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Literature review on an adaptive approach to flood and coastal risk management

FRS19221

Flood and Coastal Erosion Risk Management Research and Development Programme

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Professor Doug Wilson Director, Research, Analysis and Evaluation

Executive summary

The Environment Agency's flood and coastal erosion risk management (FCERM) strategy for England sets out the vision for a nation resilient to flooding and coastal change. One of the strategy's core ambitions is to take a dynamic approach to risk management, known as an 'adaptive approach'. This project provides the evidence to better understand how adaptation pathways are used to help design and apply an adaptive approach to planning flood and coastal risk management activity.

The project has carried out a rapid evidence assessment (REA) of academic and nonacademic (grey) literature, supported by stakeholder engagement and expert insights, to explore various themes in relation to developing and applying adaptation pathways also referred to as adaptive pathways. It provides recommendations for applying best practice to adaptation pathways to inform evidence-based decision making.

Adaptive approaches are an emerging technique that risk management authorities (RMAs) can use to make decisions under uncertainty.

Taking an **adaptive approach** allows risk management authorities working with partners to better plan for and adapt to future climate risks. By considering climate change upfront, an adaptive approach enables practitioners and policy makers to plan to monitor and review how they are adapting to future flooding and coastal risks over time. Adaptive approaches should be proportionate and appropriate to particular places and circumstances, ranging from simple no regrets actions (e.g. avoiding inappropriate development in high flood risk zones or incorporating sustainable drainage into the design of new developments) to more complex activities (e.g. developing adaptive pathways plans to manage future flooding and coastal change over large geographies).

Adaptive pathways (also known as adaptation pathways¹) are a way of developing a long term climate adaptation plan for a place, often looking out to the end of the century (2100) or beyond. Adaptive pathways provide a range of actions that policy makers and practitioners can take for better anticipating and responding to a range of future possible climate scenarios. This includes preparing for 2 degrees global warming but planning for higher scenarios including 4 degrees warming. These pathways are linked to specific thresholds or 'tipping points' where a change to our understanding of the impacts of climate change, the local environment or other socio-economic conditions may require further adaptive action. Adaptive pathway plans need to be regularly monitored and evaluated so that they can remain agile to managing future risks over time. A world leading example of a live adaptive plan in action is the Thames Estuary 2100 Plan.

The REA details the current knowledge, enablers, barriers and best practices of adaptation pathways applied in risk management. Key findings are summarised as follows:

 Adaptation pathways are the most effective tool available for dealing with uncertainty and risk management over long-term planning horizons. The process increases collaboration, improves understanding of uncertainty and provides options for future response. They are an effective way of securing buy-in and commitment from local stakeholders.

¹ The term 'adaptive pathways' has been used in the national FCERM strategy for England. The term 'adaptation pathways' is more commonly used in published literature on the topic so has been used throughout this report.

- Success is increased by establishing adaptive approaches such as suitable governance procedures and getting commitment from stakeholders.
- Complexity of future uncertainty is the main barrier to implementing adaptation pathways. Adaptation pathways address this through flexibility, transparency, contingency planning and monitoring.
- Adaptive approaches to planning FCERM can range from simple to complex, according to resource availability and funding arrangements.

These findings have been highlighted in adaptation pathways that have been developed, implemented and reviewed across the world. The most developed examples of adaptive planning approaches are for large, national-scale infrastructure projects that focus particularly on flood risk management and rising sea levels, particularly the Thames Estuary 2100 Project and the Dutch Delta Programme. Results from both projects and developed plans highlight the importance of monitoring and stakeholder engagement to the success of adaptive plan projects.

Effective monitoring of adaptive plans is an underpinning principle of the approach and vital for their success. Following implementation of the preferred plan, the system conditions, triggers and indicators, and adaptive actions must be monitored. Challenges to the monitoring phase include lack of guidance, funding or confusion over responsibilities. It is suggested that these factors should be considered when developing the plan.

The literature on adaptation pathway projects highlights the particular importance of stakeholder engagement in changing behaviours and attitudes to dealing with risk over an uncertain future. Interviews and/or workshops/focus groups are the main techniques used to engage stakeholders. Key stakeholders should be identified at the start of the project and active engagement with them to gain their buy-in should be included within the plan development.

The success of adaptive planning approaches depends on budget availability, suitable governance procedures and technical knowledge. These factors apply to all adaptive plan projects from large-scale, national projects to smaller, local-scale adaptation pathway projects. Once these factors are in place, the details of a suitable approach can be determined.

Recommendations for policy makers to successfully implement adaptation pathways include providing:

- a clear, long-term strategic vision that supports adaptive planning, including governance procedures and financial backing
- appropriate guidance to help overcome funding and resources barriers

Recommendations for practitioners to implement adaptation pathways include:

- considering a range of future scenarios to increase trust from stakeholders, making sure the project is resilient, reduces concern about future climate, and supports investment (particularly in low-regret options that are quick to implement and have benefits are well evidenced)
- considering 'extreme scenarios (such as the high++ climate scenario²) in developing and implementing adaptation pathways, to manage uncertain risks

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 $^{^{2}\} https://www.theccc.org.uk/publication/met-office-for-the-asc-developing-h-climate-change-scenarios/$

- establishing clear baseline conditions at the outset to support future decision making and a periodic review (at least every 5 years)
- involving stakeholders frequently to consider future scenarios, better understand issues, share ideas and options and increase awareness of risk management
- developing detailed plans that define with clear roles and responsibilities, funding arrangements, monitoring, points when management options are reviewed ('tipping points'), and engagement plans, and that capture records of decisions made and justifications.

After reviewing barriers and enablers of adaptation pathways and considering local conditions, a number of environments that would suit adaptation pathways projects have been identified. These locations include coastal locations in rural and urban environments, owing to the chronic risk of increasing sea level rise over time. In contrast, the risk of surface flooding in inland environments tends to be more random in nature, and therefore more difficult to design and implement adaptation pathways.

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1 Overview

1.1 Project summary

The future is highly uncertain and presents significant challenges for risk management authorities (RMAs) seeking to address current and future flood risk within the UK. To mitigate these risks the Environment Agency has developed the national flood and coastal erosion risk management (FCERM) strategy (Environment Agency 2019a). This strategy sets out the strategic aims, roles and responsibilities, and funding arrangements for current and future flood and coastal erosion risk management in England. A strategic objective of the FCERM strategy is to apply adaptive approaches within national and local polices to improve the resilience of the nation to future flooding and coastal change. A core ambition of the strategy is to develop a national package of tools and guidance to help risk management authorities, people, businesses and public bodies identify the steps and decisions needed to take an 'adaptive approach' to planning for flood and coastal resilience.

Adaptive planning approaches aim to design and implement flexible and robust plans which can anticipate and effectively respond to uncertain future changes by combining low-regret, short-term actions (ones that are quick to implement and have benefits are well evidenced) with long-term options to adapt, if necessary. Developing flexible and robust adaptation pathways can be a key way of realising an adaptive approach to flood risk management in the UK. To enhance the FCERM Strategy, equip RMAs with the knowledge they need and make sure these objectives are achieved, the Environment Agency needs to better understand the enablers, barriers and limitations of using adaptation pathways to support the design of an adaptive plan. This project has carried out a rapid evidence assessment (REA) of academic and non-academic ('grey') literature, supported by stakeholder engagement and expert insights, to improve the Environment Agency's, researchers' and practitioners' understanding, knowledge and guidance on these and related issues.

This report describes the results of a systematic literature review and expert interviews discussing various themes in relation to developing and applying adaptation pathways in flood risk management. It provides recommendations for applying best practice to adaptation pathways to inform evidence-based decision making. The results of this project are intended to provide firm evidence to inform future policies. Ultimately, this will support more informed, evidence-based strategic planning and decision-making relating to flood and coastal erosion risk management across the UK given uncertainty about the future.

1.2 Report structure

- Section 2 describes the background of the study, including the purpose of the FCERM strategy in relation to flood risk management and adaptation planning. Adaptation pathways are introduced, including their purpose and approach to identifying, assessing and mitigating flood risk and climate change impacts while considering uncertainties about the future.
- Section 3 describes the methodology framework of the study, including details of the proposed approach that has been taken to deliver a systematic REA to assess all available information analysed as part of this study. This includes considering academic and 'grey' literature.

- Section 4Error! Reference source not found. introduces the concept of adaptation pathways.
- Section 5 presents the results of the REA and literature analyses, representing the current state of knowledge. The results are discussed in the context of different research themes, including the enablers and barriers of adaptation pathways, together with a comparison with conventional approaches applied in flood risk management.
- Section 6 presents a series of case studies on adaptation pathways, incorporating insights from interviews of experts involved in implementing these projects. These case studies supplement the main findings of the study, while drawing out similarities and differences of different adaptation pathways.
- Section 7 focuses on monitoring and evaluating adaptation pathway projects. Monitoring and evaluation are key requirements, allowing tipping points, critical thresholds (points when management options must be reviewed) and the effectiveness of different adaptation measures to be tracked.
- Section 8 discusses approaches, benefits and techniques for engaging stakeholders in developing adaptation pathways. Ongoing liaison and collaboration are key requirements of the FCERM strategy, and this is discussed in the context of the development and implementation of pathways.
- Section 9 draws together findings and highlights best practices that demonstrate how adaptation pathways can be implemented at different scales and contexts for all sources of flooding and a range of climate change future scenarios. This includes considering gaps in evidence on implementing adaptation pathways. It presents recommendations for policy makers and practitioners, while suggesting some potential locations for adaptation pathways in England.

2 Background

The Environment Agency has developed a national flood and coastal erosion risk management (FCERM) strategy – published in 2020. This strategy sets out the strategic aims, roles and responsibilities, and funding arrangements for flood and coastal erosion risk management in England. The FCERM strategy recognises that climate change represents a significant threat to the economy, the environment, and the health and wellbeing of people across the country. This is expected to get worse in the future due to an increased risk of flooding attributed to coastal and rainfall changes.

Defra has overall national responsibility for policy on FCERM in England. Risk management authorities (RMA) are responsible for managing risks from all water sources, including rivers and streams, reservoirs, the sea, eroding coastlines, surface water, groundwater and sewers. As they are often responsible for different water sources co-operation between these RMAs is particularly important. RMAs include:

- the Environment Agency
- · local flood authorities and regional flood and coastal committees
- district councils
- internal drainage boards
- highway authorities
- water and sewerage companies

The UK is expected to experience widespread flooding and coastal change in the future and RMAs have been very able and willing to adapt to and manage these risks, making significant progress in this area. However, they clearly need to adopt a different approach to respond more effectively to the future risks of climate change. The FCERM strategy sets a vision for '*climate resilient places*' that can manage and adapt to flooding and coastal change now and into the future. This vision will only be possible if local people and partners work together to implement strategies and solutions.

