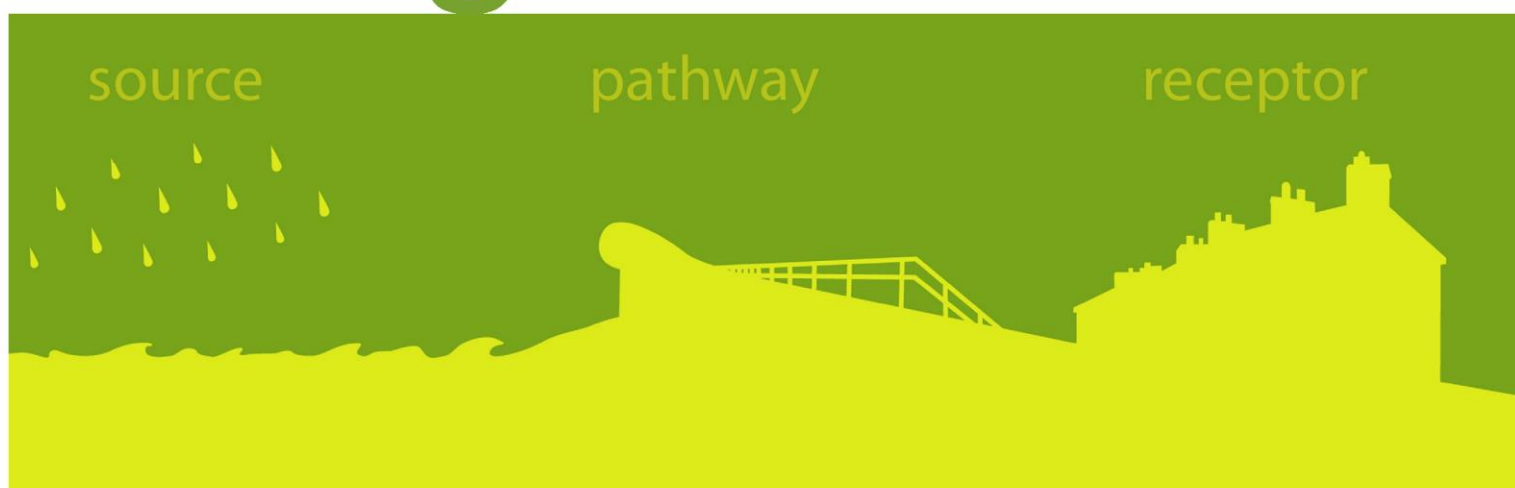


delivering benefits through evidence



Accounting for adaptive capacity in FCERM options appraisal

User guide – SC110001/R1

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This report is the result of research commissioned and funded by the Joint Flood and Coastal Erosion Risk Management Research and Development Programme. The Joint Programme is jointly overseen by Defra, the Environment Agency, Natural Resources Wales and the Welsh Government on behalf of all Risk Management Authorities in England and Wales:

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Professor Doug Wilson
Director, Research, Analysis and Evaluation

Executive summary

Flood and Coastal Erosion Risk Management (FCERM) has always faced the challenge of decision making under uncertainty. However, there is an increasing need to understand and develop solutions in the face of multiple uncertainties (in the climate, the economy and society) and often conflicting or competing agendas, while ensuring cost-effectiveness. These uncertainties will affect future flood and coastal erosion risks and our capacity to address them; they cannot be ignored or avoided, but need to be recognised and managed if we are to develop safe and sustainable solutions now and for the future.

This Guide is intended to assist stakeholders, FCERM project managers, consultants and the Environment Agency in developing and appraising managed adaptive approaches. It provides practical guidance and tools which should assist in taking forward the Green Book supplementary guidance on climate change and in using the most recent Environment Agency advice on climate change to value adaptability.

The Guide is relevant to the appraisal of FCERM plans and projects in England and Wales and supplements existing appraisal guidance such as FCERM appraisal guidance (FCERM AG). This guide describes tools and techniques that can be applied to help value adaptability, but it is important to note it is not a compulsory element of all project appraisals. Anyone considering its use to inform the business case for FCERM investments should discuss their plans and application of this guidance with the Environment Agency's Flood and Coastal Risk Management Risk Assessment & Investment Team for their support.

While the Guide is of relevance to all FCERM projects, it is important that the guidance and tools contained within are applied in a proportionate way. For smaller, more constrained projects that are unlikely to be affected severely by future uncertainties, referring to the Guide on a 'checklist' basis to ensure that adaptive approaches are not being precluded would be sufficient. But, for projects and plans where uncertainties about the future are high, future climate change is likely to cause significant impacts, and a high level of protection is required, it is strongly recommended that the Guide is followed in a more detailed yet still proportionate way.

The Guide promotes a proportionate, step-wise approach which introduces the concepts of adaptability, and aims to ensure that these are fully embedded through the early identification of adaptive options and their full appraisal. Ultimately the Guide enables practitioners to account for the ability to manage risk in an adaptive manner as part of the investment decision-making process.

The Guide is a 'living document' and will be updated over time to ensure it reflects relevant developments in science and policy.

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1 Introduction

1.1 Background

Adopting a **managed adaptive approach** to Flood and Coastal Erosion Risk Management (FCERM) involves investing now in actions that manage today's risks, monitoring the change in risk over time and managing these changes. The managed adaptive approach, therefore, involves planning for multiple interventions and investments in the future, although the future choices and the timing of these interventions will be uncertain.

If the rate of climate (or other) change diverges from our present-day expectations, then a managed adaptive approach offers flexibility to respond to its impacts and hence provide greater resilience. However, it may be that there are also costs associated with maintaining this flexibility. This Guide will help in appraising options where we need to account for the costs and benefits associated with future flexibility.

Traditionally, uncertainty has been managed by adopting a precautionary approach, for example by applying additional freeboard to a design crest level or preventing development in flood-prone areas. These approaches are still relevant and relatively straightforward to appraise. However, it is now recognised that a wider and whole systems approach to a broader suite of uncertainties is required in order to achieve better value for money and greater sustainability and flexibility in the measures to address flood and coastal erosion risks. It is also acknowledged that in some circumstances a highly precautionary response may still be appropriate, where an identified limit to the flexibility of the solution is acknowledged.

This guidance seeks to provide a suite of concepts and supporting tools based on the following principles:

- We have to prepare for future changes in the frequency of extremes of rainfall, river flows or sea levels, the performance of systems of flood defences and our vulnerability to floods when they happen. We also have to be prepared for future uncertainty concerning the availability of funding for investment in FCERM schemes.
- We can sometimes account for such changes by enhancing FCERM measures so that they perform more effectively in more extreme conditions (e.g. increasing sea levels), or in the light of increasing exposure to risk (e.g. more economic development).
- The scale and potential impact of current uncertainty and the range of possible future changes and their impacts may challenge whether a FCERM plan or project is sustainable in the long term.
- Understanding the reasons for changes and the mechanisms by which they could affect us can be as important as quantifying their scale.
- Accepting that the future is uncertain, we need to understand whether an investment would be resilient under plausible future changes to help assess whether there are trade-offs to be made between future resilience and investment costs.

1.2 The purpose of this Guide

This Guide is intended to help with the ‘How do I do it?’ question by advising on the assessment of the costs and benefits of adaptation, identifying and promoting adaptive attributes (which can be used to improve the adaptability and flexibility of existing as well as new projects and plans) and also helping to identify whether it is worth investing time and effort in promoting managed adaptive approaches. This responds to findings from previous research (Defra 2009b) and market research for this project that identified specific barriers to the development and appraisal of adaptive approaches, namely:

- a lack of systems thinking involving narrow problem definition;
- a focus on the status quo; risk and uncertainty aversion;
- an inability to value the benefits of adaptation and the costs of not adapting;
- the lack of an evidence base explicitly identifying examples of adaptive approaches or evidencing their effectiveness.

The Guide encourages adaptive thinking from the outset and aims to embed this throughout the appraisal process. This document supplements guidance provided by the Environment Agency, Defra and Welsh Government for conducting appraisals of plans and projects within England and Wales.¹ Although not prescriptive, elements of this Guide will be relevant to all projects or plans including Shoreline Management Plans (SMPs), Catchment Flood Management Plans (CFMPs), Surface Water Management Plans (SWMPs) and projects

1.3 Intended audience

The guidance is targeted at practitioners conducting and scrutinising appraisals related to FCERM decision making at all levels. Other interested parties, specifically stakeholders within communities affected by flooding and coastal erosion, planners and economic development officers may also find the guidance useful in explaining, justifying, developing, implementing and monitoring adaptive responses. Table 1.1 suggests the potential uses and users of the guidance.

Table 1.1 Potential users of this guidance and how it should be applied

User group	How the guidance should be applied
FCERM consultants	Development of plans and projects Undertaking appraisals
Environment Agency	Development of plans and schemes Undertaking appraisals Scrutinising appraisals
Defra and Welsh Government	Plan and appraisal scrutiny Awareness raising of the adaptive agenda
Local authority officers	Information, awareness raising. Justification, input to, development of and appraisals of local plans and projects
Communities affected by flood and coastal erosion risk	Information, awareness raising. Justification, input to and development of local plans and projects
Local authority elected members	Information, awareness and decision making

¹ FCERM AG (Environment Agency 2010a), Defra project appraisal guidance (Defra 1999) and Defra guidance for CFMPs, SWMPs and SMPs (Defra 2010a, 2011).

1.4 Linkage with other existing guidance

This Guide supplements existing appraisal guidance. It has been developed within the broad framework of the HM Treasury *Green Book* (2003) and as such should be applied on an iterative basis in which options are developed and discarded throughout the appraisal. Figure 1.1 shows how this guidance (second row down) links to and aligns with key stages of the *Green Book*, FCERM appraisal guidance (FCERM AG), Environment Agency 2010a) and guidance for plans such as CFMPs, SWMPs and SMPs (Defra 2010, 2011, Environment Agency 2004).

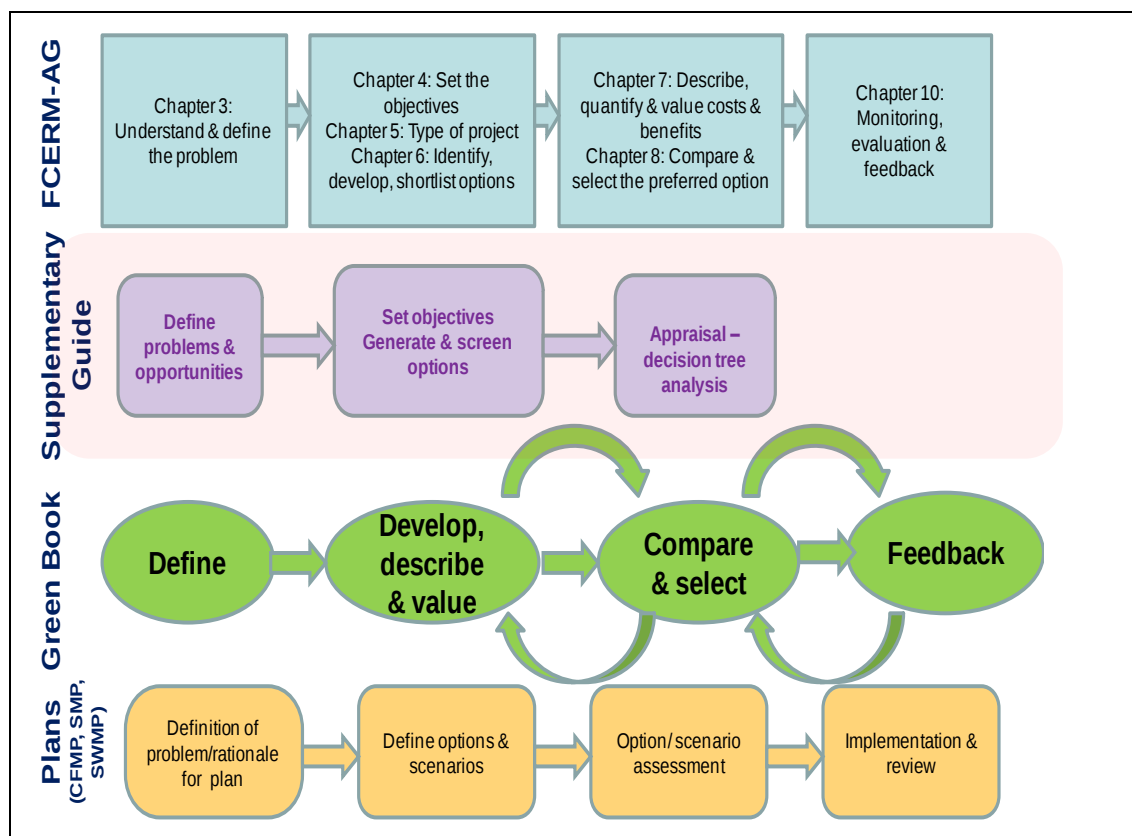


Figure 1.1 Linkages between guidance

It takes forward the Green Book supplementary guidance on climate change (HM Treasury/Defra 2009) and uses guidance published in the Environment Agency's climate change advice for FCERM authorities (Environment Agency 2010c).

