each scenario.

These portfolios were then evaluated in order to quantify their effectiveness in reducing risks, to estimate their costs of implementation, and to draw lessons. These portfolios of responses should be regarded as examples of possible futures, rather than predictions or recommendations.

The four different portfolios of responses (one for each scenario) were drawn from the pool of responses that had previously been individually evaluated. The choice for each was influenced by the characteristics, values and wealth of the scenarios in which they were to operate. For example, a very costly response might not be selected for a scenario that embodied relatively low national wealth, whereas a response which required a high degree of regulation might not be selected in a scenario that embodied laissez-faire governance.

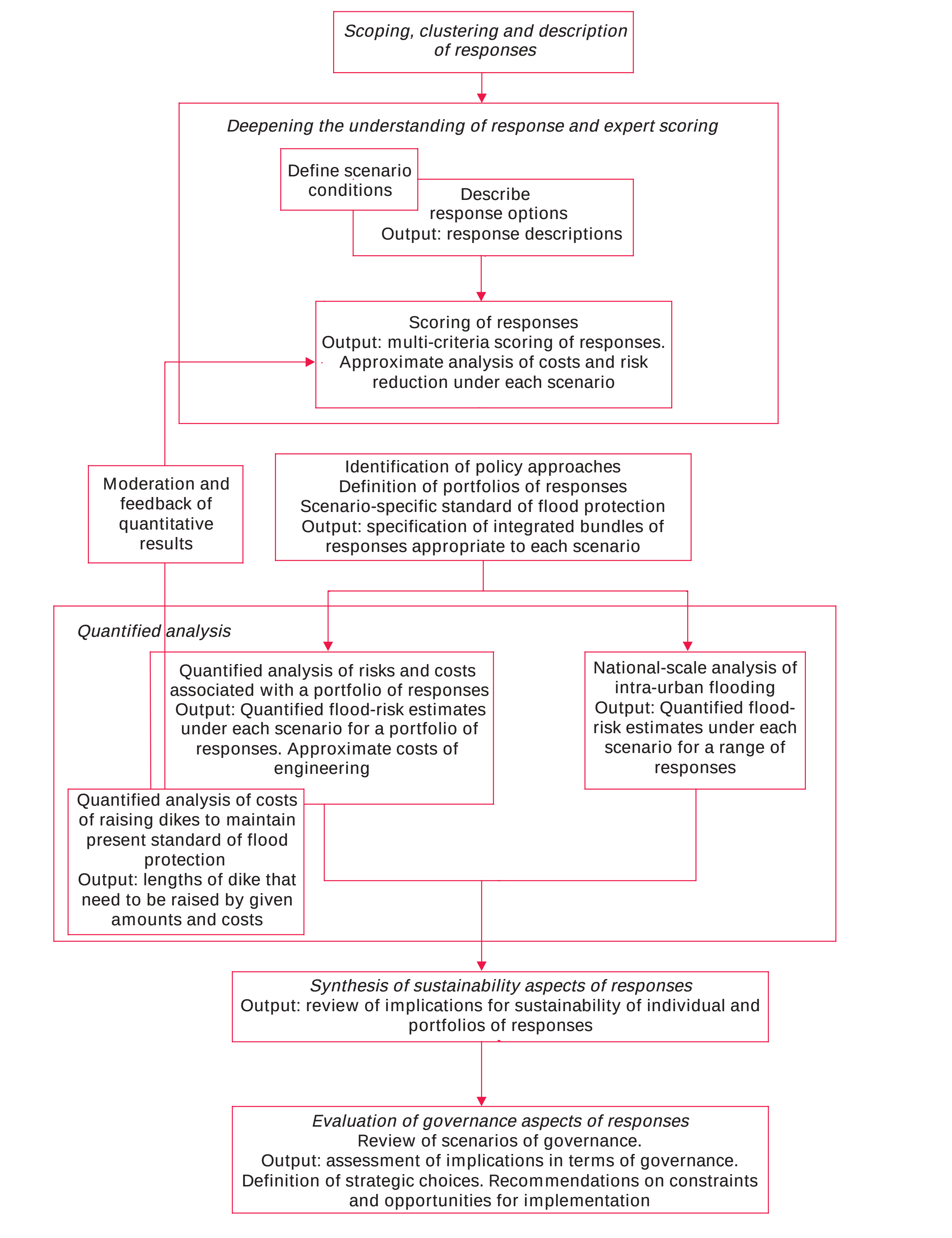
These portfolios were designed to be reasonably distinct from each other. Together they covered a wide spectrum of possible types of response and spatial implementations. They were set against four climate-change and socioeconomic scenarios, including different trajectories of national wealth and governance. These four scenarios provide policy-makers with four alternative flood-management futures and the risks associated with those futures.

To assess the integrated sets of responses within their respective scenarios, it was necessary to estimate the probabilities of flooding that each portfolio of responses would be designed to achieve. These standards of flood protection for each portfolio of responses were selected according to the people and assets at risk and whether the defence protects from fluvial or coastal flooding. Standards of flood protection for each portfolio of responses were chosen based on expert judgement about public expectations and the future availability of resources for reducing flood risk. By choosing different standards of flood protection for each portfolio of responses, we were attempting to construct four plausible and self-consistent futures for analysis.

Approximate analysis of some of the costs was conducted, by costing the engineering component of each set of responses. It is recognised that the engineering component does not represent the full cost to society, especially in scenarios with a relatively small engineering component; however, it was considered that the information provided was nevertheless of interest.



Figure 1.3 **Phase 3 methodology**



### 1.3.4 Quantified analysis of integrated policy approaches

Estimates of flood risk were produced for each portfolio of responses in their respective scenario. This enabled the performance of the responses in reducing flood risk to be assessed. Two types of model were used, as mentioned above:

- For catchment – and coastal – scale risks, a national-scale flood risk assessment model applying to all of England and Wales was used (as in Phase 2).
- For intra-urban risks, urban drainage models of sample cities were used and the results scaled up to cover all of the UK.

The costs of implementing each set of responses were also evaluated.

In addition to the analysis outlined above, further analysis was performed on the Global Sustainability scenario – the costs of meeting the target levels of catchment-scale protection (which in this case roughly corresponded to present-day levels) were evaluated on the basis that engineering measures alone would be used to address additional risks (over present day). This enabled the costs of the integrated portfolio approach to be compared with a more engineering-orientated approach.

### 1.3.5 Evaluation of sustainability and governance aspects

The responses and portfolios of responses were evaluated from the point of view of sustainability, using the metrics mentioned above (see Section 1.2.5).

An evaluation of governance issues was also conducted to assess the institutional constraints and requirements for implementing the responses – individually, and grouped together.

Finally, the project addressed the identification of strategic choices for present-day policy-makers in the context of wider government policies – for example, in transport and housing.