The FCERM strategy states that the country should be planning for a 2°C rise in global temperatures but be prepared for as much as 4°C. In order to meet these risks, significant investment will be required. The Environment Agency has suggested that annual investments in flooding and coastal change infrastructure of £1 billion will be needed over the next 50 years (Environment Agency 2019b). This will need to be spread across government, business and people by promoting sustainable management and greater collaboration, requiring new forms of investment and infrastructure delivery.

The FCERM strategy also calls for more dynamic approaches – 'adaptive approaches' - to flood and coastal risk management to be applied. These approaches are intended to respond to continually changing flood risk and coastal change. Adaptive approaches or adaptive planning approaches can provide a range of benefits (Figure 2.1). Benefits include providing space for greater collaboration with interested groups, opportunities to develop new and innovative funding and higher standards of protection for flooding and coastal infrastructure. The direct and indirect benefits are presented below:



Enables active collaboration with local communities and partners



Influencing long-term strategic spatial planning and resilient place-making



Unlocks relationships with partners to fund FCERM investment



Better data, modelling and monitoring of climate change impacts



Alignment of capital investment programmes with transport and utilities



Regular review to check the 'right pathway' is being followed

Figure 2.1 Potential benefits of adaptation pathways. Source: Environment Agency, 2019a

2.1 Adaptation pathways

Adaptation pathways are a new way of addressing uncertainty when making decisions about managing risk. This approach considers long-term planning horizons and uncertainty in future conditions from the start when making decisions. Adaptation pathways are increasingly recognised for their value in supporting *decision making under uncertainty*. They are broadly described as situations where there are a number of different possible outcomes and stakeholders cannot agree how likely they are to happen due to uncertain factors such as climate change.

It is increasingly recognised that decision-makers often face substantial uncertainty when trying to understand long-term conditions that have potential impacts on decisions or investments. This is particularly the case in flood risk management and investment in flood protection to mitigate potential current and future risks. Additionally, decisions that are made today often have a long lifespan and therefore need to be appropriate for future planning horizons to avoid over investment or inadequate protection due to a changing climate.

Adaptation pathways are sequences of potential actions that can be taken to anticipate climate threats, risks and opportunities, as well as other uncertainties like societal, growth and economic changes. These actions are linked to specific thresholds or tipping points where a change in circumstances (for example, higher sea levels or increased occurrences of flooding events) happens and further action is needed. Exploring and evaluating alternative adaptation pathways helps to identify low-regret, short-term actions (ones that are quick to implement and have benefits are well evidenced) and long-term options to adapt, if necessary. This provides a plan of activity for the future to help ensure decisions are resilient to a changing climate.

Adaptation pathways can take the form of 'decision trees' or 'route maps'. These illustrate the range of adaptation options, how they are sequenced over time and how these might be implemented as the future becomes clearer. Each decision within an adaptation pathway is triggered when conditions change or are likely to change as they

approach a threshold or tipping point, beyond which there could be an unacceptable level of risk or loss of performance of the system, and an alternative option is needed.

This approach identifies decisions that need to be taken over different timescales. Some of the actions may need to be taken in the short-term to address the challenges risk management authorities face. In other cases, options may not be needed now, and can be delayed into the future. Adaptation pathways are being increasingly used in flood risk management and other fields such as water resources, heat and natural resource management to diagnose, manage and respond to a changing environment.

The overall approach to creating an adaptive plan is set out in BS EN ISO 14090 Adaptation to Climate Change (ISO, 2019). This highlights that adaptation pathways can provide an effective approach for planning for climate change uncertainty. Following on from this, the British Standards Institution (BSI) is developing a draft BSI 8631:2020 'Decision-making for climate change – Adaptation pathways – Guide' (T. Reeder, personal communication, 2019). This is a generic guide that sets out a 9-step framework for developing an adaptive plan based on exploring adaptation pathways (Figure 2.2). It is intended to support the mainstreaming of adaptation pathways in policy and practice.



Figure 2.2 Steps to develop climate change adaptation pathways. Source: T. Reeder, personal communication, 2019

The guide sets out case studies and highlights that adaptation pathways can be developed using differing levels of analysis. Qualitative pathways and narrative development (Level 1) adaptation pathways can be very helpful in raising awareness with stakeholders and encouraging debate on possible actions that can be taken to address thresholds of future change. A more detailed, comprehensive full assessment of pathways (Level 3) requires more extensive model requirements but can be useful for large-scale or complex problems. Typically, more advanced forms of adaptation pathways will include cost benefit analysis of flexible measures (also known as 'real options') as well as specific trigger points that are carefully monitored. The range of approaches is reflected in the findings of the report (Figure 2.3).

Practical consideration for guidelines: Levels of Analysis



Figure 2.3 Levels of analysis that can be considered in adaptation pathways. Source: Personal communications Marjolijn Haasnoot and Tim Reeder

Monitoring indicators can observe trends and changes in the system to derive signals (for example, when a threshold is reached that indicates an adaptation tipping point may be reached soon). Signals could support decision making on additional research, implement follow-up actions in an adaptive plan, or make adjustments to the adaptation pathway. This approach allows RMAs to plan, prepare, prioritise and stagger investment in adaptation options while minimising the risks they face in an ever-changing world. Adaptation pathways account for uncertainty in the future by considering multiple possible future scenarios when initial decisions are made.

3 Methodology

This report describes a rapid evidence assessment (REA) carried out to assess current knowledge, enablers, barriers and best practices concerning adaptation pathways applied in risk management. The REA assesses published literature, providing comprehensive and robust evidence for researchers, practitioners and decision makers.

Several real and hypothetical case studies, focusing on flood and coastal erosion risk management, are included to demonstrate the potential for considering adaptation pathways. In particular, 4 case studies are highlighted in detail in section 6. These represent the most developed and established examples of adaptation pathways to date, drawing together findings from academic and non-academic literature.

The evidence from the literature review is further enhanced through targeted expert stakeholder interviews, to assess the benefits, enablers and limitations of adaptation pathways. Interviewees were chosen to seek expert insight from those involved in designing and implementing adaptation pathway projects as facilitators, policy decision makers and as local stakeholders and beneficiaries.

3.1 Rapid evidence assessment

The aim of the REA was to identify evidence of development and application of adaptation pathways. Full details of the REA methodology are available in Appendix A and are summarised in Figure 3.1. REA is a robust approach for evaluating relevant studies on a specific topic in a rigorous, systematic and repeatable way. It searches available literature for details and information focused around key research questions.



Figure 3.1 REA process used within this project. Source: Wood, 2020

The aim of the REA was to determine current knowledge on the implementation of adaptation pathways, understand gaps in evidence associated with the approach, and to learn from international and national case studies. Five primary research questions were developed:

- In what context do different adaptation pathway methods yield measurable outcomes which could support risk management authorities?
- What are the primary barriers, enablers and limitations of adaptation pathways applied to flood and coastal erosion risk management and other industrial sectors?
- How successful/transferable are different adaptation pathway approaches compared to conventional approaches and techniques?
- What monitoring and evaluation approaches and/or techniques are required to realise potential benefits of adaptation pathways?
- To what extent has stakeholder engagement been undertaken to support the development of adaptation pathway projects (project inception – research question and objective definition, project delivery – co-design workshops and integrated modelling, project close – peer review of the developed pathways) and what were the outcomes?

The results of the REA are presented in this report. They have been mainly focused on flooding and coastal erosion risk management, while also looking at lessons and insights from other sectors and adaptation pathways applied in a range of fields from forestry to urban planning.

3.2 Case study analysis

A key objective of this REA was to understand where adaptation pathways have been applied in different contexts. This would be used to help RMAs develop their capacity to produce and implement adaptive pathway plans contributing to climate resilient places. Based on this understanding, recommendations will be made for different types and situations where adaptation pathways should be applied and the benefits they can provide (see section 9.6).

The REA framework (see Appendix A) has been used to screen and search the literature for examples of real case studies where adaptation pathways have been applied. Given that adaptation pathways are a relatively new planning and risk management tool, hypothetical and experimental case studies have also been collected. These describe situations and planning decisions that lend themselves to adopting an adaptive approach to decision making.

3.3 Expert interviews and stakeholder engagement

The understanding and evidence collated from the literature review of adaptation pathways has been enhanced with targeted expert interviews. Experts representing a range of decision-makers, policymakers, practitioners and beneficiaries in adaptation pathway projects were selected.

A semi-structured interview approach (see Appendix B) was designed and used to capture insights from these experts. The views of those involved in the projects, lessons learned, and insight gained from previous projects has been captured within this report and recommendations.

4 What are adaptation pathways?

4.1 Adaptation pathways

Adaptive planning approaches and adaptation pathways are a reasonably established approach when dealing with long-term and uncertain changes attributed to climate change. The concept of adaptation pathways was first developed around 2005 through the TE2100 project and the start of the Delta Programme (Jeuken and Reeder 2011). Collaboration on the issue between London and New York followed soon after in 2007 (Reeder and Tarrant 2007). To date, adaptation pathways have been applied in a large number of countries across the world (Figure 4.1).



Figure 4.1 Application of adaptation pathways (Source: Project Team)

Adaptive planning approaches aim to anticipate and respond to future changes by considering decision making over time, including incremental and transformative adaptation, and integrating low-regret, short-term actions (ones that are quick to implement and have benefits are well evidenced) with long-term options to adapt, if necessary. Many studies exploring this type of policy are forward looking, exploring the ideal design of an adaptation pathway and how this could possibly tackle the challenges brought by climate change.

These approaches contrast with a precautionary approach that aims to identify a single significant action, and typically large investment that mitigates future risk throughout its lifetime. However, as a result of climate change and other uncertainties, the risk may increase in the future, making the single significant action with large investment less effective and not mitigate the risk. This can mean that the mitigation action delivers a level of mitigation for less time than planned (the 'functional lifetime' is shortened causing a 'risk mitigation deficit'), reducing the benefits and the return on investment. This can mean that other measures are needed to continue providing the level of mitigation earlier than planned (Figure 4.2). This could result in stranded assets, costly retrofitting or larger costs for implementation of alternatives (Haasnoot and others, 2019).

Adaptation pathways can show the functional lifetime of investments under multiple future scenarios. They can also show how dependent they are on future changes and how flexible they are to future alternatives.



Figure 4.2 Adaptive management versus precautionary approach. Source: Wood, 2020

4.1.1 Applying adaptation pathways in FCERM

Adaptation pathways can be applied to a wide range of climate risk management decisions (Ranger and others, 2013; Lenagan 2018). The literature has highlighted that adaptation pathways can be applied in different sectors and across a range of scales, entities and geographical areas. These span natural resource management, urban heat island effect, coastal risk management, river management, pavement design, airport infrastructure, forestry, water resources, technology development and medicine.

The same adaptive process can be applied to situations with a range of uncertainties such as climate change and lack of data availability. Adaptation pathways are considered to be better than conventional approaches, because they are so transferable (Ranger and others, 2013).