In addition to appraisal guidance, the linkage with the land-use planning system, as set out in the National Planning Policy Framework (NPPF) (DCLG 2012a, 2012b), is important. Managed adaptive approaches may involve using less traditional FCERM approaches such as relocation of properties, which will require support from local planning policies. Also, where coastal change management areas (CCMAs) have been identified, the link with local planning authorities is of crucial importance as there are specific requirements (set out in the NPPF) concerning the identification of appropriate development in these areas.

1.5 Application of the Guide

The guidance provided is for general application to FCERM. However, it is particularly relevant to plans and projects being appraised in England and Wales. While different guidance² is used by the two administrations, all relevant guidance has its basis in the model promoted by the HM Treasury Green Book, which also provides the context for this supplementary guide. Throughout the document, reference to appraisal of plans and projects applies equally to England and Wales.

Application of the full Guide is appropriate where plans and projects include complex, long-term projects facing significant impacts with multiple uncertainties. The assessment set out in the full Guide is of particular relevance for the appraisal of strategies and plans. Projects requiring a more light touch appraisal include those aiming to maintain the status quo, such as sustain standard of service (SoS), cost-effectiveness assessment (CEA) and project appraisal reports (PARs).

The light touch approach would typically involve sensitivity testing and a professional judgement as to whether a more explicit managed adaptive approach is taken or sufficient qualitative justification of why the proposed measure or option meets the principles laid out in section 1.2. The detailed approach will need to utilise some of the tools and techniques provided in this guidance, with a formal analysis of possible futures to represent uncertainties.

Figure 1.2 suggests how the guidance should be used for three typical situations.

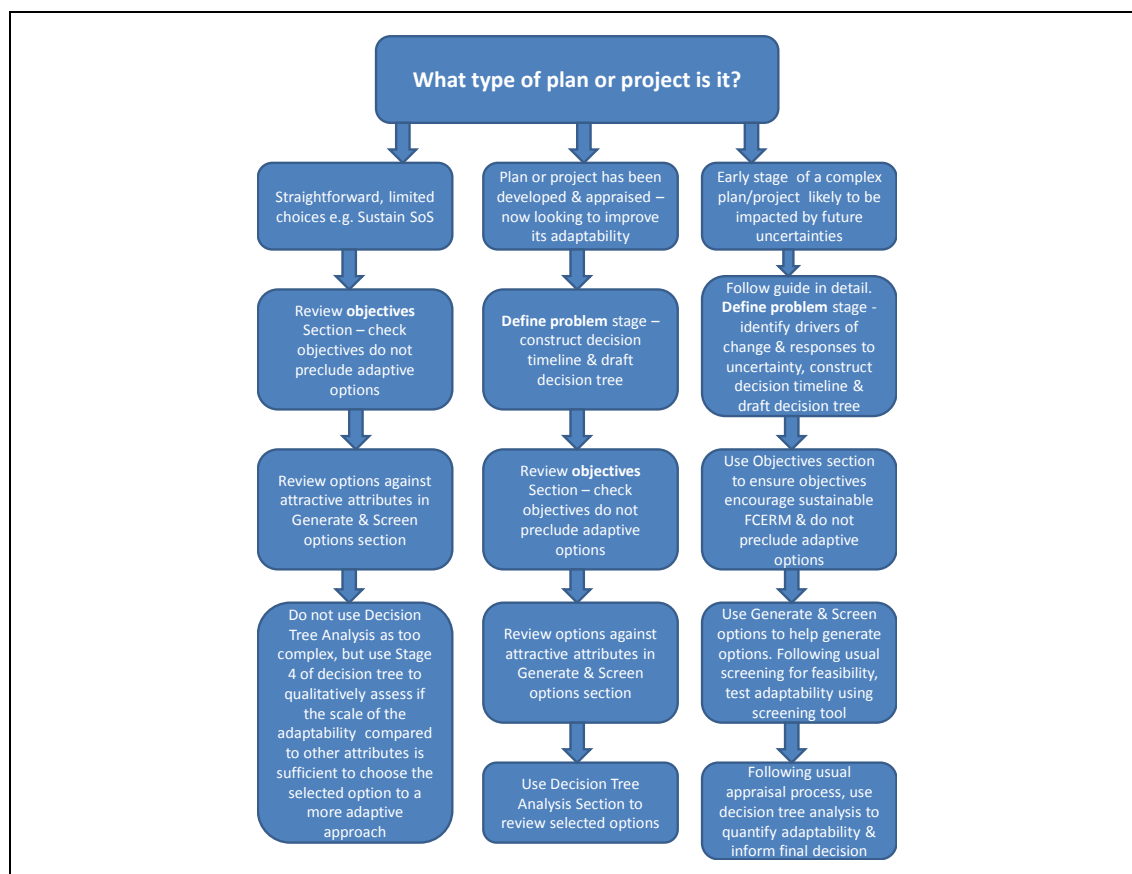


Figure 1.2 Suggested approach for proportionate application of this guidance

² FCERM AG is only relevant to the Environment Agency in Wales, with Defra project appraisal guidance still being used by local authorities. In England, FCERM AG applies to both the Environment Agency and local authorities.

1.6 Structure of the Guide

Section 1 (this section) gives an introduction to the Guide.

Sections 2 to 5 provide detailed guidance for embedding adaptation into the different stages of the appraisal process. Each is set out in a consistent format with the following sections:

- **Overview** – rationale for additional advice at this stage of the appraisal process to promote adaptive approaches, links with prevailing appraisal guidance, requirements in terms of the information required and target outcomes.
- **Approach** – the information that practitioners will need to use the guidance, and detail of approaches and associated tools that will assist them in developing a more adaptive response.
- **Examples from practice** – examples and case studies that exemplify the approach or method being promoted.

Section 6 provides a summary of the key points highlighted by the Guide.

2 Define problems and opportunities

2.1 Overview

2.1.1 Rationale and links with other guidance

The importance of defining perceived challenges and opportunities as seen from a full range of perspectives (economic, societal, individual and environmental) is a well-established principle of appraisal. The explicit consideration of the way perceived problems and opportunities and their resulting impacts may change provides a vital first step towards developing plans and projects. In developing plans and projects, the potential impact of climate change, plus other changes relevant to the local context, will need to be considered.

Once the key problems and opportunities have been explored, and there is an understanding of the likely impact of future uncertainties on present-day problems, there is a need to identify how beneficial a managed adaptive approach will be in addressing problems and capitalising upon opportunities.

This section of the Guide supplements Chapter 3 'Understand and define the problem' within the FCERM AG and the 'Definition of the problem/Rationale for the plan' stage of SMPs and SWMPs. Higher level plans and strategies may be an appropriate starting point for defining the problem. However, it is important that these plans and strategies are reviewed to ensure that they have taken the opportunity to look at adaptive options with the benefit of a full understanding of possible futures.

2.1.2 Required inputs

To ensure the definition of perceived challenges and potential opportunities is well founded (and relevant to the particular location and community) the following types of information could be required:

- Related planning documents that may be useful to inform future uncertainties for FCERM, for example:
 - river basin plan
 - SMP, SWMP or CFMP
 - local plan and local development framework
 - major business and infrastructure plans (rail, roads, energy)
 - environmental management plans (e.g. Habitat regulations in relation to saltmarsh)
 - community strategies
 - economic development strategies.
- The range of uncertainties associated with the analysis of key variables used in the modelling of the range of applicable flood and coastal erosion risk measures, such as flows, water levels and performance of defences.

- Climate change projections (and associated impact on sea and river levels, surface water and coastal overtopping).
- Potential trigger points and key future decisions (as currently understood).
- Local population projections, make up and potential demographic changes.
- Economic growth projections.
- Future funding scenarios and opportunities for private funding contributions.

The information available at this stage will inevitably vary in quality and the time horizon over which it is relevant. To support the appraisal of options it is recommended that the information gathered is summarised over several future time horizons. In this respect, Environment Agency FCERM advice on climate change adopts ‘the 2020s’, ‘the 2050s’ and ‘the 2080s’ as time horizons for consideration of future climate. Each of these future horizons broadly corresponds to the 30-year period centred on the cited decade (e.g. the 2050s can be interpreted as representative of the period 2040 to 2069).

2.1.3 Expected outcomes

Using this Guide should assist practitioners in taking a structured approach to the appraisal:

- i. Identifying and quantifying the potential drivers of future change or responses to uncertainty.
- ii. Identifying and quantifying the potential impacts (risks and opportunities) of these changes on the system of interest (community, catchment etc.).
- iii. Identifying a set of alternative futures of external change and describing these in terms of storylines relevant to the FCERM problem being considered.
- iv. Representing choices available in appraisal options as a high level decision tree.
- v. Understanding the benefits of a managed adaptive approach in relation to the specific problems and opportunities identified.

2.2 Approach

2.2.1 Ensure effective stakeholder collaboration

Communicating uncertainty about future change brings many challenges, so effective communication and engagement with local decision makers and communities is essential to identify and negotiate agreement on how to respond to relevant future uncertainties. There is a need to go beyond standard approaches of consultation and engagement to collaborative ways of working and strong partnerships that are fully involved in developing, and potentially implementing, challenging solutions.

When the scale of uncertainty is such that it could affect the delivery and outcomes of a specific plan and subsequent project choices, decision makers need to be aware of and comfortable with postponing decisions that do not affect short-term outcomes provided that there are plans, monitoring processes and trigger points in place that allow more informed solutions to be developed in the future. This is a real choice which does not prevent decisions being made, but ensures that high regrets choices are not

adopted in situations where there is no pressing need for an immediate decision. Ensuring true stakeholder collaboration and engagement is likely to take longer where managed adaptive approaches are being developed as these are a departure from traditional FCERM and involve more complexity. This needs to be built into the project planning process.

2.2.2 Set study boundaries and appraisal period

Boundary setting is an important stage for capturing the extent of the flood risk management problem. Adaptation to climate change is a social and economic issue and this stage needs to identify boundaries not only in terms of flood cells and catchment areas but also the implications for economic wellbeing on a wider development plan area basis. FCERM AG requires a consideration of current risks and future risks. Managed adaptive solutions require more detailed consideration of future risks and benefits, which may involve modelling impacts of future uncertainties including climate change scenarios and scenarios linked to other variables such as economic growth and regeneration or population change.

Boundaries need to be set in terms of:

- The appraisal period – FCERM AG states that ‘the appraisal period is usually taken as 100 years unless the life of the asset(s) (taking maintenance into account) or the potential to predict future events is such that a shorter or longer time frame is more appropriate’. It is suggested that where a change in economic circumstances is likely then this will tend to be known within a shorter period, but the appraisal should be undertaken over a long enough period for the benefits of FCERM measures to be realised.
- Where the risks and the potential solution are predicted to extend beyond the flood or coastal cell then the geographic extent of the appraisal should be extended. Including ‘space for water’ concepts can then be considered, which may help to identify a true community response to how future uncertainties could be managed in the long term.

2.2.3 Collate evidence on the drivers of future change

The future is uncertain. Some aspects of the future can be directly influenced by the flood or coastal erosion manager while others are wholly outside of their control, and are referred to as ‘autonomous’.³

Before risk modelling commences, it is important to think broadly, with stakeholders, about the impact uncertainties could have on the local community. At this stage, there is a need to:

- identify the drivers of future change and sources of uncertainty;
- quantify the nature of change and the time period over which it takes place;
- assess the likely impacts of the specific changes and their scale on the locality in question;
- identify potential trigger points and key decisions (e.g. whether or not a regeneration scheme is promoted in the local development framework);

³ The term ‘autonomous’ refers to ‘all future developments which are not purposefully influenced by flood risk management measures and related policy instruments’ (de Bruijn et al. 2008). Care should be taken not to confuse this usage, relating to external changes, with the separate concept of autonomous adaptation, referring to adaptation that occurs without the need for deliberate intervention.

- collate the supporting evidence.

The exploration of the drivers of change should be as broadly based as possible, covering a full range of relevant issues and stakeholder interests. It is also important to consider how these uncertainties could play out in future and what the impacts are likely to be over specific time periods and on specific areas.