4.1.2 Approaches for adaptation pathways

Within the literature, approaches for adaptation pathways are typically presented as circular flowcharts, decision trees or route maps (Figure 4.3). These diagrams highlight the approach methodology, decisions taken and options available. Common to all diagrams is the importance of the review and repeating the process. The number of nodes (representing methodology steps, decision points or actions available) reflects the complexity of the different systems.



decision trees

Figure 4.3 Schematic diagrams showing the graphical techniques used to represent approaches to adaptation pathways. Source: Wood, 2020

The first step in the approach is to set objectives, assessing the vulnerabilities in the current situation and assessing future scenarios. In the most basic approach, only a limited number of future scenarios will be assessed, while more complex approaches will consider a range of future scenarios, including high-end estimates. The type of model used to assess future scenarios also varies in complexity from simple understanding of general trends to specific modelling results of individual situations. Additional actions taken in more complex cases include decisions on acceptable risk levels with stakeholders (Carstens and others, 2019) and carrying out portfolio appraisals and priority setting (Ramm and others, 2018a).

The next stage of the process considers different actions and evaluates these in terms of cost and effectiveness. It includes developing pathways and, in some cases, identifying triggers for monitoring. This stage of the process can be considered as a single step, while most cases split this into a number of decision points each requiring involvement with stakeholders (Ranger and others, 2013, Buurman and Babovic 2016).

The third general theme is selecting and implementing the preferred pathway. The adaptive plan should describe short-term actions and long-term options. Short-term actions are not only the first actions, but also preparatory actions to keep the long-term actions open. The plan should include an appropriate governance model to ensure long-term actions will be implemented at the appropriate time.

In the final stage, monitoring, evaluation and learning feed into an iterative process (Jeuken and others, 2015; Ranger and others, 2013). The final 2 steps of the process are strongly linked, and, in most available literature, they are grouped, as monitoring changes in conditions may affect the preferred pathway. The assessment and implementation of long-term options are vital as part of this monitoring phase.

The final phase of monitoring is required to ensure the objectives of the preferred possible pathways are being achieved. An iterative loop is therefore formed where any stage of the process may have to be re-evaluated as a result of changing variables or situations. A substantial change in circumstances or information requires the initial stages of the plan to also be re-evaluated (Figure 4.4).



Figure 4.4 Schematic diagram representing the common features of approaches taken to adaptation pathways presented in the literature. Source: Wood, 2020

The literature indicates that adaptation pathways like those described above can be incorporated into existing policy frameworks. For example, Mendoza and others (2018) present a framework to assess climate uncertainty within the existing policy context for resource management. The adaptation pathway approach is incorporated to improve flexibility when considering options and avoiding selecting and sticking with ('locking in to') one single strategy.

The complexity of the approach to adaptation pathways varies depending on the situation, risk and funding availability (Table 4.1). Several sources also discussed the potential for more complex approaches to adaptation pathways, which are applied in combination with other policy options such as real options analysis (ROA). ROA is an option appraisal technique which applies evaluation techniques that recognise uncertainty in capital budgeting decisions. Burrman and Babovic (2016) discuss the potential for ROA to enhance adaptation pathways, where instead of just comparing the costs and benefits of individual pathways, the economic value created by flexibility can be realised by using ROA (Figure 4.5).

This approach, combining adaptation pathways and ROA, is complimentary as uncertainty is quantified in ROA and then flexible policies to cope with the uncertainty are developed and guided by adaptation pathways (Burrman and Babovic 2016). In the context of water resource planning, Baker and others (2018) describe adaptation pathways to be used where the implementation of ROA is unfeasible or too costly.



Figure 4.5 Approach to ROA in adaptation pathways. Source: Buurman and Babovic, 2016

Dynamic adaptive policy pathways (DAPPs) are used to help policy makers develop adaptive strategies under deep uncertainty. The steps are the same as those outlined in Figure 4.6. Eisenhauer (2016) suggests that there may be synergy between DAPPs and socioeconomic pathways. For decision makers, socioeconomic pathways can provide relevant and useful information, while DAPPs can provide the methods and tools. In terms of closing the gap between climate knowledge and action, DAPP approaches could address usable and useful information in a framework that acknowledges nonlinear (inconsistent or unpredictable) change and uncertainty within real-world values and views.



Figure 4.6 Dynamic adaptive policy pathways. Source: Hasnoot and others, 2013

Stage of adaptive pathway approach	Simple approach	Complex approach
1. Framing of the problem, objective setting and scenario analysis	Some involvement of key stakeholders in framing the problem Shared objective defined by stakeholders in project aims Qualitative assessment of baseline Single future scenario considered	Large involvement of multiple stakeholders in framing the problem Governance framework developed Competing objectives from different stakeholders incorporated into project aims Quantitative assessment of baseline Multiple future scenario considered including a high-end scenario
2. Option appraisal, pathway development and identification of triggers	Consideration of a limited range of options Trigger points identified	Consideration of a wide range of options incorporating different stakeholder views on acceptable risk levels Trigger points identified, indicators selected and monitoring framework identified
3. Select preferred pathway and implementation	Preferred pathway developed Implementation in a single stage with key stakeholder involvement	Multiple pathways developed with preferred pathway identified based on advanced analysis such as real option analysis or cost-benefit analysis Implementation over a multi-year programme with involvement of multiple stakeholders
4. Monitoring, evaluation and learning phase	Longer review cycle of the actions Re-evaluation when drastic changes in conditions or circumstances	Shorter, more regular review cycles including review of the actions, decisions and approach taken Re-evaluation as required of the plan Re-evaluation when drastic changes in conditions or circumstances

Table 4.1 Key differences in simple and complex approaches applied to adaptation pathways. Source: Wood, 2020

5 Current knowledge

In exploring the main REA question "In what context do different adaptation pathway methods yield measurable outcomes which could support risk management authorities?" the authors have attempted to identify measurable outcomes and benefits of adopting adaptation pathways, and the benefits of including them within policy that could help RMAs meet their responsibilities.

5.1 Benefits

5.1.1 Long-term planning horizons

A key outcome of adaptation pathways is their effectiveness in keeping decision processes going forward, ensuring final approval of a long-term plan. In adaptation pathways decisions are not fixed but are flexible and can be changed over time to continue to achieve objectives as the future unfolds (Bloemen and others, 2018).

Adaptation pathways increase awareness of uncertainties, a key component when considering climate change policy. Therefore, this type of policy allows authorities to make sense of complex environmental dynamics and effectively use them in vulnerability assessment and adaptation planning. This is especially important when considering uncertain future scenarios such as those presented by potential impacts from climate change (Ramm and others, 2018b). Adaptation pathways can provide essential support to RMAs who are facing increasing pressure to ensure communities and places are sustainable.

In long-term planning horizons, there is considerable uncertainty relating to future outcomes. Adaptation pathways enable uncertainties to be addressed by decision makers and engineers by consistently adapting the system (Manocha and Babovic 2016; Brotchie and others, 2018).

In turn, this detailed understanding and consideration of uncertainty helps gain political support. It allows [political] leaders to keep long-term options open and modify their plans to better accommodate future conditions (Bloemen and others, 2018). Adaptation pathways help to implement options at the right time to achieve long-term coastal flood risk management objectives (Ramm, Watson and White 2018). Adaptation pathways are therefore able to influence long-term strategic planning and help to make places more resilient.

5.1.2 Cost effectiveness

Adaptation pathways have been shown to be cost-effective in many cases, with results showing that they can even improve economic efficiency when compared to single adaptation strategies (Haasnoot and others, 2013; de Ruig and others, 2019; Hall, Harvey and Manning 2019; Knott and others, 2019). In traditional planning, where risk mitigation options are explored, evaluated and a long term solution is implemented, the options are selected based on conditions and knowledge at the time. Exploring potential options and pathways to deliver them can highlight dependencies between actions and where efficiencies can be found (particularly in when action is taken). Options taken are flexible to react to changes in conditions (current and future) and knowledge which can lead to economic efficiency and assets that can have longer life times. Transfer costs (the costs of correcting options implemented to respond to changing circumstances) can be used for this. Transfer costs are determined by the

sequence and timing of investments, and therefore depend on the pathways and on how the future unfolds due to climate change and socio-economic conditions (Haasnoot and others, 2013).

One study of adaptation pathways in coastal mega cities (cities with over 10 million people) suggested that implementing adaptation pathways could potentially improve economic efficiency by up to 10% in net-present value, compared to implementing a single adaptation strategy (de Ruig and others, 2019).

Analysing multiple options means the most cost-efficient option and sequence of adaptation options can be selected. For example, in Los Angeles, a study demonstrated that high economic efficiency can be achieved through a pathway that first invested in beach nourishment (sediment lost through erosion is replaced from other sources) and flood proofing buildings before later switching to a pathway focused on hard engineering solutions such as dikes (de Ruig and others, 2019).

The adaptation pathway enables future management options to remain open while not requiring commitment at an early stage in the project (Environment Agency 2019a). Through frequent monitoring and review, the plan can be monitored as required in the future in response to changes in social, environmental and economic needs. This means that investments can be made incrementally, avoiding over or under investing for climate change (Gilroy and Jeuken 2018), therefore avoiding cost inefficiencies where long-term social and environmental outcomes of investment decisions are ignored (Nikkels and others, 2019).

5.1.3 Considering alternative pathways

Exploring alternative pathways opens the opportunities for making several iterative decisions over time rather than committing to one decision at a fixed time. Unravelling a plan into short-term actions and long-term options helps to overcome policy paralysis due to deep uncertainty (Haasnoot and others, 2019).

Haasnoot and others (2019) found that a key benefit of adaptation pathways is being able to consider different pathways and their long-term effectiveness. Ranking policy actions and pathways depends on future scenarios considered, such as the projected magnitude of climate change. Different pathways will perform differently given different rates of change in circumstances, different time horizons considered, and future conditions being realised.

Understanding these differences in detail means decision makers can prepare and select the most appropriate pathway based on their risk allowances. It also offers the ability to secure economic investment for different solutions across a wide range of climate scenarios, although this investment may not all be required at the outset of the project (Gilroy and Jeuken 2018).

Evaluation and assessment is a key part of all stages of adaptation pathways from the design to the monitoring stages. In this way, adaptation pathways provide a regular review to confirm the adaptation options being taken and ensure the benefits are realised.

5.1.4 Collaboration and improved understanding of risk

Stakeholders and local collaborators are key to the success of adaptation pathways. Often the local stakeholders have the power and tools to make the changes needed for the adaptation pathways to be effective.

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Involving stakeholders from the beginning has been common to many projects (see section 6). This collaborative process has increased opportunities to appreciate diversity between aims and objectives of different groups, learn from each other and past experiences of risk management, and identify different options for future pathways (Vervoort and others, 2014; Bardsley and others, 2018; Nikkels and others, 2019). All of this helps to create a more resilient adaptive plan that will be successful for all interested parties.

An additional benefit of collaborating with local communities and partners is transferring knowledge and greater understanding of uncertainties and the decision process (GHD and Trioss, 2018). Adaptation pathways, including facilitated discussions with stakeholders, has helped stakeholders better understand future scenarios and associated uncertainty (Magnan and Duvat 2018). This has helped to shift the perspective away from short-term, static planning and encouraged openness to long-term strategies (Bardsley et al 2018).

Furthermore, adaptation pathways have given local communities and residents a better understanding of the rationale for decision makers with regard to risk management (Magnan and Duvat 2018). This is critical when these decisions will have implications and possible constraints for local communities' lifestyle in terms of residential, leisure or economic habits, for example, those of coastal communities vulnerable to sea level rise (Magnan and Duvat 2018).

For successful collaboration with local communities and partners inclusiveness, commitment and transparency are essential to build the trust of stakeholders (Gell and others, 2019).

5.1.5 Environmental added benefits

Although the main objective of adaptation pathways projects is often to reduce the risk associated with one particular hazard, for example, sea level rise or river flood risk, the adaptation options can have significant added benefits. These include social, economic or environmental improvements. Ecological improvements in particular are suggested as a co-benefit of adaptation pathways (Hasnoot and others, 2019).

These co-benefits can be included in the analysis of different options and may have a substantial impact on the ranking and attractiveness of different pathways (Hasnoot and others, 2019). However, it can be challenging to quantify the value of these co-benefits, especially at the onset of a project (Hasnoot and others, 2019).

5.1.6 Key examples in risk management

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Major examples of successful approaches to adaptation pathways in Europe are the Thames Estuary 2100 project introduced in the United Kingdom as a long-term strategy for managing tidal flood risk (Penning-Rowsell and others, 2013) and the Dutch Delta Programme introduced to prevent flooding in the Netherlands (section 6). These two programmes have become the new standard for flood risk management in Europe. They involved a system-based approach, embracing experimentation and learning and involved multiple stakeholders. A key measurable outcome from the Dutch Delta Programme is mitigation from coastal erosion and the restoration and maintenance of a safe coast (Zandvoort and others, 2017).

5.2 Barriers, enablers and limitations of adaptation pathways

The Environment Agency requires an understanding of the barriers, enablers and limitations to implementing adaptation pathways. This information is vital to ensure there is buy-in from stakeholders and the approach is successfully implemented. The literature review considered the following primary question "What are the primary barriers, enablers and limitations of adaptation pathways applied to flood and coastal erosion risk management and other industrial sectors?"

Barriers and limitations are negative factors that affect design, implementation or the outcomes of adaptation pathways. Barriers are circumstances or obstacles that prevent progress, while limitations hinder progress but do not prevent the approach from being used. A large volume of evidence was identified regarding barriers and limitations of adaptation pathways.

In contrast, enablers are positive factors that contribute to making adaptive planning approaches using adaptation pathways possible.

5.2.1 Enablers

Identifying and quantifying uncertainty robustly

Identifying and separating sources of uncertainty is highly important in this type of approach. False representation of true uncertainty affects the quality of adaptation planning and decision making (Rosenzweig and Solecki 2014).

Timely detection of tipping points in situations with large natural variability is essential for the success of the approach (Bloemen and others, 2018). As such, models for running scenarios must balance model completeness, credibility, flexibility and calculation time (Walker, Haasnoot and Kwakkel 2013).

Using high emission scenarios was critical to stakeholder engagement in the Thames Estuary 2100 project. This conservative approach, including high-end projections was effective in persuading the Mayor of London that uncertainty was being thoroughly considered.

Appropriate governance arrangements for adaptive planning approaches

Having appropriate governance arrangements in place on adaptive planning approaches will be crucial to ensure successful and timely implementation and reassessment. Governance structures that define clear roles and responsibilities, encourage effective and integrated communications between different team members and operate on multiple levels within the organisation/government is critical (Butler and others, 2014; Zevenbergen and others, 2016).

Regulatory instruments have also been suggested as a method to increase success of adaptation pathways, especially over long-time horizons. Regulatory instruments could include urban planning arrangements such as land use regulations (Dulal 2017) or safeguarding principles for land that may be required for future adaptation options. Creating appropriate governance arrangements, regulatory instruments and a willingness to adapt from local communities will help implement timely adaptation policies (Ramm and others, 2018b).

The adaptation strategy requires periodic updates, or regular review, to incorporate the latest data, knowledge, uncertainties and observational values to support ongoing monitoring of the objectives, uncertainties, options, pathways, signposts and triggers. Ongoing political leadership and governance, especially with regard to monitoring systems, will enable adaptive process over long timeframes (Lawrence and others, 2019).

It is recognised in the evidence that institutional arrangements, policy and development patterns can constrain management options for the present day and the future. This approach encourages infrastructure 'lock-in', limits innovation and reinforces the status quo, leading to slow progress and high implementation costs (Gell, Reid and Wilby 2019). Ensuring that organisations are adaptable to future change can enable adaptation pathways to be implemented successfully. It is important they understand how existing policies and regulations may hinder or promote adaptation strategies and how this affects how viable they are (Arango-Aramburo and others, 2019).

Stakeholder engagement

Expert and stakeholder engagement is also key to successfully implementing adaptation pathways. This type of strategy requires a high amount of effort and engagement from a large number of participants and experts. Facilitated discussions between key stakeholders can create opportunities to appreciate diversity, learn from each other, and enable the identification of potential future pathways (Nikkels and others, 2019). It was found that social and human capital is crucial in responding to coastal issues, especially in cases where there are persistent and low levels of financial and built capital (Dulal 2017).

Within stakeholder engagement, inclusiveness, commitment, and transparency are essential for building trust and ownership of the process. This involves structured codesign of initial options, triggers, and performance indicators with participatory decision-making throughout. Stakeholders and experts should also be involved in the specification of measurable triggers for the monitoring period (Smith and others, 2013). Further information on the value of community engagement for adaptation to climate change is available (Environment Agency, 2019c).

5.2.2 Barriers and limitations

Managing uncertainty

One of the main barriers to adaptation pathways is understanding uncertainty around future projections. In particular, different types of uncertainty exist which all have an individual and compounding impact on adaptation pathways:

- epistemic uncertainty in the underlying modelling of a process, sometimes referred to as unknown-unknowns
- aleatory inherent uncertainty due to natural variability, sometimes referred to as known-unknowns

Uncertainty regarding future outcomes will limit any long-term planning approach, including adaptation pathways (Jeuken and others, 2015). When carrying out long-term planning a range of factors must be considered, all of which are associated with uncertainty, for example, demand requirements, urbanisation rates, socio-economic scenarios, climate change trajectories. Furthermore, there may be uncertainties

regarding the current baseline conditions resulting from a lack of data available (Ranger and others, 2013).

A major obstacle in applying adaptation pathways as an adaptive planning approach is accepting, understanding and managing uncertainty since not all uncertainties about the future can be reduced or eliminated. As such, this needs to be considered when making informed decisions, so that opportunities are not missed (Walker and others, 2013).

Four key elements of the adaptive pathway approach that help to manage uncertainty are:

- Flexibility: ensuring the pathways are flexible so that future decisionmakers can change actions based on changing conditions, therefore allowing the plan to cope with uncertainty (Hasnoot and others, 2019).
- Inserting contingency actions: where it is not possible to shift to an alternative pathway (for example, because of lag times), contingency actions help to maintain the preferred pathways, ensuring that objectives can be achieved.
- Transparency: consideration and treatment of uncertainty within the pathway design process should be transparent within the pathway approach to ensure future decision-makers are able to make informed decisions (Stephens and others, 2017).
- Monitoring: a dedicated phase of monitoring as part of the adaptive planning approach of adaptive pathways ensures that conditions and decisions are reviewed regularly reducing the chance of incorrect actions being taken.
- Monitoring: a dedicated phase of monitoring as part of the adaptive planning approach of adaptive pathways ensures that conditions and decisions are reviewed regularly reducing the chance of incorrect actions

Navigating complexity in designing adaptation pathways

Adaptation pathways require clear definition of objectives that are often set by a variety of participants and stakeholders. Defining and formulating objectives can be challenging as they must be specific enough to provide measurable outcomes but also general enough to be relevant to all participants involved. As such, the pathway approach can be highly complex with numerous different actions and thresholds, different drivers of these actions and the general system complexity of real-life planning situations (Carstens and others, 2019).

In addition, adaptation pathway implementation requires expertise in the field of the studied impacts which may not be feasible within the budget constraints of regular planning projects (Carstens and others, 2019). There is often lack of practical guidance on how to develop adaptation pathway plans, including identifying tipping and trigger points. This can represent a significant barrier particularly when the risk management authority does not have expertise or experience in developing adaptation plans, and using external personnel would increase the project costs.

Designing adaptation pathway approaches could be made easier by suitable guidance. Based on the experience and opinions of those involved in current adaptation pathway projects (see Appendix B), this would need to cover guidance on where adaptation pathways can be applied, governance procedures, ways to deal with uncertainty, scenarios to consider and monitoring indicators. Such guidance documents are being developed, including the BSI: 8631:2020 'Decision-making for climate change – Adaptation pathways – Guide' (T. Reeder, Personal communication, 2019).

Another approach to dealing with complexity in the design process is to focus on high level aspirations and objectives. In some cases, studies may keep objectives vague (for example, enough water supply). Actions could then be ranked and sequenced based on performance to achieve these high-level objectives. This was the approach taken in the Dutch Delta Programme which started with high-level national objectives.

Overcoming a traditional short-term focus around decision-making

Traditionally key decision-makers, like elected officials, have limited political will and/or funding to implement long-term adaptations (Dulal 2017). Climate impacts have often been considered a 'future problem' and are therefore not considered as a priority, reducing the effectiveness of adaptation pathways.

These problems might also be enhanced by instruments and analysis only considering short-term time horizons. For example, infrastructure assets are generally long-lived but most financial instruments used to cost them will only consider a time horizon of a few decades. There is therefore a mismatch between the financial and political horizon and operational lifetime which also represent significant barriers to this type of approach where long-term funding commitments are needed (Haasnoot and others, 2019).

Another barrier to adaptation pathways is the lack of human and institutional capacity for flexibility (Dulal 2017). Institutional path dependency and capacity constraints represent barriers to adaptation, as they restrict how readily practitioners may incorporate a long-term adaptation perspective into decision-making processes (Kingsborough and others, 2016). Current planning frameworks are designed to promote static and time-bound planning and legal instruments. There is limited possibility for enforcing future action in adaptation pathway plans and therefore evidence has found that professionals prefer static solutions as they involve a clearer commitment to action from the onset (Carstens and others, 2019).

To date RMAs have not shown significant progress in adapting to and managing flooding and coastal change risk, particularly in the context of the UK's capital flood defence programme. RMAs need to adopt a different approach to respond more effectively to the future risks of climate change. A systemic shift in approach to risk management would need to be supported by appropriate governance, guidance and funding for RMAs.