2.2.4 Undertake a qualitative assessment of potential impacts and opportunities

Understanding the impact of different drivers on change on risk and the potential benefits and costs of intervention provides an initial insight into **which drivers may be most critical** in terms of the FCERM decision making. Some simple modelling of the economic impacts of increasing or decreasing the benefits, for example, may demonstrate the scale of change that could occur in the future and how that could alter the scale of scheme that could be considered now. Table 2.1 provides a way of considering a range of future uncertainties and their potential impacts.

Table 2.1 Future uncertainties and their potential impacts used to formulate a series of futures

Drivers of future change	Sources	Pathways	Receptors and consequences/ impacts	Funding
External drivers	Climate change Uncertainty in hydrological estimates Population and economic growth leading to land-use change impacting in upstream run-off/ shoreline drift or downstream controls/drift	Population and economic growth leading to land-use change	Population and economic growth leading to land-use change Population/demographic change Change in values and attitudes Environmental designations and attitudes to protecting habitat	Availability of national and local funding Funding eligibility rules Other organisations, types of plans and projects with competing objectives
(More) controllable interventions	Provision of storage Land management Spatial planning (e.g. land banking, flood storage and blue corridors)	Sediment management (rivers and coasts) Managing the performance of flood defences Property measures	Preparedness/ community resilience Warnings, property level protection take-up, evacuation processes	Local contributions

2.2.5 Develop alternative futures to represent uncertainties beyond the control of the flood and coastal erosion manager

Identify futures

The proposed approach to appraisal (set out in section 5) is based upon testing the range of performance of options and plans in the context of a number of plausible alternative futures. In developing these alternative futures, consideration should be given to the following:

- Defining a small number of distinctive futures that can be used to derive a qualitative or quantitative understanding of the performance of proposed options (as a guide, up to 3 alternative futures should be sufficient for most cases, but up to 10 could be employed in more complex cases where information is available).
- Each future should be distinctly different from the others – the inclusion of closely related or mutually dependent futures can introduce undue bias within the appraisal.
- The futures described should cover a wide range of plausible future scenarios, drawing on climate projections and related information.

The alternative futures should be developed in association with a broad range of stakeholders and bring together relevant quantified scenarios, such as:

- climate change (flows, sea level, waves, water quality);
- economic growth and development and/or regeneration;
- environmental designations and desire for habitat protection/creation;
- population and behavioural change;
- funding security (from private and public sources).

Assigning probabilities to scenarios

Scenarios in relation to climate change and other variables are brought together to form the alternative futures described above. There is existing guidance available to help in defining these scenarios suitable for use in FCERM. The Environment Agency's climate change advice (2010c) provides a standard range of projections for peak river flows in England (broken down by river basin district and for three future time horizons) and for sea level rise. The Environment Agency also provides a package of information⁴ about other parameters relevant to local flood risk, such as seasonal and extreme rainfall projections, and guidance on how these information resources can be applied pragmatically to assess the influence of climate change on flood risk.

Weighting futures

In some situations, alternative futures can be assigned weights reflecting evidence or judgements about their relative probability.

Stakeholders may perceive some futures to be more likely than others, but may well disagree in their judgements. There is currently unlikely to be sufficient objective

⁴ Climate change tools to support local flood risk management strategies, available from <http://www.environment-agency.gov.uk/research/planning/135749.aspx>.

evidence to resolve these disagreements completely. Where objective evidence can be used (based on the scenarios informing the futures) then a relative weighting can be assigned. If there is subjective discussion of weightings by stakeholders then the sensitivity of appraisal outcomes to those weights should be assessed (see section 5 for an example). For climate change projections, weightings derived from UKCP09 (Defra 2009c) and related research should be used; stakeholders should not assign alternative weights to climate change projections.

Example

An example set of alternative autonomous futures is set out in Table 2.2. Each future is described as a combination of climate change, economic change and funding change drivers. Together these three aspects describe one future. In this situation, economic growth underpins the local planning authority's development aspirations and availability of Partnership Funding could have a significant impact on successful delivery of the scheme.

Table 2.2 Example set of 'autonomous futures' defined in terms of three main uncertainties and impacts by 2050

Future	Climate change (increased river flow)	Change in economic impacts – development, growth etc.	Funding conditions (availability of Partnership Funding (PF))
1	20%	None	PF score achieved using national funding only
2	10%	None	PF score achieved using national funding only
3	5%	None	PF score achieved using national funding only
4	20%	Low increase in economic value	Local contributions required @20% of total cost
5	20%	Medium increase in economic value	Local contributions @ 70% of total cost
6	20%	High increase in economic value	Local contributions @ 20% of total cost

Ensuring the independence of drivers underpinning these futures is challenging. Growth and funding are often linked, especially if local contributions are needed, but are worth exploring as independent drivers. The important first step is to assess which elements make a significantly different future. If the sensitivity of the damages to an increased flow regime or coastal erosion, either as a result of uncertainty in the hydrological analysis or as a result of climate change is small, then this can be removed from the alternative future under development.

2.2.6 Establish potential trigger points and associated monitoring

A crucial element of ensuring that adaptive approaches are delivered effectively and efficiently is the identification of trigger points and implementing an appropriate monitoring regime to ensure awareness of trigger points being reached or approached.

Investigating and identifying trigger points at an early stage in the process will give reassurance to stakeholders that appropriate action will be taken at the right time.

Such trigger points vary depending on, for example, physical points on the ground reached by coastal erosion requiring a different approach, performance of existing flood defence infrastructure (e.g. number of times flood barrier put in place) and new information becoming available regarding climate change projections, economic growth and development, and/or funding regimes and availability.

A monitoring system needs to be put in place to ensure the correct intelligence is collated and analysed to enable action in advance of trigger points being reached. The actual content of monitoring requirements will depend on the relevant trigger points, which will be context specific but likely to focus on the condition of defences, external conditions (climatic, environmental and socio-economic), points reached on the ground, or a combination of all three. In setting out monitoring requirements, the importance of keeping up to date with predictive modelling and the need to be prepared to intervene before defences fail – rather than waiting until this actually occurs – is essential. This should prevent immediate reactions to events with responses that are not within the agreed suite of actions.

2.2.7 Develop decision tree

Decision trees represent an intuitive and widely applied method of describing the evolution of a series of future investments, where each node within the tree represents a different management choice that can be taken, and each pathway through the tree represents a different ‘decision pathway’, comprising various options. Decision trees are a useful tool for supporting decisions and making it clear what the decision is that is being taken and the nature and timing of required future decisions.

At the initial defining the problem or opportunity stage, it is suggested that a decision tree should be constructed for the options reflecting two generic management approaches (as depicted in Figure 2.1):

- **Adaptive** – maximising adaptation, and monitor and decide, where upfront costs are low and large investments are deferred into the future.
- **Precautionary** – acting as early as possible to manage potential risks, where upfront costs are high.

The output from the decision tree approach should be a series of streams of costs and benefits related to each of the different decision pathways through the tree.

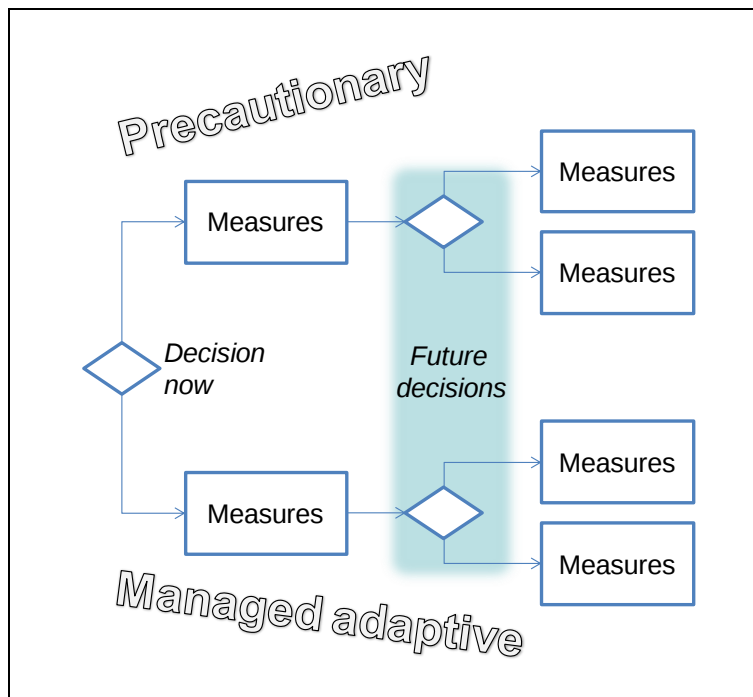


Figure 2.1 Decision tree approach

2.2.8 Understand the benefits of an adaptive approach

This Guide is focused on providing advice for the appraisal of managed adaptive approaches. However, it is recognised that these will be more relevant and beneficial in some situations than others. During this early stage, it is recommended that FCERM managers and stakeholders give explicit consideration to the likely benefits to be achieved from a managed adaptive approach using criteria such as the extent of competing interests and the significance of future uncertainty for decisions.

A detailed analysis of adaptive options will have more relevance for circumstances in which it is economically advantageous to build future flexibility into an investment plan. Broadly, this will be where:

- uncertainties about the future are high and the possibility of very high or very low climatic change and significant subsequent impacts;
- it is necessary for a very high absolute level of protection to prevail under uncertain and changing future circumstances;
- projected rates of increase in risk mean there is a strong likelihood that FCERM measures will require updating midway through the design life; this is of particular importance if the upgrade is to achieve a relatively high level of protection;
- decisions taken could be high regret; that is, costs could exceed benefits if future uncertainties are not realised.

Alternatively, flexibility in the solution is likely to be less critical if the flood or coastal erosion risk situation is tightly confined to a specific location; responses are constrained by geography, technology or environmental impacts; or the flood risk is so severe that effective action is required now to manage the risk.

The scoping exercise undertaken to identify the drivers and likely scale of uncertainty, the triggers for decisions and the nature of the decision tree for the project including

collaboration with partners and stakeholders will inform the assessment of the benefits to be achieved via a managed adaptive approach.

2.3 Example from practice

Area A is a highly productive agricultural lowland catchment, which is heavily reliant on a number of pumping stations, facing multiple future uncertainties in terms of climate change, food security, fuel prices and national policy/funding.

Such multiple uncertainties influence current agendas that compete and interact; for example, the price of energy not only affects how much it costs to pump flood water but impacts on farm viability (transport of goods, fertilisers, dryers, pumps and tractors). Stakeholders considered these multiple uncertainties and their implications over time, and also identified the differing policy drivers in flood management and farming and the national strategies available to guide decision making (see Figure 2.2).

By expressing the change required over time, it became clear that a phased handover of assets and change in governance could be achieved, when further drivers became more concrete. This helped overcome decision paralysis, which can be a very real risk when faced with significant, multiple uncertainties. By planning a way forward and developing an evidence base that was shared by all stakeholders to reduce those uncertainties, a tangible suite of scenarios could be formed. These scenarios allowed those involved to formulate their response and conclude who should take full responsibility for making the changes from the current unsustainable position.

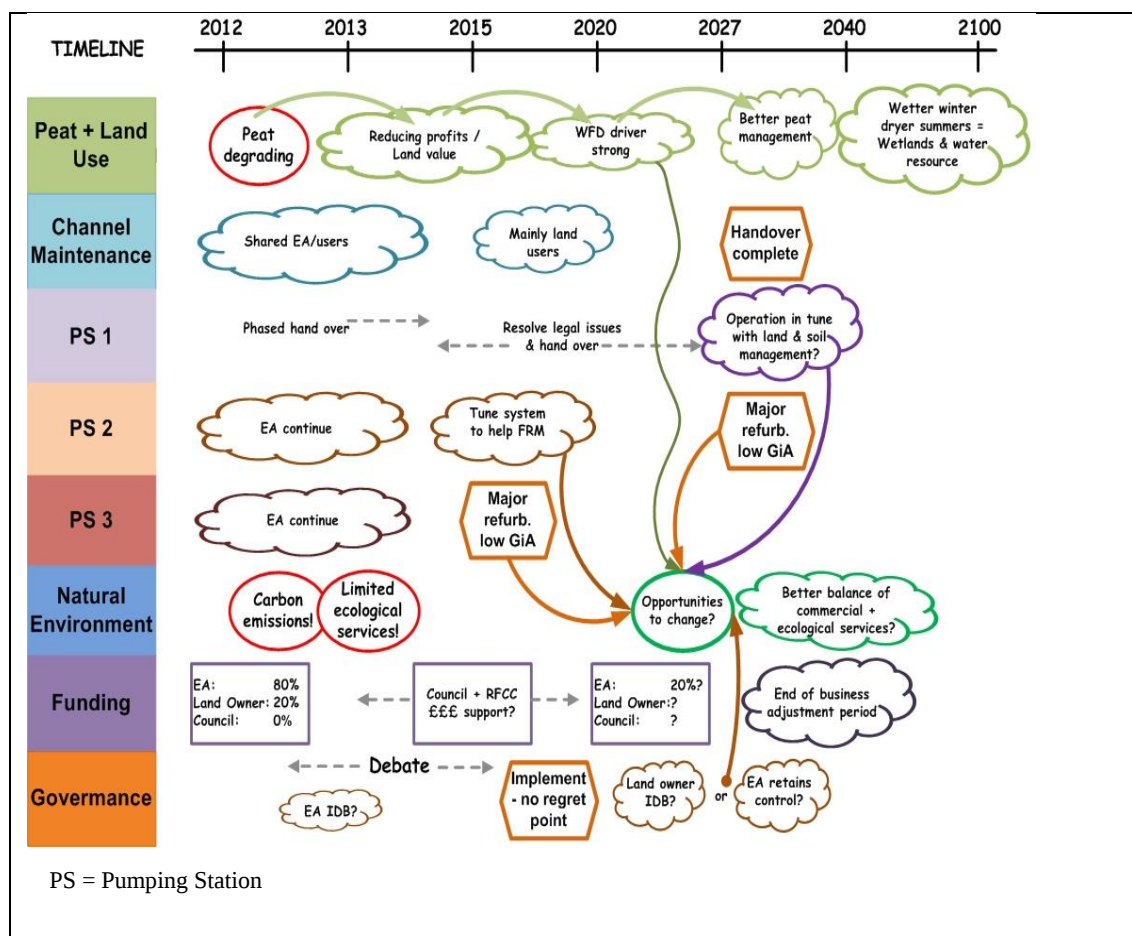


Figure 2.2 Mapping of issues and drivers in order to capture multiple future uncertainties

3 Set objectives

3.1 Overview

3.1.1 Rationale and links with other guidance

The way in which objectives are set fundamentally influences the way that plans and projects are developed and implemented. In recent years, FCERM objective setting has been extended to include a range of risk-based outcomes: economic, environmental and social. In turn, this has driven the development of more rounded risk management and promoted the move away from simply flood defence. Equally, adaptability can only be accounted for in the appraisal process if objectives are set that promote flexibility and embrace the notion that the future will be different from today.

This section supplements Chapter 4 ‘Set the objectives’ within the FCERM AG and the ‘scoping/option development’ stages of SMPs, CFMPs and SWMPs.

3.1.2 Required inputs

The key inputs are:

- Relevant policies and legislation at local, regional and national levels; these set out the overall aims of FCERM.
- An understanding of the alternative futures (from ‘Define problems and opportunities’ stage).
- Objectives set out in related plans such as the CFMP, SMP and/or SWMP.

3.1.3 Expected outcomes

This section should assist in:

- Ensuring objectives from all sources do not prevent the development of adaptive responses.
- Ensuring objectives promote long-term sustainability, with explicit references to adaptation and resilience.
- Unpacking the more general objectives used to reflect the wider role that adaptive solutions may have.

3.2 Approach

Appropriately set objectives should facilitate and encourage the development of adaptive options, where possible and appropriate, and certainly not preclude them. To embed adaptability more meaningfully within the project, objectives should consider, explicitly, promoting long-term sustainability, adaptive approaches and resilience.

- **Promote long-term sustainability** – to support adaptability, objectives must promote sustainability over the whole appraisal period under the alternative futures.

- **Promote adaptive approaches** – using the objective setting process to promote responses that do not foreclose future options or unnecessarily constrain future choice, are effective under the widest set of all plausible future uncertainties and enable appropriate modification of policies, plans and projects as the reality of the future becomes known.
- **Promote resilience** – plans or projects that are able to withstand a range of threats, including ones that are readily foreseeable and do not ‘fail’ catastrophically when exposed to events more severe than those foreseen, and are able to recover (rapidly) from a disruptive event.

3.2.1 Developing monitoring indicators

The potential for adaptability should be articulated in the indicators selected for monitoring progress against objectives. This should follow on from the identification of trigger points, as detailed in section 2.2.6, and the identification of required data and intelligence to provide forward notice that trigger points are being approached.

3.3 Example objectives

The following example objectives facilitate the development of adaptive approaches:

- Promote a sustainable approach to FCERM management which allows future changes to be made to flood and coastal protection to address uncertainties, such as climate change, as their impacts become more evident.
- Take an integrated approach to adapting to climate change by working with partners to satisfy economic, social and environmental objectives through approaches to FCERM, which can be adapted over time to address future challenges and opportunities as they arise.
- Develop adaptive approaches to flood risk management based on integrated catchment flood management with an emphasis on non-structural measures such as using natural flood plains to store water.
- Promote a sustainable approach to FCERM, which can be adapted over time, through a package of measures that together aim to reduce the risk of flooding and minimise the economic, environmental and social costs of flooding and coastal erosion.
- To deliver the greatest environmental, social and economic benefit over a suite of futures that reflect the current range of uncertainties in knowledge or future economic conditions.

The following example objectives could **prevent adaptive solutions**:

- To maintain the standard of protection through increasing the height of flood defences.
- To minimise the impact of flooding on residents through the installation of flood defences.
- To reduce the risk of flooding to a specific town by raising flood walls above expected climate change levels.

4 Generate and screen options

4.1 Overview

4.1.1 Rationale

To promote adaptive approaches, alternative measures and policies must be generated with future flexibility in mind. However, this is not easy and the development of adaptive options requires a clear and structured approach. By definition they tend to involve a wider range of skills and a broader suite of stakeholders. This section therefore focuses on two related issues: the generation of adaptive options and refining and developing options.

It is important to understand that, while an adaptive approach and options are recommended, there is no requirement for all component measures to be adaptive. For example the TE2100 strategy (Environment Agency 2012) is widely recognised as a good practice example of a managed adaptive approach, yet few of its constituent measures could be construed as adaptive.

4.1.2 Links to other guidance

This section of the Guide supplements Chapter 5 'Type of project' and Chapter 6 'Identify, develop and shortlist options' in FCERM AG and the 'define options and scenarios' stage in SMPs, CFMPs and SWMPs.

The FCERM AG also details criteria that are typically used to compare the performance of alternative responses. These are summarised in the appraisal summary tables (ASTs) (Environment Agency 2010b), which cover economic, environmental and social aspects. The criteria detailed in the next section can be used to supplement these core categories and ensure that managed adaptive options are retained throughout the shortlisting process and taken forward for full appraisal.

The requirements of the land-use planning system set out in the NPPF should also be taken into account in the development of options, particularly adaptive responses relating to the use of land rather than more traditional flood protection defences.

4.1.3 Required inputs

A willingness to be innovative and think laterally in the development of alternative responses is required. Therefore, stakeholder collaboration and engagement is a particularly important requirement when adaptive options are being considered and their input at this stage should involve generating, developing and short listing potential options.

The required inputs at this stage may need detailed information concerning the specific location – hydraulic model output for a broad range of assumptions to describe potential futures, flooding/erosion history, hydraulic modelling of the range of measures being considered, socio-economic context and projections, plus engineering expertise concerning the probable performance of specific options.

4.1.4 Target outcomes

Using this guidance should assist FCERM practitioners in:

- generating options that support a process of managed adaptation;
- achieving support through reasoned argument and visuals with key stakeholders;
- identifying promising options for carrying forward to further development and (if appropriate) more detailed appraisal.

4.2 Approach

At the option generation stage, it is not suggested that all options should be planned to allow for further future adaptation; this may not always be appropriate and less adaptive or precautionary approaches may be preferred in some locations dependent on the local context. However, it is always sensible to compare and contrast the benefits of an adaptive approach with a more rigid alternative. Adaptive approaches have some particular advantages, such as the potential to achieve better value for money over the long term and alignment with other policy initiatives such as Making Space for Water. These wider benefits need to be considered and promoted to move thinking and action beyond the reliance on the status quo (the precautionary approach).

An adaptive response is one that is capable of being adapted readily (or at least in a planned way) to changed future conditions. Such responses can be structural (e.g. physical changes to structures, upstream storage) or non-structural (land-use change, relocation, public awareness and resilience) or a combination of both. Typically a portfolio of responses is utilised – staged in space and time – forming part of a programme of activities to manage risk.

The FCERM AG states (p. 154) ‘Even unrealistic, impractical options may trigger thoughts on innovation that may inspire modified alternative options that could be considered’. This highlights the importance of thinking creatively and innovatively in the process of generating options and of avoiding dismissing potential options too early.

In generating a range of options, it will be important to try to identify potential responses that are:

- **No regrets** – measures that are worthwhile (i.e. they deliver net socio-economic benefit) regardless of how the future turns out.
- **Low regrets** – measures which work well in the majority of futures, have relatively low development and implementation costs and high benefits, and/or can be readily modified (and avoid locking in future choices).
- **Win-win** – measures that deliver a range of benefits to a range of stakeholders, mitigating the risk that future benefits will not be achieved.⁵

4.2.1 Promoting options with attractive adaptive attributes

The question list in Figure 4.1 is designed to help identify low or no regrets measures, or measures that deliver multiple benefits regardless of future change.

⁵ Derived from UK CIP (undated) AdOpt tool.

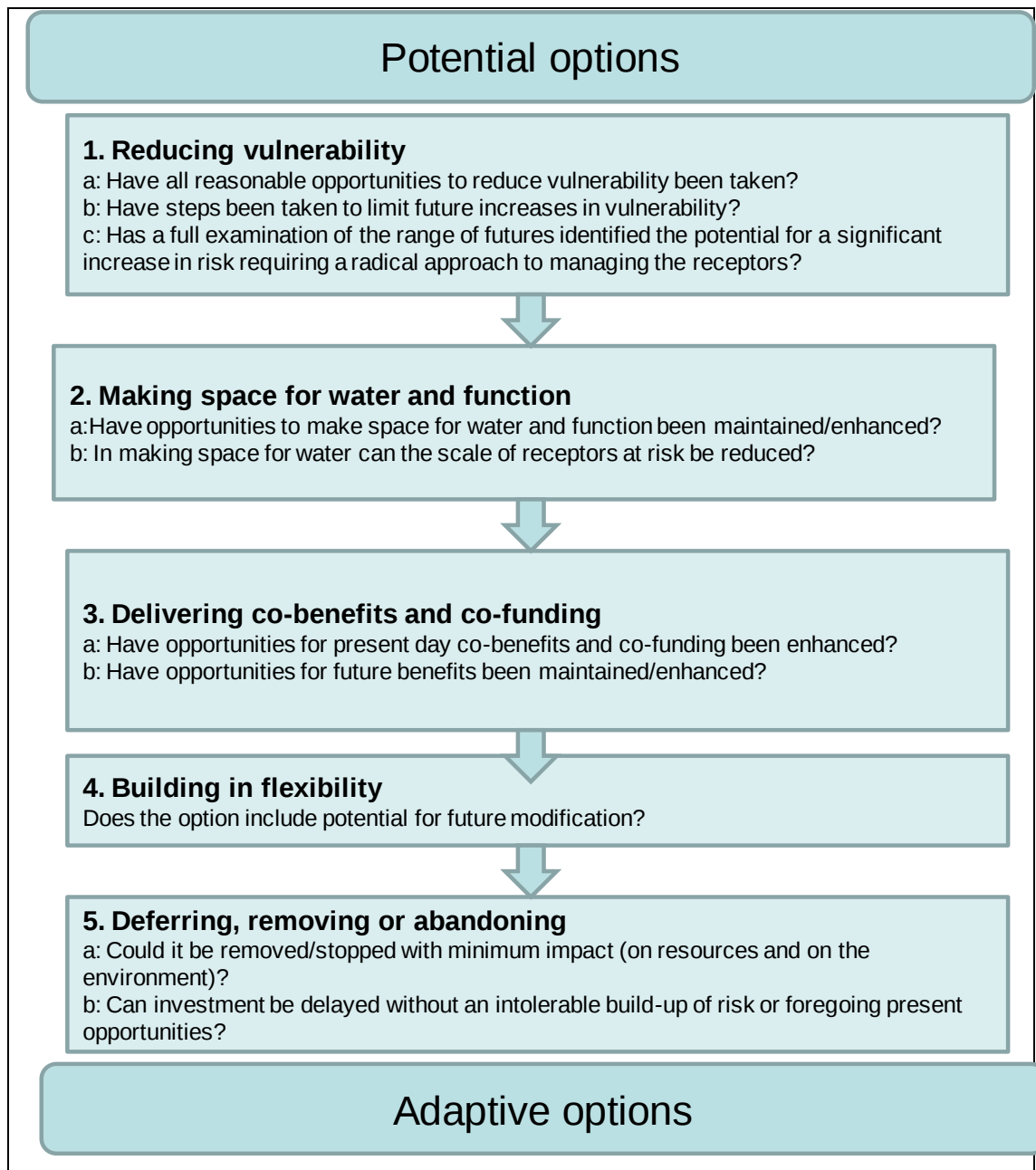


Figure 4.1 Considerations to enable the development of adaptive options

The list of questions in Figure 4.1 is intended to highlight the following attributes:

- 1. Reducing vulnerability** – reducing the consequences should a flood occur is usually preferable to managing the probability of flooding through structural interventions in the pathway or indeed the source of the flood waters. Similarly, reducing the consequences of flood erosion is often considered in SMPs. Actions taken to reduce vulnerability through improved preparedness, warning and evacuation are typical non-structural responses that can easily be modified or involve minor structural responses that are easily changed or moved. A focus on reducing vulnerability is promoted as it is (typically) more adaptable than efforts devoted towards reducing probability. Lowering the vulnerability of an area by changing the land use is highly effective, although should be considered carefully. In addition, options should be taken to ensure that future vulnerability is not increased.