Securing wider institutional commitment and support

Another major barrier to adaptation pathways is the lack of commitment of regional and local authorities, non-governmental organisations (NGOs) and the private sector to climate adaptation from blueprint planning to adaptive plans (Bloemen and others, 2018). In part, this may be because these types of policies are introduced at a national or regional level, and implemented at a local level where there is no shared 'problem perception', and therefore barriers to implementing pathway approaches are caused through diversity in the opinions of people involved (Zandvoort and others, 2017).

Local government is more likely to have unclear responsibilities, limited financial capacity and technical expertise, face governance constraints and liability concerns about adaptation policies (Ramm, Watson and White 2018). With these constraints,

they may be more apprehensive to engage or initiate the adaptive planning approach of adaptation pathways.

Over the past year, many UK county councils, district councils and local authorities have declared climate emergencies. These declarations and the supporting actions taken by the councils increase the communication between different regional and local stakeholders and encourage long-term thinking. Adaptation pathways could offer a solution to addressing the climate emergency on a local level.

5.3 Comparison to conventional approaches

Risk management is defined as the identification, evaluation and minimisation of risks. Traditional approaches to flood risk and coastal erosion management are often responsive, dealing with risks that have become unacceptable or are likely to pass an imminent threshold. In comparison, adaptation pathways are anticipatory, attempting to understand and manage the risks in advance and creating highly tailored, specialised solutions that are unique to the context of the project.

Subsequent REA questions focused on understanding the differences between these different techniques by asking "how successful/transferable are different adaptation pathway approaches compared to conventional approaches and techniques?" Whilst adaptation pathways were present in the literature, few sources made direct comparisons between approaches to adaptation pathways and conventional approaches and techniques. This may be reflective of the early level of uptake of adaptation pathways as long-term progress and monitoring has not occurred. Conceptually, adaptation pathways are typically treated as an extension of established adaptation approaches such as adaptive management.

5.3.1 Comparisons between adaptation pathways and conventional approaches

Generally, conventional approaches include static planning, where a single fixed strategy is used for a predicted future. Static planning approaches, while effective in the short term in terms of mitigating risk, can result in assets being over engineered. For example, building a flood embankment to a 1:100 AEP standard may result in it being over engineered for the first ~50 years of operation (that is, upfront costs could potentially be saved until later). Static planning approaches may also prevent assets from being easily adapted and can limit the standard of protection provided if our understanding of hydrology or climate changes.

Static planning for a single 'most likely' future scenario is considered unlikely to work under the conditions of high uncertainty and change where the future may be different from the predicted scenario (Bosomworth and others, 2015). Adaptive planning approaches offer an alternative, preferable method that is flexible and allows for future uncertainty and change. As well as uncertainty over future conditions, adaptation pathways are preferable to static approaches in contexts where there is a long-term planning horizon and high flexibility of possible solutions (Figure 5.1).

A number of real-life case studies have found adaptation pathways to be beneficial compared to static approaches, including in airport infrastructure design (Kwakkel and others, 2012) and pavement design (Knott and others, 2019). Adaptation pathways were found to minimise cost and maximise performance. In contrast, static approaches, including those used in water management, were limited because they are unable to represent a wide range of future scenarios and are therefore more likely to fail if the future turns out to be different from the hypothesised future (Ranger and others, 2013).

These case studies highlight that where future trends and variables are difficult to predict, or a wide range of scenarios are possible, adaptive planning approaches would often be preferable to static approaches.



Figure 5.1 Factors affecting decision to use adaptive planning. Source: Brotchie and others, 2018 (Adapted from Wiseman and others, 2011 and Maier and others, 2016)

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6 Case studies

Adaptation pathways are a relatively new planning and risk management tool. However, a number of studies from across the world have been developed, implemented and, in some cases, reviewed. Globally, 2 main flagship projects in adaptation pathways are generally recognised; the Thames Estuary 2100 project and the Dutch Delta Programme, which were early adapters of the approach having been implemented since 2010.

These 2 case studies are described in detail in section 6.1 and section 6.2 respectively. Other case studies were identified in the REA literature as key projects that are considered best-practice examples of adaptation pathways application, river basin management in New Zealand (section 6.3), Australia resource management planning (section 6.4), and various urban and rural environments. These case studies are not as advanced as the previous two but have undergone multiple stages of the adaptive planning approach with adaptive pathways.

Insight provided by experts involved in the projects has also been incorporated in the case studies to enhance understanding.

These case studies are used to develop an understanding of where adaptive approaches have been applied in different contexts and are used to inform recommendations (Section 9.6).

6.1 Flood risk management in the Thames Estuary

The Thames Estuary 2100 (TE2100) (Figure 6.1) project pioneered using adaptation pathways to address uncertainty surrounding climate change impacts, mainly with respect to sea level rise. The project involved developing pathways and adaptation options for the Thames Estuary and its 15 million inhabitants, against a 1 in 1,000-year flood event.



Figure 6.1 Thames Estuary 2100 Project includes maintenance and review of the Thames Barrier. Source: Wikimedia Commons
Context

Established in 2002 by the Environment Agency, the TE2100 project aimed to develop a strategic flood risk management plan for London and the Thames Estuary through to the end of the 21st century. This multi-section, major infrastructure project was resource intensive, long-running and had government backing. The project captured existing ageing flood infrastructure defences within the region that were known to require upgrades in the future due to climate change.

General approach

Over the last 18 years, the TE2100 project has undergone a number of stages spanning the full cycle of the adaptive planning approach using adaptation pathways from design to implementation to review. These are described as:

- 1. The initial design stage from 2002 to 2012 involving 5 stages each aiming to answer a specific question to develop the plan (Environment Agency, 2012):
 - a. What is TE2100? setting the vision and objectives of the project
 - b. What are the problems? understanding flood risk within the Estuary and determining the baseline conditions and TE2100 policies
 - c. Solution development including developing options and selecting locations, considering local issues and consequences of actions taken bearing in mind uncertainty and supporting evidence
 - d. Identifying choices and partnerships deciding on the preferred pathway for implementation, identifying and building partnerships needed to achieve the plan's actions
 - e. Governance of the plan identifying who is responsible for what and when it needs to be implemented in an action plan that was published in 2012 (Environment Agency, 2012).
- 2. Implementation of the plan according to the plan with the support of key stakeholders.
- 3. 5-year review of the indicators identified within the action plan in 2016. This aimed to provide an early assessment of whether anything within the plan needed to be updated or amended. This found that the changes in the Estuary are generally taking place in line with the Plan's predictions and that the action plan remained appropriate (Environment Agency, 2016).
- 4. 10-year review of the action plan to be completed in 2022 and in the initial phases currently.

The start of the project involved a resource-intensive risk assessment assessing the existing levels of vulnerability and generating climate information in collaboration with the scientific community. Several future climate scenarios were developed, including high-end, plausible but unlikely, extreme projections. This ensured that planning considered multiple possible futures and took into account the full range of future uncertainty.

Thresholds causing unacceptable levels of risk were defined. These were fed into the monitoring procedures of the plan, identifying trigger points where action would be required. The results of this initial phase were detailed in the plan published in 2012.

Potential adaptation options were then developed and appraised. The option appraisal included determining cost-effectiveness and residual risk. Consideration was given to differing socio-economic scenarios and sensitivity analysis against the rate of change.

To allow for flexibility in the design, the timing and sequencing of adaptation options were considered. The preferred pathway map identified short-term modifications (including flood management from local measures), through to selectively raising defences when required, to eventual replacement of the barrier once a critical threshold of sea level rise is reached.

The approach has included developing new tools in collaboration with key academic stakeholders. Tools include the E-RISE tool which aims to improve early detection of sea-level rise to inform actions to upgrade or replace coastal flood defence infrastructure which often has a relatively long lead time (University of Southampton, 2020). These complex tools have been used to support the decision-making process and monitoring programme.

Stakeholder engagement

Support and ownership from key stakeholders (for example, Mayor of London, local authorities and councils) was critical to the success of this programme. Stakeholders provided knowledge (considering local factors), solutions (contributing different options), expertise and governance procedures (safeguarding land for future adaptation options). These factors were critical for the success of the project.

Stakeholders have included public organisations, local communities, councils, private sector developers and influential stakeholders. Due to the number of stakeholders because of the large project area, prioritisation of key stakeholders (specifically local councils with the authority to implement flood risk management strategies) was required to ensure that the critical stakeholders were involved in the project from the very start.

The findings have been embedded into key supporting strategies such as the London Plan (Mayor of London, 2016) and long-term national government spending plans (Defra, 2019). Local planning regulations developed by councils have safeguarded land for potential future adaptation options. Gaining this support was achieved at a local, regional and national level through ongoing engagement activities. The use of a wide range of scenarios was deemed important in gaining stakeholder trust and buy-in to the project.

Different techniques for stakeholder engagement have been used, including workshops, one-to-one discussions, briefing packs, presentations and public consultations.

Monitoring and review

A monitoring programme was set up on a 5-yearly basis. Key indicators such as relative sea level rise and peak surge tide levels were monitored, for plan evaluation (Environment Agency, 2016). An iterative process has begun in identifying monitoring indicators that would be useful to consider within the project but may not have been considered in the initial plan.

The first whole scale review of the TE2100 plan has begun and is due in 2022. The review considers what has changed in the Estuary, reviews the recommendations and actions of the plan, and considers the indicators and monitoring process.

Outcomes

TE2100 has helped in long-term planning. The plan has allowed decision processes to continue to evolve and provided a better understanding of uncertainties. The 5-year review of TE2100 found the action plan to be suitable given the changes in the Estuary, showing that the approach was robust and provided accurate results. It is expected to cost £3.3 billion to maintain and improve the flood risk management assets in the

Thames Estuary until 2050. This protects 1.3 million people and £275 billion worth of property from flooding.

Ongoing challenges

The baseline situation was not documented well enough at the implementation stage and needs to be clearly defined in all decision documents. There is a lack of awareness around the project, in part due to a reduction in stakeholder engagement in the early implementation phase.

Lessons learned

Better guidance is needed on how to identify and use monitoring indicators within the plan to support decisions on when to change to an alternative pathway, implementing different adaptation options.

The implementation stage of an adaptation pathway project should not be underestimated. The implementation process is ongoing and continuous, with actions often spaced out over a number of years. To ensure successful implementation, it is vital that the actions are carried out, monitoring is performed and stakeholder engagement is continued.

6.2 Flood risk management in the Dutch Delta Programme

This nationwide programme involves a variety of stakeholders in the long-term planning for flood risk management in the Netherlands. The programme has developed a set of coherent frameworks, standards and structuring choices to improve flood risk management, minimise water shortages and make the Netherlands more robust and prepared for future climate change and socio-economic conditions. These were used to develop regional route maps (Figure 6.2), representing potential adaptation pathways and preferred pathways to be implemented in the final adaptation plan (Figure 6.3).