2. **Making space for water and function** – options that contribute additional, or do not restrict, space for water and function are more likely to perform well under different futures than those that do not. Such options can contribute additional space either at source (through source control) or throughout the pathway (set back, defence lines, preferential flood routes, wetland re-creation etc). They radically reduce the vulnerability of the receptors previously at risk.
3. **Delivering co-benefits and co-funding** – alternatives that draw on multiple sources of funding tend to have been developed by partnerships of stakeholders. This enables a natural integration of FCERM within the broader goals of planning and ecosystem services and the associated assurance that at least some benefits will continue to be delivered ‘no matter what happens’. These types of schemes will tend to look at wider agendas and will facilitate discussions concerning solutions that are changing the status quo. This is likely to result in the introduction of adaptive options that are in alignment with the wider aims of the area.
4. **Building in flexibility** – alternatives that enable future modifications or decisions to be implemented more readily within minimum resources and impact (social, financial and ecosystem) characterise adaptability. For example, land banking for future defences, foundation strengthening or widening for future crest raising etc. By proactively developing staged approaches, decision makers are better able to respond to future change. Effective and flexible modification is often supported by implementing measures in smaller, more frequent increments, than traditionally is the case. An example is roll back or beach nourishment (i.e. to maintain the higher foreshore level) as opposed to defence height increases to maintain the overtopping performance of sea defences.
5. **Deferring/removing or abandoning** – alternatives that can be either deferred until later or removed, if structural, or stopped, if non-structural, with minimum disruption and impact (social, financial and environmental).

4.2.2 Short listing and developing options

It is important that early screening and development to refine the list of options does not remove adaptive options prematurely. In addition to the usual option screening approach set out in FCERM AG, there should be an additional check for adaptive attributes using the list of questions set out in Figure 4.1.

In situations where assessing the relative adaptability of options on a quantitative basis is considered useful to aid discussion with stakeholders, a spreadsheet tool has been developed based on multi-criteria decision analysis (MCDA). This quantitative approach provides a graphical presentation of the relative merits of all options, within the context of a range of potential alternative futures.

4.2.3 Examples of adaptive options

Tables 4.1 and 4.2 provide lists of possible adaptive options that could be adopted under a range of circumstances and in a range of locations. The lists are not intended to be exhaustive but provide some suggestions illustrating how adaptation can be implemented.

Table 4.1 Examples of adaptive options for coastal situations

Structural	Non-structural
Plans	
Some hard defences may need to be sustained in the short term to 'buy the time' required to prepare communities for policies which may lead to a required change in land use. For example, there could be the case for continuing to maintain and repair defences for 5 to 10 years while preparing communities for and developing policies of managed realignment or active intervention. Soft engineering provides tangible protection to coastal communities by adapting to and supplementing natural processes while providing wider benefits such as enhanced habitats, better aesthetics and improved ecosystem services.	Develop and deliver a tiered, enhanced support package for communities to adapt to coastal change informed by existing successful adaptation measures, broader plans (e.g. SMP) and coastal change adaptation strategies (e.g. community strategy, local plan core strategy). Development of local partnerships to develop options and plans for change, including studies to gather historical, economic, visitor and landscape information to inform consideration of options. Information measures (e.g. warning, awareness raising etc.) are all important, help improve preparedness and resilience and reduce vulnerability. Community-level adaptation supported by the move towards localism. Community-focused schemes will help raise awareness, thus increasing preparedness, and ensure that community-based operations are implemented etc.
Projects	
Building the potential for future adaptation into new flood defences (e.g. building foundations that are larger than required for the current height of the defence enabling heightening in the future if required). Even where structures are built, it may be possible to include a degree of adaptation by limiting the standard of protection and/or the design life. For example, a lower quality structural solution might involve placing a limited amount of rock armouring at the base of an eroding cliff to reduce, but not prevent, its recession. In flood risk areas, similar approaches might involve designing an earth embankment with a limited standard of protection. Such solutions could be used to allow a local community more time to adapt and find a long-term solution. Another example could be use of rock in preference to concrete for beach management groynes or erosion protection revetments where the uncertainties are unresolved. The rock can be reused at a different location depending on how the shoreline processes evolve.	Deliver practical support to facilitate relocation for those at risk – for example, through discussions with utilities and other service providers and identification of possible sites for relocation. Increase awareness of erosion/flooding processes by, for example, installing a viewing platform so that local people can see coastal erosion processes in action.

Table 4.2 Examples of adaptive options for fluvial situations

Structural	Non-structural
Plans	
The provision of land drainage assets is refocused on protecting property but supporting a no regrets outcome, whereby permanent change of agricultural land use does not occur.	Establishment of local partnerships to develop options and plans for change, including studies to gather historical, economic, visitor and landscape information to inform consideration of options.
Projects	
Building the potential for future adaptation into new flood defences (e.g. building foundations that are larger than required for the current height of the defence, enabling heightening or widening in the future if required). Where structures are built, it may be possible to include a degree of adaptation by limiting the standard of protection and/or the design life to suit the planned lowering of the vulnerability of the receptors that are currently protected. Ensuring an overland flow path as a high level 'what if' solution to a fixed asset such as a culvert, pumping station or flood defence should the uncertainties be realised. For example, reducing the cost of replacing and increasing the height of an earth embankment along its total length by concentrating the risk at one location where it can be managed effectively (i.e. planned overflow that can be altered depending on performance).	Design for exceedance principles have been established for over a decade, and integration of that approach in multi-functional projects is a key non-structural response to uncertainty. For example, ensuring green infrastructure provision ties in with flood management schemes where an overflow route is used to manage the uncertainties in performance and climatic conditions. Adoption of resilience measures and emergency plans within new regenerated development within the flood cell to manage uncertainties in defence or surface water system performance and modelling uncertainties. Management of land planned for future FCERM management or to allow adaptation strategies to be applied.

5 Appraise the options

5.1 Overview

5.1.1 Rationale

The purpose of option appraisal is to enable shortlisted options to be evaluated in more detail and the preferred investment choices to be made. This appraisal is undertaken on a whole life basis, using discounting to calculate the present values when considering costs and benefits of these options.

The guidance presented below uses a decision tree approach to represent the range of future choices and then considers external uncertainties by appraising the performance of **each decision pathway through the tree** for alternative futures (Figure 5.1). The approach set out below is straightforward in principle, but from experience of undertaking the case studies can prove to be complex in practice. A proportionate approach is recommended relating to the complexity of the problem or opportunity being addressed and degree of uncertainty faced.

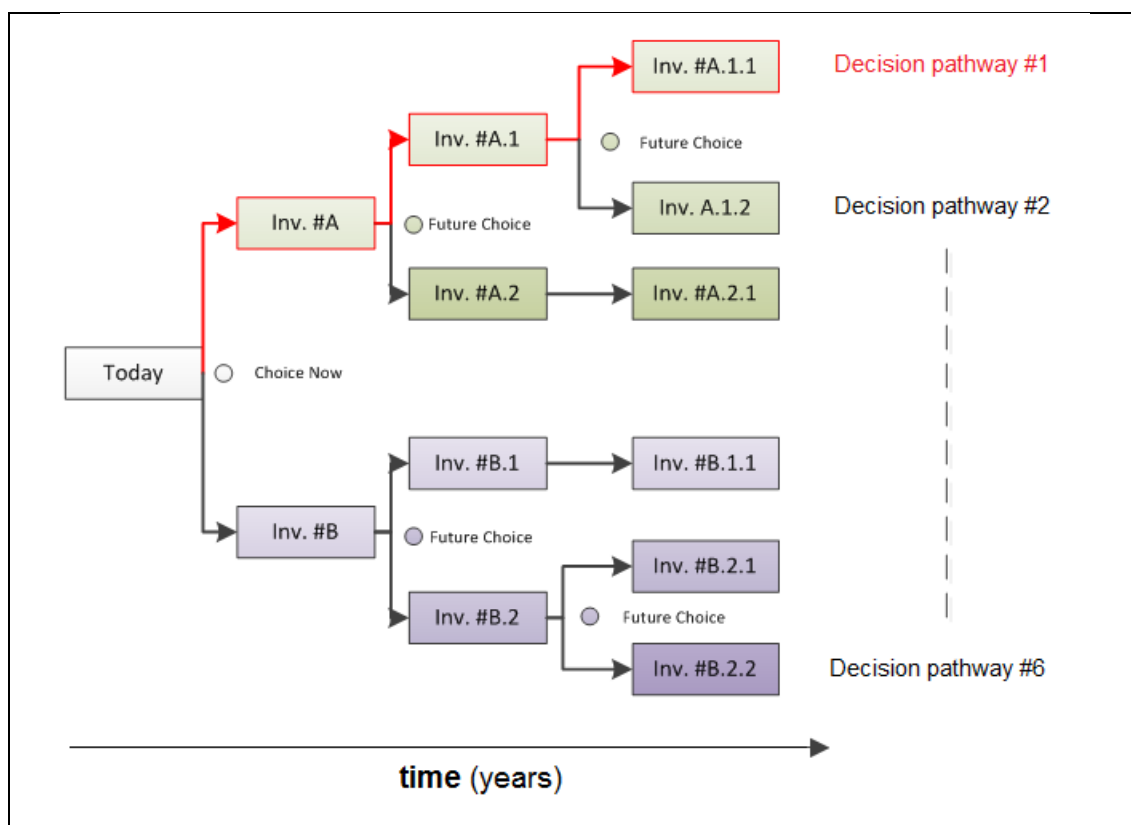


Figure 5.1 Illustrative decision tree representing six decision pathways and the associated choices that the FCERM manager may make, both now and in the future

Decision pathways represent a key addition to the existing FCERM AG. Costs and benefits for each option are still evaluated as in existing guidance and entered as an annual stream of values into FCERM spreadsheets to generate net present values (NPVs). However, additional performance measures are introduced to value the flexibility, robustness and opportunity lost through making particular decisions. The

decision tree analysis proposed here can, and should, be approached with a varying amount of rigour depending on the type of application being considered. It is suggested that the full method set out in the remainder of section 5 is particularly applicable and highly recommended for circumstances in which it is advantageous to build future flexibility into an investment plan.

5.1.2 Links to plan and project guidance

The FCERM AG states (p. 31) 'One approach that can be used to take account of future change, such as the effects of climate change, is called 'Real Options Analysis'. It is based on the use of decision trees to map out sequences of actions, decision points and events throughout the timescale of a project. Real Options Analysis is additional to the usual appraisal process as it requires the value of flexibility to be taken into account'. This approach is further elaborated in the HM Treasury Green Book (2003) and the climate change supporting document (HM Treasury/Defra 2009), but no complete and detailed method is laid out. The approach recommended in this Guide includes the key components of this approach and provides a measured step towards a full real option analysis (by explicitly accounting for future uncertainty and measuring flexibility).

The guidance supplements Chapter 7 'Describe, quantify and value costs and benefits' and Chapter 8 'Compare and select preferred option' in FCERM AG. The guidance presented in these chapters (on deriving costs and benefits, using loss-probability curves, applying discount rates, defining baselines) is highly relevant and should be used in conjunction with this Guide. The fundamental appraisal approach has not changed here but the Guide introduces performance measures to help evaluate flexibility about future choices in an uncertain future, which can be used to supplement the findings resulting from a standard appraisal.

5.1.3 Required inputs

The decision tree analysis requires information on:

- Future uncertainties described through autonomous futures, with associated weights where these have been derived.
- Investment costs associated with each of the shortlisted options.
- Investment timings associated with each of the shortlisted options.
- Benefits associated with each of the shortlisted options, evaluated with respect to each future uncertainty.

The background and scoping to derive this information should have been undertaken at the 'Define problems and opportunities' stage set out in section 2. It is important that the planning of any appraisal, especially one where managed adaptive approaches are being considered, involves the early identification of key (trigger) points on the decision tree via discussion with stakeholders.

5.1.4 Expected outcomes

Using this guide should assist FCERM practitioners in:

- appraising different options/pathways within decision trees;
- appraising multiple options under future uncertainty;

- evaluating and comparing options using performance measures to provide tangible evidence and promote decision making;
- measuring the adaptive capacity of multiple decision pathways.

The approach detailed here should ensure that full consideration is given to the potential adaptability of shortlisted options following full option appraisal to assist in the decision-making process.

5.2 Approach to decision tree analysis

5.2.1 Measures of performance

Performance metrics are required to evaluate quantitatively how well each branch of a decision tree will perform under future uncertainty. The following metrics are applicable whether or not the decision tree is being assessed using probabilistic weighting of the alternative futures:

- **Flexibility:** the number of future options that remain open following any investment choice (a measure of foreclosure).
- **Robustness:** the proportion of possible futures in which a given option has the highest performance.
- **Opportunity loss:** a measure of the potential benefits foreclosed by a choice, also known as **regret**, defined here by a comparison, in a given future, between the best outcome attainable from a chosen option and the best outcome attainable from any option.

For a choice between two options A and B, the opportunity loss associated with option A is $|\max(\mathbf{O}_A) - \max(\mathbf{O}_A, \mathbf{O}_B)|$, where $\mathbf{O}_A$ represents the set of outcomes that are available contingent on making choice A, expressed on an interval scale (e.g. NPV).

Conventionally, opportunity loss is expressed on an interval scale. However for outcomes expressed on a ratio scale (e.g. benefit cost ratio or BCR), a corresponding factorial opportunity loss can be defined. The factorial opportunity loss associated with option A would be $\max(\mathbf{O}_A, \mathbf{O}_B) / \max(\mathbf{O}_A)$. For example, if the best BCR achievable from option A is 6 and the best BCR from option B is 8 then choosing A loses the opportunity to achieve an outcome that is $8/6 = 1.333$ times more cost effective.

When probability weights are available for alternative futures, it is possible to report a further metric:

- **Expected performance:** an average of the economic performance over all defined futures

Further explanation of these metrics is provided in the Evidence Report which supports this Guide.

5.3 Step by step example

Evaluation of the performance metrics is illustrated below using a simplified decision tree for a case where three autonomous futures have been defined. The data are hypothetical and for illustrative purposes. A standard discounted cash flow analysis is assumed, as per HM Treasury Green Book guidance and the FCERM AG (and so the figures represent hypothetical NPV calculations in this case). Benefits would be defined

as the risk avoided in terms of annual flood damages with respect to a baseline representing the conditions that would exist without the investment.

5.3.1 Evaluation of the tree with no weightings for alternative futures

In the decision tree presented in Figure 5.2, there are four available decision pathways before the practitioner has chosen to make either decision A or decision B, and the **flexibility** therefore equals 4. For either choice A or B, the flexibility reduces to 2.

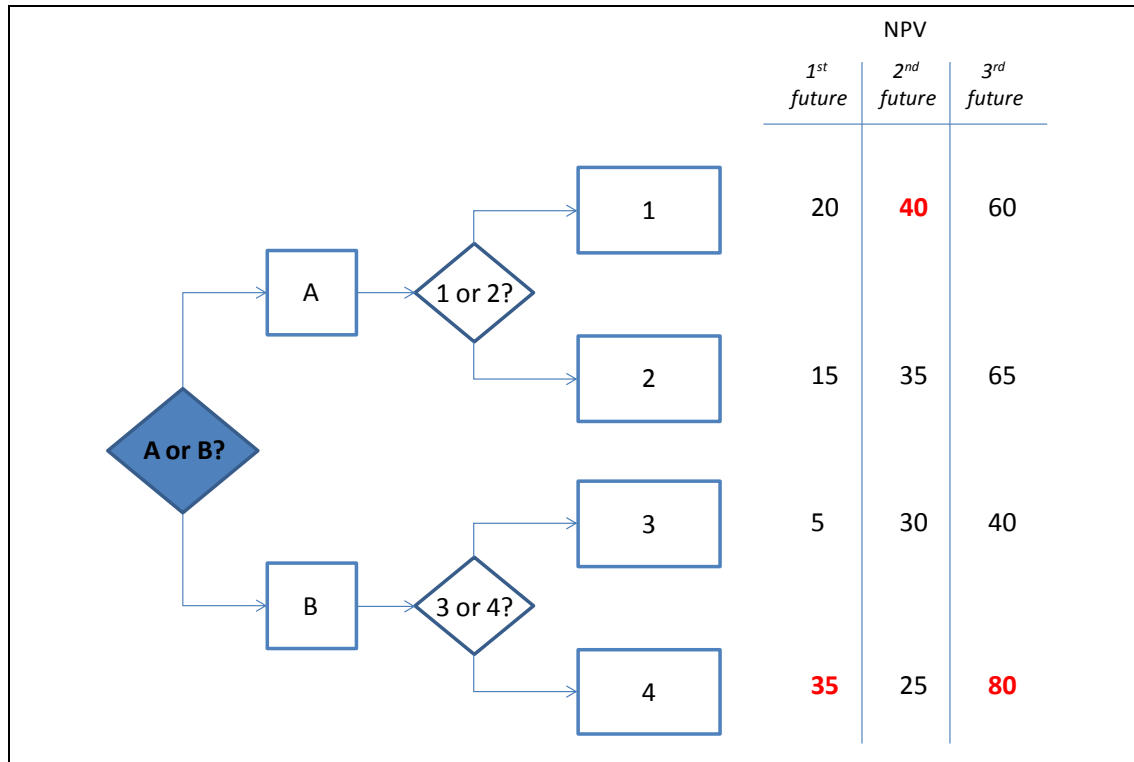


Figure 5.2 Example decision tree with example NPVs used to determine performance measures

In the example, the decision faced now is a choice between strategic options A and B. In each case, there are trigger points reached in future leading to a further decision. Because it is not known at present which future will materialise, each of the four possible sequences of choices (decision pathways through the tree) should be evaluated using costs and benefits. In this illustration, the outcomes are assumed to be expressed in terms of NPV. The best outcome performance for each future is shown in bold red text. This data can then be used to determine the metrics described above.

Robustness is evaluated by determining how well a given sequence of decisions would perform under each future. In this case, choice B offers the best performance in 2 out of 3 of the identified futures. Its robustness is therefore 2/3. The robustness of A is 1/3. Clearly option B would be preferred based on consideration of the robustness. However, should the second future be realised, both of the decision pathways available in B would be out-performed by both of the decision pathways available in A.

A regret table for choices A and B can be constructed (Table 5.1) assuming that by the time the future trigger points are reached, there will be enough additional knowledge available to ensure that the best available subsequent choice (1, 2, 3 or 4) will be taken.

Table 5.1 Regret table for options expressed in the decision tree assuming that future decisions will be taken so as to achieve the best possible outcome

	1st future	2nd future	3rd future
Option A	$35 - 20 = 15$	0	$80 - 65 = 15$
Option B	0	$40 - 30 = 10$	0

The largest regret that would result from making the initial investment choice B is therefore 10. This represents the maximum **lost opportunity** from choosing B now and hence being able subsequently to choose between the future options 3 and 4, but forgoing future options 1 and 2 (which are only available if we make the initial choice A).

5.3.2 Analysis assuming futures are weighted to reflect probabilistic information

Where the futures used to represent external uncertainties are weighted, then it is possible to consider the expected performance of decisions with respect to the range of uncertainty. The expected performance in this context is an average performance for a sequence of decisions over the range of futures. This implies the existence of some weighting on the futures, although if the simple arithmetic mean average is used then the weighting might have been explicitly articulated.

Continuing with the earlier example, if the three futures have been chosen so as to have equal weighting then the **expected performance** can be calculated as the mean performance over all three futures for each decision pathway, as shown in Table 5.2.

Table 5.2 Expected performance for each decision pathway

Initial choice	Outcome	Expected value (NPV)
A	1	40
A	2	38
B	3	25
B	4	47

If it were to be assumed that the decision maker's future choices are all equally likely, then a possible estimate for the expected performance of option A would be $E(O_A) = 0.5(40+38) = 39$ and, for option B, $E(O_B) = 0.5(25+47) = 36$. These results would suggest a slight preference for choosing option A. However, this analysis would clearly ignore the adaptive capacity associated with the flexibility to choose between alternative outcomes within either option A or option B.

Using the concept of regret, the value of this flexibility can be expressed by comparing the base expectation with the outcomes that could be attained under each future.

Given the flexibility to make future choices, decision makers could potentially improve on the expected value for option B (36 units) by 44 units, should the third future materialise (by choosing outcome 4, for which NPV = 80 units).

If option A were to be taken, then the best improvement available for any particular future would be only 26 units of value (again for the third future). The spreadsheet-based decision tree can be used to test whether choosing different weights for the futures leads to a different picture of adaptive performance.

The example analysis above can then be summarised as in Table 5.3.

Table 5.3 Summary of adaptive performance for example analysis

Performance of each option against adaptive attributes	Precautionary branch (A)	Adaptive branch (B)	Summary
Flexibility	4 available decision pathways, reducing to 2 in this branch	4 available decision pathways, reducing to 2 in this branch	Equal flexibility
Robustness	This branch only performs better in 1 out of 3 futures	This branch is robust in 2 out of the 3 futures	Branch B performs best
Opportunity loss	NPV index value of 15	NPV index value of 10	Minimax regret decision rule would also favour B
Expected performance (assuming equal weights)	NPV index value of 39	NPV index value of 36	Slight preference for branch A, but using concepts of regret, branch B has the greatest potential to improve
Commentary	Marginally better expected performance, but not significant enough to adopt measures in branch A	Robustness metric would be one of the clearer indicators that branch B measures should be included in the full appraisal guidance option	Branch B offers more adaptive attributes and should be considered in more detail

A more detailed worked example is provided in Box 5.1.

The decision tree analysis provides a simple representation of adaptive performance of choices and by inference the options chosen, that requires only small extensions of existing appraisal techniques.

Clearly these adaptive metrics need careful interpretation. The worked example in Box 5.1 provides further narrative for a more realistic case.

It is recommended that this analysis is undertaken in stages, with a reality check on the performance of options being undertaken first across just a few futures, before testing a larger suite of futures or expanding the number of branches and decision points on the tree. This analytical approach to demonstrate managed adaptive performance is heavily reliant on the analyst taking a step back from the previous option appraisal or preconceived demands of stakeholders to undertake an independent review of real strategic choices that are focused on the long term, and not the short-term needs of a flood or coastal cell.

Box 5.1: Worked example

Town X is a small market town located in England. It has a population of around 5,000. The River C, a tributary of the River B, flows through the centre of the town. Town X has a history of flooding, the most notable recent events occurring when nearly 200 homes were flooded in both 2005 and 2009. The existing flood defences, constructed in the 1980s, are not able to provide the necessary standard of protection (SoP) to new properties that have since been constructed in the town. A new flood defence scheme is therefore required.

Definition of futures

Seven futures have been identified in this example (see Table 5.4). They are a function of climate change, economic change and habitat change. It is assumed for illustration that each future can be weighted (equally in this case), but note that this is merely a basis to explore sensitivity to the weighting.

Habitat change represents the future arrival of a protected species at the reach of river, with the implication that any future action involving works within the river (in this case further raising of flood defence walls) will suffer a penalty in terms of either increased costs or reduced benefits because of the environmental impacts.

Table 5.4

Future	Climate change (increased flow)	Economic value	Other	Weighting
1	Low	None		1/7
2	High	None		1/7
3	Low	+20%		1/7
4	High	+20%		1/7
5	Low	-20%		1/7
6	High	-20%		1/7
7	High	+20%	Protected habitat moves into local area	1/7

Economic change is assumed to occur linearly from 2008 (the initial investment) and reaches a minimum/maximum value (-20% or +20%) by 2025. This could be caused by an increase or decrease in population (and therefore housing development) within the flood cell between 2008 and 2025 (the stated regeneration period of the development plan), or a gradual increase in affluence of this market town, for example. No further economic change is observed after this point (this is a simplification for the sake of keeping this example straightforward). Climate change projections are evaluated at three distinct climate change points: 2025, 2055 and 2085. Between each of these points, the climate is assumed to change linearly (starting at the initial investment in 2008). The protected species is assumed to arrive in 2025.