Figure 6.2 Adaptation pathway route map for the Dutch Delta Programme. Bloemen and others, 2018

Context

Developed at a national scale, this major water management project provides a longterm risk management strategy for flood risk and fresh water supply. The strategic overview and context for this project is to provide a proactive, system-based approach to these issues given uncertainty in climatic and socio-economic future conditions. The Programme is split into 6 different regional strategies that cover different landscapes, from delta environments to coastal stretches to large lakes. The Delta Decisions provides a coherent framework for the whole region, although the preferred regional strategies have been developed specific to the unique local issues and adaptation options available. Funding has been secured until 2028 for this project.

General approach

The adaptive delta management (ADM) approach involved the following stages from design to implementation:

- 1. Objective setting: setting of strategic objectives which were defined as no flooding, meeting water quality targets and ensuring enough freshwater availability.
- 2. Pathways development on a regional and national scale: based on these objectives, and considering 4 different climate and socio-economic futures, several pathways were developed for national level strategies. The futures considered included high and medium climate change scenarios and consideration of socio-economic changes.

- 3. Specific pathways development on a local scale: these national, high-level pathways were used to generate regional, specific pathways with detailed adaptation options for national and regional water managers and water users. Consideration was given to tipping points and threshold values where portfolios of measures would no long be viable options such as when sea levels rose over a certain level. In most cases, portfolios of measures were sequenced in short, mid and long-term actions. Lead times required to implement actions, their efficiency, sell by date and cost were all considered in developing pathways.
- 4. Monitoring procedures consider both: a) evaluation of implementation and effectiveness of measures, and b) monitoring of signposts that can be used to implement or adjust pathways as more information becomes available.

Implementation: regional strategies were implemented and monitored around the Netherlands.

Stakeholder engagement

Stakeholders were involved in the project from national to regional to local levels. Stakeholders included national governments, provinces, municipalities, NGOs, academics, private sector and water boards. Engagement with this range of stakeholders was found to benefit the programme by considering an increased number of strategies. It also assessed the interlinking between short- term actions and longterm goals.

Monitoring and review

The regional strategies will be reviewed every 6 years. The government will carry out this monitoring in consultation with experts. Key decisions, assumptions and trigger points to cause adaptation are considered. In addition, a group of experts (called Signal Group) was set up to detect relevant climate change and socio-economic signals. They developed an approach and determined indicators to give timely, reliable and convincing signals that would trigger action (for example, research, adaptation decisions). Indicators include quantitative and qualitative signposts, observations and projections, as well as local monitoring stations and regional or global data. Data is mainly derived from the extensive monitoring programme that had been implemented in the Netherlands over the past 100 years, and used for a tailored analysis.

Outcomes

This project was successful in developing a national strategy for adaptation pathways in delta risk management. Short-term actions were linked to long-term goals, incorporating flexibility and different strategies to account for uncertainty in future projections. The visualisation of the adaptation pathways was found to be useful.

Ongoing challenges

The plan did not always clearly define values for indicators to show when thresholds/tipping points had been passed and new actions would be needed. Instead, it identified a short, mid-term to long-term portfolio of actions. Additionally, the approach to monitoring needs further development to ensure that detection of signals is timely and reliable enough for decision making.

Lessons learned

The importance of stakeholder engagement has been stressed as a way to develop new approaches to traditional problems, ensuring collaborative design and evaluating pathways. The implementation stage is vital in the plan and must be embedded in local and regional decisions with secure funding mechanisms in place.



Figure 6.3 Adaptation pathways maps as presented in the adaptive plan for fresh water supply in the Northern region and for flood risk management in the rivers (Delta Programme 2015).

The pathways maps show short-term actions, as well as long-term options under different scenarios. They present measures for national water managers, local water managers and water users (for example, agriculture), and research needed to make decisions.

6.3 River basin management in New Zealand

Much of New Zealand's urban areas are in coastal areas around harbours, estuaries, creeks and lowland rivers (Figure 6.4). National government advice is strongly supportive of using adaptation pathways in risk management of hazards such as coastal erosion, river flooding, sea-level rise and storm flooding. Increasingly, this approach has been used regionally around New Zealand where natural hazard management falls under the jurisdiction of local authorities.



Figure 6.4 Quantification of coastal flood risks around New Zealand. Bell and others, 2017

Context

There is strong regional governance in place, with support from the national government, for adaptation pathways (Bell and others, 2017). This guidance encourages the long-term adaptive planning approach of adaptation pathways in risk management and, since its publication, several projects have used adaptation pathways in risk management.

General approach

To design and implement adaptation pathways, 4 stages have been applied over a 4year period. This 4-stage process involved:

- 1. creating interest in the project and engaging stakeholders
- 2. building a knowledge phase aiming to increase awareness of the risk
- 3. considering future simulations and scenarios during workshops with stakeholders to test and identify different pathway approaches
- 4. implementation and uptake of adaptive planning approaches using adaptation pathways

Within these stages, hazards have been assessed and their uncertainties quantified through hazard mapping. Hazard scenario modelling has then been used to understand the complexity of the problem and possible decision pathways.

In line with national guidance, 4 climate change scenarios were considered within the New Zealand projects, ranging from a low/ net-zero scenario to an upper-end extreme scenario. The extreme scenario is primarily used for stress testing adaptation plans where the risk tolerance is low and/or future adaptation options are limited.

Stakeholder engagement

Stakeholders, including local government technical advisors, councillors, members of the community and indigenous people, have been engaged through a series of methods across New Zealand both nationally and regionally. Stakeholder engagement has been viewed as very important as there is a perception from communities that coastal margins will be maintained and managed such that they remain safe from natural coastal hazards.

Initial surveys were conducted on a national scale to determine views on coastal management. These were presented in the national guidance that is used in local projects to inform scoping.

On a regional level in the Hawke's Bay coastal adaptation study, an assessment panel including local community stakeholders was set up to conduct the assessment of actions and options for adaptation pathways. The mandate of the panel was to include public participation in the decision-making process (Britton and others, 2011).

In another regional project, considering flood risk management in the Hutt River catchment, workshops were run involving stakeholders to understand and access the different options and pathways available. These simulation workshops presented different climate scenarios and adaptation options to stakeholders. Stakeholder perspectives were all considered and included within the implementation plan.

Using a collaborative decision-making process involving the community has led to an increased understanding of changing risks over time. It has influenced stakeholder behaviour and perception changes, with increased awareness of the need to take early action to shift to new pathways as or when necessary.

Monitoring and review

Monitoring has been set on a 10-yearly basis although reviews will be carried out sooner if conditions or information changes. Monitoring indicators and their trigger points were identified as part of the development process. Communities have been involved with participant-science projects taking place to review indicators.

Outcomes

The major outcome of this project has been increased awareness, understanding and acceptance of the associated risks by local stakeholders. This increased understanding has led to perception shifts and support for adaptation pathways in risk management.

Through simulation games (serious gaming and role playing), local and national governments became familiar with the approach and its possibilities. This resulted in a group of people, across research, policy and decision-making agencies, advocating the approach. It helped to lay out the options for the long term and for developing policy on funding adaptation.

Ongoing challenges

A significant challenge to the approach involved shifting the short-term protectionbased planning context to a more long-term anticipatory approach. This was overcome by engaging with different stakeholders and working to increase awareness and understanding while incorporating different objectives into the overall project approach.

Lessons learned

Successful use of adaptation pathways relies on building trust in its use which is increased through a transparent process that involves stakeholders and improves their understanding. Monitoring systems are vital in the approach. Sharing learning globally will be useful in increasing the uptake of this application to risk management.

6.4 Natural resource management in Australia

In Australia, natural resource management organisations have been piloting adaptation pathways on a catchment scale to understand future risks and explore future adaptation options. The approach used has focused on understanding the baseline situation and vulnerability of the systems to fully determine the objectives of the project. Following this analysis, adaptation pathways were developed through workshops with key decision makers and stakeholders (Figure 6.5) to develop mitigation options.



Figure 6.5 Worksop process and relationships in the adaptation pathway approach for Australia resource management. Bosomworth and others, 2018

Context

Climate change will put increasing pressure on natural resource management organisations, especially from the impacts of extreme weather events (including droughts and wildfires). Adaptation pathways have been applied to a variety of systems, from freshwater systems to National Parks to river catchments to coastal areas.

Pilot projects have included land and water management by 2 catchment management authorities in Victoria: the Southern Slopes Cluster Climate Change Adaptation Research Partnership (SCARP) and the National Parks and Wildlife Services in New South Wales. These systems are often very complex, highly dynamic and represent interlined social and ecological drivers adding to the challenge for risk management authorities.

General approach

A 'problem-structuring' approach to adaptation pathways has been trialled. This approach focuses on firstly understanding the drivers of the system and different perspectives and viewpoints to determine the themes and objectives of the project. The next step of the approach is then to implement adaptation pathway solutions for future adaptation.

Within the piloted studies, 4 key steps have emerged:

- 1. Developing a detailed understanding of the current situation and baseline conditions.
- 2. Analysing possible futures.
- 3. Developing pathways and future adaptation options.
- 4. Monitoring, evaluating and learning.

These pilot programmes ran over 3 years and were developed through a series of stakeholder workshops at each stage.

Stakeholder engagement

Stakeholders were included in every stage of the decision-making process through a series of workshops. These workshops involved a variety of stakeholders, including local community members, business owners and decision makers. The workshop process ensured learning from past experiences of local risk management, historic events and local knowledge was transferred from the community to decision makers. Additionally, engagement was found to empower stakeholders with knowledge of the complexities of the uncertainty and encouraged a whole-system approach to adaptation.

Stakeholders and decision makers tended to focus on the worst-case scenario rather than assessing a suite of possible futures. This challenge was overcome through the workshop approach, which facilitated increased awareness and knowledge of the adaptive planning approach using adaptation pathways and ultimately lead to increased stakeholders' trust in the long-term adaptation pathway.

Monitoring and review

The final stage of the process within the pilot studies was the implementation, monitoring, evaluation, reporting, improvement and learning (MERIL) phase. It is recommended that this is designed from the onset such that the decision-making processes can consider suitable indicators and triggers to ensure the adaptation options are measurable, successful and suitable for long-term planning horizons. Transfer of learning between projects is seen as critically important to improve the iterative process.

Outcomes

These pilot studies provided learning for further application of adaptation pathways in Australia. Next steps are identified for the 2 pilot case studies to continue adaptation work, building on the project's work and developing citizen science projects. Research gaps were identified as areas for further research, including developing adaptation governance in natural resource management, developing scenario planning and increasing engagement beyond workshops.

Ongoing challenges

A foreseen challenge in extending this approach beyond the pilot projects is the governance of the process, especially in the implementation and MERIL phases. Suitable governance models are needed to enable implementation, which clearly incorporates long-term objectives and clearly identifies tipping points.