Shortlisted options

The aim of the flood risk manager is to reduce the impact of flooding in the area being considered. This area (the flood cell) is highlighted orange in Figure 5.3. Three principal measures have been shortlisted that are anticipated to meet the desired aim over the duration of the appraisal period:

1. Raising the existing wall on the south bank of the river (both now and in the future) to protect all properties in the flood cell.
2. Installation of property level protection (PLP) to provide protection up to a height of 0.5 metres at all properties in the flood cell.
3. Construction of a bypass channel to remove all flooding at all properties in the flood cell.

These three measures are shown spatially in Figure 5.3.

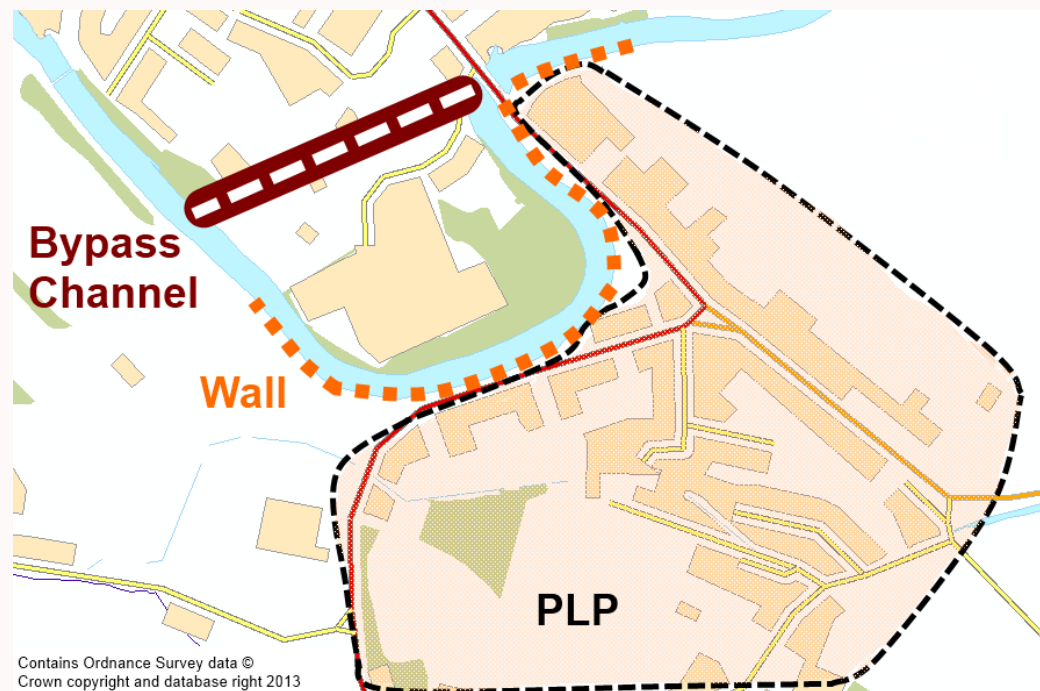


Figure 5.3 – Case study plan

A decision tree is constructed that consists of four decision pathways and six options (combinations of measures), shown in Figure 5.4. Capital investments, maintenance costs and investment timings are also summarised on this diagram.

The upper routes – replacing the wall and strengthening the foundations – (routes labelled A1 and A2 in blue) involve large upfront costs. These represent a precautionary (or reactive) approach, where investments are ‘locked-in’ early in the appraisal period. The lower routes – installing PLP and maintaining the existing wall – (routes labelled B1 and B2 in orange) involve small upfront costs and larger future costs. However, the benefits are suitably lower due to the limited performance of PLP in the more extreme events. These represent a more adaptive approach, where larger investments are deferred to later in the appraisal period.

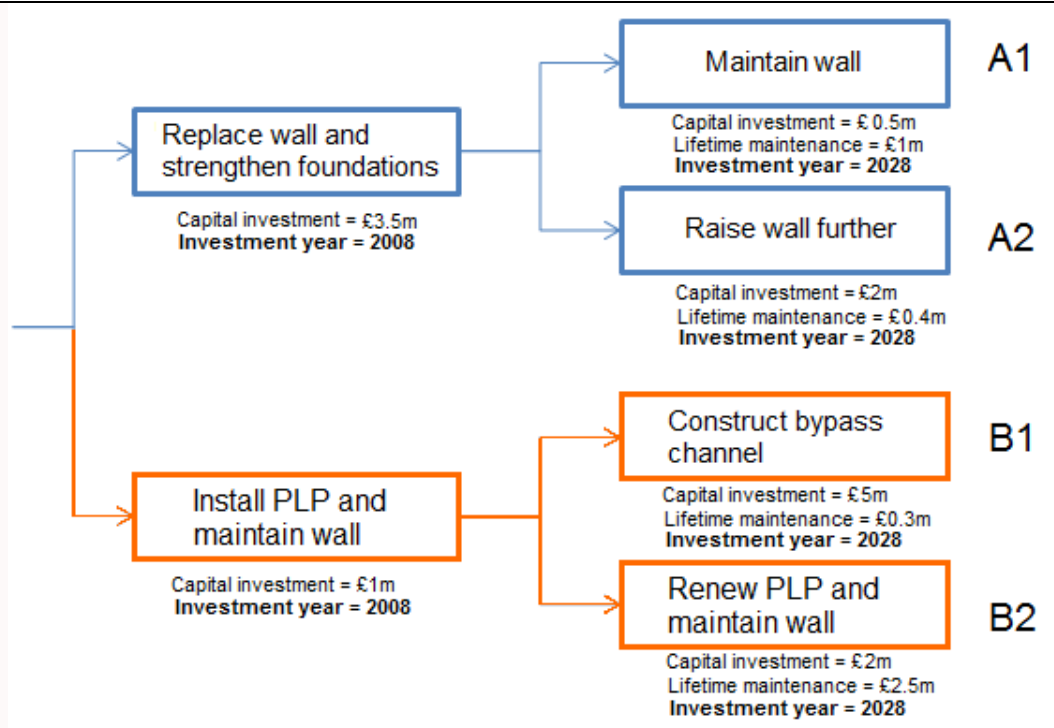


Figure 5.4 – Case study decision tree

Hydraulic model data was used to determine the economic damages associated with each of the proposed decision pathways, and a baseline was calculated in order to determine the benefits associated with each decision pathway. Further guidance on determining the baseline, costs and benefits is provided in Chapter 5 ('Type of project and baseline') and Chapter 7 ('Describe, quantify and value costs and benefits') of the FCERM AG.

Performance measures

The NPV was calculated for each of the decision pathways outlined in Figure 5.4 using standard discounted cash flow analysis, as per FCERM AG and HM Treasury Green Book guidance. The intention is to determine the **flexibility, robustness, opportunity lost** and **expected performance** for the tree, to help inform which decision pathway(s) should be taken forward to a fuller appraisal.

Table 5.5 presents the NPV (in millions of pounds) calculated for each decision pathway under each future, as well as the expected performance of each decision pathway. Values in bold represent the highest NPV that is predicted to occur under each future across all decision pathways.

Table 5.5

Future	1	2	3	4	5	6	7	
Weight	1/7	1/7	1/7	1/7	1/7	1/7	1/7	
Decision pathway								Expected performance (NPV)
A1	£14.36m	£13.00m	£17.16m	£15.53m	£11.56m	£10.48m	£14.51m	£13.80m
A2	£13.98m	£13.79m	£16.83m	£16.60m	£11.13m	£10.97m	£9.49m	£13.25m
B1	£14.43m	£13.88m	£17.22m	£16.56m	£11.64m	£11.19m	£15.37m	£14.33m
B2	£14.53m	£11.14m	£17.11m	£13.05m	£11.94m	£9.23m	£12.32m	£12.76m

The performance measures derived in this example have been determined by using a spreadsheet calculation that requires the inputs described in section 5.1.3.

Analysis without weighting

- i. **Flexibility.** Before the practitioner has chosen to make either decision A or decision B, there are four available decision pathways, and the flexibility therefore equals 4. Once either decision A or B has been taken, this flexibility will reduce to 2.

In this example, flexibility does not vary between the options and therefore is not assessed. However, if an example that involved multiple decision pathways was being considered (e.g. decision A might lead to 6 options becoming available, while decision B might lead to only 2 options becoming available) then flexibility could be used to better highlight the adaptive properties of a particular decision.

- ii. **Robustness** is evaluated by determining how well a given option performs under each of the 7 futures. In this case, option B produces the best performance in 6 out of the 7 possible futures. Its robustness is therefore 6/7.

This value is high, and implies that option B is robust and will perform well under future uncertainties. Within option B, there are four futures under which B1 is anticipated to perform better than other decision pathways and two under which B2 would perform better. Hence the robustness of making choice B now is contingent on the optionality inherent in the choice between B1 and B2.

- iii. **Lost opportunity.** The regret table for the initial options A and B is shown in Table 5.6 (in £m).

Table 5.6

	Futures						
Options	1	2	3	4	5	6	7
A	0.17	0.09	0.06	0.00	0.38	0.22	0.86
B	0.00	0.00	0.00	0.04	0.00	0.00	0.00

Should future 4 be realised, both of the decision pathways available in B would be out-performed by decision pathway A1. The maximum lost opportunity that will result from making the initial investment choice B (and hence being able subsequently to choose any decision pathway in B but forgoing any decision pathway in A) is therefore £0.04m (derived by subtracting the maximum value in branch A under future 4, £16.60m, from the maximum value in branch B under future 4, £16.56m). This value is very small, and further implies that choosing to invest in B now is a robust decision.

If, alternatively, the practitioner decided to make initial investment choice A then the maximum lost opportunity would be £0.86m (derived by subtracting the maximum value in branch B under future 7, £15.37m, from the maximum value in branch A under future 7, £14.51m). This is 20 times greater than the lost opportunity from making initial investment choice B and further demonstrates the robustness of choosing to invest in B now.

Analysis with weighting

Expected performance can be calculated as the average performance for each available decision pathway. In this case, the best outcome is £14.33m available in decision pathway B1 (install PLP and maintain wall now; and construct a bypass channel in the future).

If the future optionality in the tree is ignored, then the expected performance of option A is £13.53m and for option B it is £13.55m. There is little difference between these two figures, and on expected value alone it would be difficult to make an informed decision. However, it is clear from the consideration of robustness and opportunity loss above that option B is preferable – further demonstrating the merit of these metrics.

Since the weightings associated with the futures are ambiguous, it is necessary to consider sensitivity to changes in those weights. For example, stakeholder beliefs might consider that the emergence of protected habitat in the reach is unlikely but may wish to check whether the analysis would change if the third future (in which option A performs best) is given greater weight. The implications of this can be

tested by reducing the weight on the seventh future and redistributing this quantum onto the third future. This corresponds to asserting that the combination of high climate change, +20% economic change and emergence of a protected habitat in the reach is less plausible than the other futures, while low climate change and +20% economic change is given more emphasis than other futures. The result of this test is that the expected performance of option A increases to £14.16m while option B becomes £13.96m.

However, the robustness and opportunity loss analysis is not based on weighting and these metrics remain unchanged. Arguably the choice between options A and B remains finely balanced on grounds of NPV alone, but leans towards B on the basis of the non-probabilistic analysis.

Interpretation of results

If the decision maker chooses to invest now in decision B there will be 6 (out of a possible 7) futures in which the best expected performance or highest NPV will be realised. Furthermore, investing in decision pathway B will require relatively low 'locked-in' costs (less than a third of the costs incurred by investing in decision pathway A), and will delay making difficult decisions relating to the management of future uncertainty until a future time period. By doing so, adaptability is embedded into the decision-making process and future uncertainty is managed by waiting until better information becomes available.

There is only one future – future 4 (high climate change with +20% economic change) – in which neither of the options made available by investing now in decision B are predicted to result in the best expected performance. A2 (which involves a highly reactive process of raising defences multiple times) is the most economically valuable outcome under this future. However, it is not recommended that A2 is taken forward, given that option A is not robust (since it would only be preferred in 1 out of 7 futures), and generates considerable lost opportunity. These factors suggest that the adaptive capacity associated with option B is highly advantageous. It is instead suggested that decision pathways in option B are taken forward.