Lessons learned

The final stage of the pilot projects highlighted the iterative nature of an adaptation pathway project. It is recommended that this system is established at the onset of the project to increase flexibility and ensure continual learning and improvement in the pathway as conditions develop.

6.5 Applying adaptation pathways in urban environments for FCERM

The majority of the world's mega cities with significant populations are located in lowlying coastal areas. These cities, their infrastructure and communities are highly vulnerable to flooding from multiple sources, including sea level rise and coastal storms. The impacts of climate change are likely to exacerbate these risks in the near to long-term future. While the response of each city is unique to the governance, requirements and characteristics of the city, learning and understanding can often be transferred between different cities.

Within the literature there are details of several cities that are developing adaptation pathways to deal with these risks. Rapid urbanisation and social change mean that the future socio-economic context of these city environments is also highly uncertain and must be considered in the development of adaptation pathways.

- New York, United States: Following the significant flooding caused by Hurricane Sandy in 2012 there was a step-change in the approach taken to flood risk management. Adaptation pathways have now been adopted to increase the city's resilience and the dynamic robustness of adaptation options. The flexible adaptive planning approach using adaptation pathways has been based on detailed climate scenarios and will be updated every 3 years (Rosenzweig and Solecki 2014).
- Los Angeles, United States: To develop adaptation pathway plans, current and future coastal flood risk has been simulated under different sea level rise scenarios. This has been used to determine risk thresholds now and into the future and to develop adaptation options. In designing pathway solutions, economic appraisal of the options has been considered to support decisions (De Ruig and others, 2019).
- Shanghai, China: Adaptation pathways were developed to reduce the risk to the city from coastal, pluvial and river flooding. Actions were presented and assessed based on their impact (measured in terms of safety, side effects on nature, shipping and attractiveness), their expected 'sell by' date based on expert judgement and cost expectations. As part of the plan development contingency actions, signposts and triggers were identified at the onset (Ke and others, 2016).

6.6 Applying adaptation pathways in rural environments for FCERM

A rapid adaptation pathways assessment has previously been piloted with councillors from 2 communities at risk from fluvial flooding in Somerset. The stakeholders chose the vulnerabilities that they wanted to explore through adaptation pathways considering current and future risks, including the government's high++ scenarios (Lowe and others, 2009). This was used to determine response options and formulate adaptation pathways plans, identifying approximate thresholds and actions to introduce at those thresholds. The process was supported by seconded Environment Agency experts among others.

Key outcomes were:

- 1. A better understanding of what climate change means for communities, and, in some cases, a very precise understanding of the vulnerabilities, for example properties that would become vulnerable beyond a certain threshold.
- 2. A better understanding of actions that can be taken in the short term to strengthen longer term resilience, including, in one case, the value of changing the governance arrangements of a local flood management committee.
- 3. A way of understanding and accepting some of the more frightening concerns for local communities such as prospective relocation, and the conditions under which that might be required.
- 4. Developing a mental health pathway to support engagement with the most atrisk communities and facilitate conversations despite anxieties. Discussions have started with the local public health team who are very interested, and further work is expected to continue and expand adaptation pathways as an adaptive planning approach.

7 Monitoring and evaluation

For adaptation pathways to remain valid over long planning horizons, monitoring and evaluation must be included within the plan. Often this stage is determined at project conception. It requires detailed thinking on potential indicators to identify changes in conditions over time, that, if occurred could trigger a change to a planned action (such as a delay to implement planned action, change to an alternative pathway or to adjust the adaptive planning approach). These changes in conditions will require monitoring and evaluation over time and appropriate actions need to be recorded.

Subsequently, the following rapid evidence assessment (REA) question was proposed "What monitoring and evaluation approaches and/or techniques are required to realise potential benefits of adaptation pathways?" to understand the different techniques being used and the level of consideration given to this stage within the academic literature.

7.1 Monitoring approaches and techniques overview

7.1.1 Importance of monitoring in adaptation pathways

Many papers identify monitoring as part of adaptation pathways and highlight its importance in maintaining the pathway. It is recognised by Jeuken and others (2015) in a review of 4 adaptation plans for deltas and coastal cities, that all plans are underpinned by monitoring, highlighting its importance. It is noted however, that the cases reviewed are either in the pre-implementation phase where no monitoring has been conducted or are in an early phase and, as such, no evidence collected during the monitoring phases has required a reassessment of the plan.

Haasnoot and others (2013) discuss a dynamic adaptive policy pathway (DAPP) approach which includes a monitoring system with related contingency actions to keep the plan on the track of a preferred pathway. The governance around monitoring to support collaborative learning for adaptive planning approaches has been addressed in terms of who should monitor what and for whom by Hermans and others (2017).

Monitoring frameworks have been developed that include detail on what is to be monitored and how, justification for monitoring, long-term consistency, opportunities for public contribution to monitoring; and regular reporting (Bell and others, 2017).

7.1.2 Monitoring of triggers/indicators

The monitoring framework should specify what indicators need to be monitored and when as part of the project (see Table 7.1 for examples). This should be supplemented by identifying triggers that specify when a threshold has been reached in a monitoring indicator and a contingency action plan needs to be considered (Ke and others 2016). Critically, the plan should be reviewed at regular intervals (for example, every 5 years) or if a trigger is met. This combined approach should maintain the project on the track of the preferred pathway. The monitoring system should be considered as a loop such that adaptive actions are reassessed on an ongoing basis (Ke and others, 2016).

Table 7.1 Examples of monitoring indicators for adaptation pathways relating to
flood and coastal erosion risk management. Source: Project team, 2020

Monitoring indicator

Global mean sea level risk relative to a defined baseline period

Volume and frequency of required beach replenishment

Frequency of combined sewer overflows (CSOs) and receiving watercourse quality

Frequency of waterlogging and groundwater flooding (for example, basement flooding)

Occurrence of heat waves, including for example number of days >30°c

Tidal range at a certain location relative to a defined baseline period

Frequency of a flooding event (for example, 1-in-100 year annual exceedance probability, 1-in-500 year annual exceedance probability etc.)

Frequency of drought events and changes in average summer flows

Peak surge level or a description of extreme tidal flood events

Peak river flows (for example, from multiple stations, changes in winter flows or annual max)

Asset condition including flood defences (good, fair or poor condition)

Frequency of intervention actions, for example closure of storm surge barriers

Rate of erosion and deposition at different locations

Perceptions of risk management within the local community

Indicators relating to other co-benefits such as conditions of habitat

Risk is not directly observable or measurable in most cases and, as such, a range of indicators should be monitored. Risk-based thresholds in these indicators can then be used as triggers for decision-making (Kingsborough and others, 2016, p.395). For example, in a framework for adaptation planning in urban water supply system in London, indicators include storage level, rate of demand and climate hazard indicators used to help monitor risk (Kingsborough and others, 2016).

Monitoring and reviews vary between projects. Many of the examples in coastal and flood risk management include a periodic review cycle on relatively short timescales (less than a decade). More detail on the monitoring phase is described below:

- The **TE2100 Project** has a structured monitoring review process that involves information being provided on 10 key indicators, including sea level rise, river flow and erosion rates (Bloemen and others, 2018). A mid-term monitoring review occurs every 5 years and scheduled review and detailed reappraisal of the Plan every 10 years (Bloemen and others, 2018). The ongoing monitoring of the climate and key indicators is necessary for success, with long-term planning of monitoring and funding options required (Ranger and others, 2013).
- The **Dutch Delta Programme** also carries out a systematic review of regional strategies every 6 years and a detailed review every 12 years (Bloemen and others, 2018). Periodic updates were considered important for success. The periodic evaluation of triggers is also suggested to determine whether a threshold has been reached and a new pathway should be selected (Haasnoot

and others, 2018). To anticipate future changes a list of indicators was developed, including primary indicators that are required ('need to know') and secondary (explanatory) indicators that help analysts better understand the information obtained ('nice to know').

- In the development adaptation pathways for coastal management in **Hawkes Bay, New Zealand**, triggers (via indicators) were noted to be later designed in a strategy for monitoring and review. The monitoring period was set as 10 years or less, depending on whether there were changes to information or conditions occurred (Lawrence and others, 2019).
- In **New York City**, an adaptation pathways approach takes into account the need for adjustments for changes in climate risks through its indicators and monitoring, as well as updates from the New York Panel on Climate Change every 3 years (Rosenzweig and Solecki, 2014).

The review cycle period should consider the design life of the infrastructure included in the adaptive planning approach. In the above examples, and many flood and coastal erosion risk management decisions, infrastructure will be long-lasting, spanning several decades. In contrast, other sectors will involve infrastructure or assets with shorter design life, for example, roadway structure pavement with a 20-year design life. For assessing the impact of climate change in the design of long-lived infrastructure using adaptation pathways, a re-evaluation period of every 10 to 20 years is recommended to determine whether the adaptive planning approach needs to change to another pathway (Knott and others, 2019).

7.2 Evaluation of monitoring systems for adaptation pathways

A number of studies have gone beyond developing a monitoring framework and assessed its effectiveness. Raso and others (2019) evaluate the monitoring systems for adaptation pathways by mapping trigger values and their outcomes. Using trigger-probability mapping and trigger-consequences mapping, Raso and others (2019) present a methodology which can help a decision maker decide on an acceptable level of confidence. This technique has been applied to a storm surge barrier in the Netherlands, where signposts within the monitoring framework were tested to identify if they were suitable indicators of adaptation tipping points.

The relationship between adaptation tipping points and adaptation signals is shown below in Figure 7.1. Over time the performance of a particular option decreases, once it drops below a particular threshold value this results in an adaptation tipping point. An assessment of the time needed to implement actions can then be carried out to determine the timing of initial and follow up activities to mitigate any residual risks or adapt to future change. Signals can be determined by monitoring ambient conditions to determine when a particular signal value is exceeded. In practice, a smooth line in terms of changing environmental conditions and performance is rarely observed, which, in turn, can complicate trend detection and subsequent action (Haasnoot and others, 2018).



Figure 7.1 Environmental conditions and performance signposts (Haasnoot and others, 2018)

The eRise tool developed by the University of Southampton provides an example of system which can be used to support monitoring (Figure 7.2). In the future, the tool will mean practitioners can identify the timings (with uncertainties) at which accelerations in sea-level rise might first be recognised, and to estimate the lead times for a wide range of sea-level projections.



Figure 7.3 Steps to develop a signal monitoring system for adaptation planning approach. Source: University of Southampton, 2020

Others have set criteria for evaluating the signal monitoring system, including salience (measurability, timelines, reliability), credibility (convincible, institutional connectivity) and legitimacy (Haasnoot and others, 2018) (Figure 7.4), profitability, net profit difference and robustness (Lebel and others, 2018). A mixture of signals indicators may help to better understand what is happening, and derive timely as well as convincing signals. Indicators at the source of change (drivers of change) often have a better signal to noise ratio, and may detect signals earlier than impact indicators. These impact indicators are affected by a myriad of changing conditions, but may be more convincing, as they are related to relevant impacts and objectives and have a better connectivity to actions of responsible authorities.