This example has demonstrated that:

- The adaptive capacity in multiple decision pathways can be explored through performance measures promoted in this guidance.
- Deferring large investments into the future and resisting reactive decision making is a policy that can be promoted through use of these performance measures.
- Finely balanced comparisons of economic performance can be augmented by information about robustness and opportunity loss contained within a decision tree.
- Expected economic performance can be sensitive to assumptions about probabilistic weights, but the non-probabilistic measures of robustness and opportunity loss can provide a useful alternative view.
- The approach taken here should ensure adaptability is properly considered and valued via appraisal enabling informed choices about whether or not to proceed with adaptive options.

6 Concluding comments

Understanding and managing future uncertainty is complex, and therefore developing the approaches to assess the value of responses to such uncertainty also requires a clear and structured approach. This Guide presents an approach which:

- Supplements existing appraisal guidance, such as FCERM AG. The Guide is intended to provide advice on how to take forward the approaches set out in the climate change supplementary advice to the Green Book and the Environment Agency's (2010c) climate change advice.
- Provides clear guidance on the degree to which an adaptive approach will be beneficial in different situations. Most benefits are likely to be achieved where significant change is likely and substantial uncertainty is faced. Where the situation is more certain and damages are smaller, such a full analysis is not necessarily required.
- Offers a measured step forward in illustrating how strategies can be expressed as decision trees and facilitating the development of multiple futures.
- Supports both probabilistic and non-probabilistic analysis. The Green Book supplementary guidance motivates practitioners to consider how to make the decision tree and how the real options analysis approach works in practice. A fully probabilistic analysis developing the Green Book advice remains challenging, hence the probabilistic and non-probabilistic analysis approach set out in section 5.
- Identifies situations where climate uncertainties (scenarios) can be given probability weightings based on (arguably) objective science and also deep uncertainties where this may not be appropriate.
- Improves the ability to value managed adaptive approaches in appraisal. This does not necessarily require complex analysis, but means that the realities of an uncertain future can be acknowledged and reflected in the appraisal process.

References

- de Bruijn et al. (2008) *Long term planning – robust strategic decision making in the face of gross uncertainty: tools and application to the Thames*. Floodsite Task 14, Report T14-08-01. Available at: http://www.floodsite.net/html/partner_area/project_docs/T14_08_01_FRM_Strategies_D14_1_V3_5_P46.pdf (accessed March 2013).
- DCLG (2012a) *National Planning Policy Framework*. Department for Communities and Local Government. Available at: <http://www.communities.gov.uk/planningandbuilding/planningsystem/planningpolicy/planningpolicyframework/> (accessed 10 August 2012).
- DCLG (2012b) *Technical guidance to the National Planning Policy Framework*. Department for Communities and Local Government. Available at: <http://www.communities.gov.uk/publications/planningandbuilding/nppftechnicalguidance> (accessed 10 August 2012).
- Defra (1999) *Flood and coastal defence project appraisal guidance: economic appraisal – FCDPAG3*. Available at: <http://archive.defra.gov.uk/environment/flooding/documents/policy/guidance/fcdpag/fcdpag3.pdf> (accessed 10 August 2012).
- Defra (2009a) *Appraisal of flood and coastal erosion risk management – a Defra policy statement*. Available at: <http://www.defra.gov.uk/publications/files/pb13278-erosion-manage-090619.pdf> (accessed 1 August 2012).
- Defra (2009b) *The appraisal of adaptation options in Flood and Coastal Erosion Risk Management – FD2617*. Available at: <http://evidence.environment-agency.gov.uk/FCERM/en/Default/HomeAndLeisure/Floods/WhatWereDoing/IntoTheFuture/ScienceProgramme/ResearchAndDevelopment/FCRM/Project.aspx?ProjectID=f4394a7b-5e9d-4572-88fe-b443f5af9888&PageID=424af8b1-26e4-446d-bc67-ce3a0952947b> (accessed March 2012 and 18 January 2013).
- Defra (2009c) *UK Climate Projections (UKCP09)*. Available at: <http://ukclimateprojections.defra.gov.uk/21678>.
- Defra (2010) *Surface water management plan guidance*. Available at: <http://www.defra.gov.uk/publications/files/pb13546-swmp-guidance-100319.pdf> (accessed 10 August 2012).
- Defra (2011) *Shoreline management plan guidance*. Available at: <http://www.defra.gov.uk/publications/2011/06/10/pb11726-shoreline-guidance/> (accessed 10 August 2012).
- Environment Agency (2004) *Catchment Flood Management Plans: Volume 1 Policy Guidance*. Environment Agency, Bristol.
- Environment Agency (2010a) *Flood and coastal erosion risk management appraisal guidance (FCERM-AG)*. Available at: <http://publications.environment-agency.gov.uk/PDF/GEHO0310BSDB-E-E.pdf> (accessed 1 August 2012).
- Environment Agency (2010b) *FCERM AG supporting guidance for appraisal summary tables*. Available at: <http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/geho0310bsdd-e-e.pdf> (accessed 10 October 2012).
- Environment Agency (2010c) *Adapting to climate change: advice for flood and coastal erosion risk management authorities*. Available at: <http://publications.environment-agency.gov.uk/PDF/GEHO0711BTZU-E-E.pdf> (accessed 10 August 2012).
- Environment Agency (2011) *Understanding the risks, empowering communities, building resilience: the national Flood and Coastal Erosion Risk Management Strategy for England*. Available at: <http://www.official->

documents.gov.uk/document/other/9780108510366/9780108510366.pdf (accessed 1 August 2012).

Environment Agency (2012) *TE2100 Plan*. Available at: http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/LIT7540_43858f.pdf (accessed 10 August 2012).

HM Treasury (2003) *The Green Book: appraisal and evaluation in central government*. Available at: http://www.hm-treasury.gov.uk/d/green_book_complete.pdf (accessed 1 August 2012).

HM Treasury/Defra (2009) *Accounting for the effects of climate change – supplementary Green Book guidance*. Available at: <http://archive.defra.gov.uk/environment/climate/documents/adaptation-guidance.pdf> (accessed 1 August 2012).

UK CIP (Climate Impacts Programme) (undated) *Identifying adaptation options*. Available at: http://www.ukcip.org.uk/wordpress/wp-content/PDFs/ID_Adapt_options.pdf (accessed 21 December 2012).

Glossary

Adaptability	Those characteristics of a FCERM plan that sustain and enhance the function of a system in the face of continuing change or uncertainty. Adaptability is about incorporating flexibility, not closing off future options prematurely but enabling evolution of the FCERM plan, and also the function of the system.
Adaptation	The ongoing adjustment in natural, engineered or human systems in response to actual or changing expectations in climate or other drivers of risk. Adaptation may be either autonomous (and achieved through natural change) or planned (and achieved through purposeful adaptation planning; replacing the reactive adaptation often seen in response to an extreme flood that has invariably been characteristic of traditional flood control approaches).
Adaptive capacity	The general ability of institutions, management systems and individuals to adjust to future change in order to take advantage of opportunities that arise and appropriately manage additional risks that are presented with minimum use of resources (social, financial and ecological).
Alternative, autonomous futures	Futures which are not purposefully influenced by flood risk management measures and related policy instruments and, as far as possible, are independent of one another.
Appraisal	The process of defining objectives, examining options and weighing up the costs, benefits, risks and uncertainties of those options before a decision is made.
Benefit cost ratio	An indicator, used in the formal discipline of cost-benefit analysis that attempts to summarise the overall value for money of a project or proposal. A BCR is the ratio of the benefits of a project or proposal, expressed in monetary terms, relative to its costs, also expressed in monetary terms. All benefits and costs should be expressed in discounted present values.
Decision pathway	A sequence of decisions that can be regarded as a 'unique route' through the options in a decision tree. A decision pathway is the result of applying a strategy in a given future.
Decision strategy	A set of rules which define how a portfolio of measures will be put together and how decisions will be taken in order to lead to a defined outcome.
Decision tree	A graph that sets out present and future options in a tree-like structure based on nodes (decisions) and branches (measures).
Decision tree analysis	A method of analysing the possible economic consequences of choosing a particular option, based on quantifiable performance measures.

Expected performance	An average of the economic performance of an option over all defined futures.
Flexibility	The ability of a given FCERM measure, option or plan to be changed as the reality of the future unfolds and/or projections of the future change.
Flood and Coastal Erosion Risk Management (FCERM) measure	Any physical construction (structural measure) to reduce the chance or severity of the flood waters reaching a receptor, or any measure not involving physical construction (non-structural measure) that uses knowledge, practice or agreement to reduce risks and impacts (in particular through policies and regulatory instruments, forecasting and warning, public awareness raising, training and education).
Flood and Coastal Erosion Risk Management (FCERM) option	An accepted set of measures and instruments that may be implemented from now into the future and seeks to achieve a given set of objectives. The preferred FCERM option(s), once selected, are then implemented through the FCERM plan.
Flood and Coastal Erosion Risk Management (FCERM) plan	A coherent plan(s) that set out goals, specific targets, decision points and the mix and performance of both structural and non-structural measures to be employed. Flood risk measures within the plan are then grouped into coherent packages (here termed FCERM option(s)) as the basis for further development and implementation (asset management, flood warning, development control etc).
Future scenario	Internally consistent verbal picture of a future phenomenon, sequence of events, or situation, based on certain assumptions and factors (variables) chosen by its creator. In this study we have used scenario to describe the future according to one variable (e.g. climate change projections). Alternative futures represent the future storylines that may result from a combination of scenarios (e.g. climate change and economic growth).
Future uncertainty	Conditions that may occur in the future, the exact scale, composition and impact of which are currently uncertain, such as climate change, economic growth and population change.
Investment plan	A single investment pathway with known costs and potential benefits – either fixed (no future intervention allowed) or flexible (intervention allowed).
Low regrets option	Adaptive measures which have relatively low associated costs and relatively large benefits, although these will primarily be realised under projected future climate change or the realisation of other future uncertainties.
Managed adaptive approaches	Flexible approaches that are capable of addressing future challenges and opportunities (which are currently uncertain or unknown) as they arise.

Managed realignment	This approach allows an area that was not previously exposed to flooding by the sea to become flooded by removing coastal protection. This process is usually in low-lying estuarine areas and almost always involves flooding of land that has at some point in the past been claimed from the sea.
Measures	Actions that can be taken to alleviate the impacts of flooding or coastal erosion (e.g. construction of a sea wall, development of a storage pond etc.).
Maximin	A decision method which seeks an option that has the best 'worst case' performance.
Minimax	A decision method which seeks an option that minimises the lost opportunity, or regret, should a worst case scenario materialise.
Net present value	The 'difference amount' between the sums of discounted: cash inflows and cash outflows. It compares the present value of money today to the present value of money in the future, taking inflation and returns into account.
Objectives	Specific goals that a particular project or plan is aiming to achieve.
Opportunity loss	A measure of the potential benefits foreclosed by a choice, also known as regret , defined here by a comparison, in a given future, between the best outcome attainable from a chosen option and the best outcome attainable from any option.
Option	A choice that is available at some time in the future.
Precautionary approach	Acting as early as possible to manage potential risks, where upfront costs are likely to be high.
Probability weight	A measure of belief that a particular future (climate or otherwise) is realistic.
Quality criteria	Criteria that will be used to assess whether the final outputs from the appraisal have achieved their goals and why those goals are important.
Resilience	The ability of an individual, community, city or nation to resist, absorb or recover from a shock (e.g. an extreme flood), and/or successfully adapt to adversity or a change in conditions (e.g. climate change, economy turn down) in a timely and efficient manner.
Robustness	The ability of a given FCERM measure, option or plan to perform adequately across a wide variety of possible futures.
Win-win option	Adaptive measures that have the desired result in terms of minimising the climate risks or exploiting potential opportunities, but also have additional social, environmental or economic benefits.

Abbreviations

AST	appraisal summary tables
BCR	benefit cost ratio
CEA	cost-effectiveness assessment
CFMP	Catchment Flow Management Plan
CCMA	Coastal Change Management Area
Defra	Department for the Environment, Food and Rural Affairs
FCERM	Flood and Coastal Erosion Risk Management
FCERM AG	Flood and Coastal Erosion Risk Management appraisal guidance
MCDA	multi-criteria decision analysis
NPPF	National Planning Policy Framework
NPV	net present value
PAR	project appraisal report
PLP	property level protection
RMA	Risk Management Authority
SoP	standard of protection
SMP	Shoreline Management Plan
SoS	standard of service
SWMP	Surface Water Management Plan
TE2100	Thames Estuary 2100 Plan
UK CIP	UK Climate Impacts Programme
UKCP09	UK climate projections

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