Decisions based on single criteria in the monitoring and evaluation phase can result in narrow outcomes (Radhakrishnan and others, 2018a). It is suggested that the assessment and monitoring of preferred pathways include social, economic, financial costs and benefits under different scenarios. For research conducted on heat-risk in London, metrics included mortality, residential overheating and the risk of exceeding target frequency for residential overheating events. It was noted that metrics which only reflect climate change hazard were less valuable to decision makers than metrics that represented multiple drivers of risk (for example, climate change, urban heat island effect, social vulnerability and adaptation action) (Kingsborough and others, 2017).



Figure 7.4 Steps to develop a signal monitoring system for adaptation planning approach. Source: Haasnoot and others, 2018

The preferred pathway can vary between stakeholders and decision makers, where different values and benefits can have an impact on choices (Ke and others, 2016). Sell by dates and costs of actions are incorporated into adaptation pathways to assist in pathway selection (Ke and others, 2016). These differing views should also be reflected in the monitoring framework.

7.3 Challenges of monitoring in adaptation pathways projects

In a paper comparing flood risk adaptation planning, Jeuken and others (2015) note that monitoring and reassessment of options may be hindered where some variables have trends that cannot be detected. Triggers can be based on information on the past or current situation (such as monitoring results) but also information about the future, such as new specific insights on future climate or new population estimates. It is important to monitor scientific progress and the success of adaptation policies and actions that have been implemented.

Monitoring must include the main climate drivers for change and key triggers identified to allow for early trend detection (Jeuken and others, 2015). Trigger points must be verified by monitoring signals, ideally in multiple indicators, and these must allow for timely transfer to an alternative pathway (Hiller and others, 2019). Such requirements can mean that compared to conventional approaches, managed adaptation pathways can be costly and complicated to implement (Hiller and others, 2019.

Periodic monitoring needs to be routinely carried out as part of the iterative risk management process (Ramm and others, 2018a). Monitoring factors can change slowly over time and detecting such environmental changes can be problematic due to natural variability, sparse data records and non-stationarity (Ramm and others, 2018a). Using multiple uncertain factors to describe conditions leading to adaptation tipping points adds further complexity to the risk monitoring process, and variables may change in different directions with varying rates (Ramm and others, 2018a).

In most cases, there is a lack of guidance for long-term monitoring, funding or implementation of managed adaptive planning approaches (Hiller and others, 2019). This adds to the challenge and leads to confusion over responsibilities, funding arrangements and best practices.

Statistical methods appear to be useful in determining when a signpost may give a signal under a particular scenario, and the reliability of this indication. Different significance levels could be used to derive weak to strong signals (Haasnoot and others, 2018). For example, the traditional significance value of 5% or less can be used for strong signals, while higher values can be used to announce moderate or weak signals.

A conceptual example showing the challenges for monitoring systems based on the reliance on discrete triggers and trend detection is shown below in Figure 7.5.



Figure 7.5 Conceptual example of monitoring and investment trigger points based on uncertain and stochastic projections. Source: Reeder and others, 2020

8 Stakeholder engagement and collaboration

Stakeholder engagement is generally recommended in any risk management approach to increase awareness and partner buy-in to the project. In adaptation pathway projects, stakeholder engagement has been described as particularly important to change behaviours and attitudes to dealing with risk over an uncertain future. In England and Wales, available guidance stresses the importance of stakeholder engagement and collaboration (Hiller and others, 2019).

Stakeholder engagement encompasses seeking stakeholders' views to inform the decision-making process and involving stakeholders in the design and decision making itself. A spectrum of public participation has previously been proposed by the International Association for Public Participation. This can provide a useful guide for determining the level of engagement which should be sought during the conceptualisation and delivery of a project ().

INFORM	CONSULT	INVOLVE	COLLABORATE	EMPOWER
To provide the public with balanced and objective information to assist them in understanding the problem, alternatives, opportunities and/or solutions.	To obtain public feedback on analysis, alternatives and/or decisions.	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.	To place final decision making in the hands of the public.
We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how public input influenced the decision.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision.	We will look to you for advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide,

Figure 8.1 Conceptual example of monitoring and investment trigger points based on uncertain and stochastic projections. Source: International Association for Public Participation, 2014

Elements of the spectrum of public participation are evident in the 10-step iterative decision framework developed by New Zealand's Ministry for the Environment to support coastal planning (Figure 8.2) (Bell and others, 2017). This framework highlights key questions to be raised at each step within the process and can be used as a basis to determine the engagement of different groups of stakeholders during the process based on their interests and relative priorities.

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Figure 8.2 New Zealand coastal guidance 10 step decision cycle framework (Bell and others, 2017)

Stakeholder engagement varies between different projects. The techniques used may be different, stakeholder groups will vary and the stage at which stakeholders are involved will differ. Subsequently, the following risk evidence assessment (REA) question was posed "To what extent has stakeholder engagement been undertaken to support the development of adaptation pathway projects (on inception, co-production, consultations/workshops, in end-product delivery) and what were the outcomes?"

A proportion of published studies draw on previously compiled evidence, such as stakeholder surveys, and others carry out their own form of stakeholder engagement to validate their findings. Guidance papers recommend using a participatory process (for example, Bosomworth and others, 2015; Siebentritt and Smith 2016) and several studies discuss a participatory process in case studies (for example, Bell and others, 2017; Brotchie and others, 2018; Jager and others, unknown date; Bloemen and others, 2018; Coulter 2019a).

8.1 Stakeholder engagement techniques and associated stages of undertaking

The main methods of stakeholder engagement are interviews, workshops/focus groups or a combination of both. Both techniques allow engagement with stakeholders with

diverse interests, and help facilitate adaptive learning for individual and collective action to build community response capacity (Smith and others, 2013). Stakeholders will be specific to different projects and interest parties; they include but are not limited to:

- government agencies and representatives
- non-government organisations
- district or council representatives
- civil society organisations
- academics
- journalists
- industry representatives and local business owners
- general public and the local community
- local landowners

Stakeholder interviews have been used to investigate the potential for adaptation pathways to be implemented in new settings (for example, Hiller and others, 2019), in existing frameworks (Mendoza and others, 2018) and as part of model development (Haasnoot and others, 2014).

Britton and others (2011) tested a methodology for engaging communities around climate change adaptation, where stakeholder information, consultation and participation is considered central to developing and implementing an adaptive planning approach. In the 'Room for the River' Programme, regional stakeholders across 34 regional projects make decisions and formulate plans and designs (Zevenbergen and others, 2019).

Yen and others (2019) develop a participatory approach for mapping climate risks and adaptive interventions, where local knowledge is considered the 'backbone' of the process. Stakeholders included national and provincial officials, experts and international organisations, as well as provincial agencies, research institutes, universities and high-level management institutions. Risk scenarios and levels were identified and adaptive interventions relating to risk maps derived (Yen and others, 2019). Knott and others (2019) involve stakeholders from the beginning to determine goals in a hybrid bottom-up/top-down adaptation approach to pavement adaptation.

8.1.1 Interviews

The published literature shows that interviews with a wide range of stakeholders are often carried out at different stages of the adaptation pathway planning process (for example, in the initial phases to understand priorities and to capture local knowledge, and during monitoring phases to seek feedback and learning). Different groups of stakeholders may be engaged depending on the scope and context of the project. Projects spanning a larger geographical area will require engagement with a larger group of stakeholders, often focusing on high-level decision makers (for example, TE2100 prioritised engagement with local councils), while smaller, regional projects will include stakeholders that have direct involvement on the ground at a local level.

Priorities and goals

Semi-structured interviews have been used in various projects to identify near and long-term priorities, perceived barriers and enablers, and possible adaptation options

(Butler and others, 2014; Kingsborough and others, 2016, 2017; Magnan and Duvat 2018; Bardsley and others, 2018; Herbeck and Flitner 2019).

Options identification, scenario and pathways development

Stakeholders from different sectors have been engaged to explore scenario development, where factors of future change, their uncertainty and relevance are decided at an early stage in the adaptation pathways development (Vervoot and others, 2014). Interviews have been carried out with community leaders, environmental management officials and landowners, to discuss the appropriateness of different scenarios and adaptation pathways (Milman and Warner 2016). In developing the TE2100 Plan, local parties were involved in inventorying and discussing possible measures (Bloemen and others, 2018).

Monitoring and trigger points

In the TE2100 Plan, stakeholder interviews were carried out to understand how monitoring and evaluation should be incorporated into the plan. Follow-up interviews identify which stakeholders were responsible for monitoring which indicators (Bloemen and others, 2018).

8.1.2 Workshops, consultations and focus groups

Workshops allow cross-professional interactive, creative processes and crossfertilisation between professionals (Carstens and others, 2019). They are also an effective tool in increasing participant confidence in dealing with uncertainty and understanding associated risks.

Examples of workshops include the ongoing stakeholder-led process implemented in Australia by the State Government (see Section 6.4), designed to inform local and regional adaptive planning approaches. Through 33 participatory workshops, 720 regional decision makers have been engaged across policy, planning and operations (Jacobs and others, 2018).

Priorities and goals

Workshops can occur at the inception phase of an adaptation pathway project, where local stakeholders and technical experts identify future scenarios as well as formulate reference cases, conduct assessment of acceptable risk levels and identify tipping points (Schasfoort and van Aalst 2017a; 2017b).

Within the context of sea-level rise in small municipalities, 3 workshops were carried out for problem scoping, choosing probabilities of flooding for different events and to identify adaptation pathways (Carstens and others, 2019). Drivers of change, aspirational and explorative scenarios have also been identified through 3 stages of stakeholder workshops at different administrative levels, with the outcome of 22 different driver sub-themes identified (Butler and others, 2016a). Similarly, 3 stages of workshops have also been carried out in another study to identify drivers of community vulnerability (Wise and others, 2016). Workshops have also been used to identify stakeholder groups mainly affected by conditions (Schasfoort 2017) and develop a shared understanding of the current situation. They have been used to establish a shared futures perspective, explore possible futures and identify potential tipping points and action planning (Bosomworth and others, 2018).

Options identification, scenarios and pathways development

Some studies have drawn upon existing resources in developing adaptation pathways which included prior expert stakeholder workshops to identify impacts and adaptation options from climate change (Mukheibir and others, 2017; Xu and others, 2019).

Workshops have been used to understand how management actions may adapt in response to changing climate risk in New South Wales, Australia, through obtaining information on available options, risk assessment matrices and decision framework (Jacobs and others, 2019). Workshops with operations staff have also been used to identify key values and assign risk, where management options are then investigated to protect values should the assigned risk increase (Jacobs and others, 2019). The expert judgement of stakeholders has been used to construct adaptation pathways and using 5-year interval priorities from 2015 to 2055, sequence adaptation options to develop 4 different pathways relating to water resource planning in a developing country context (Bhave and others, 2018). Both consultations and workshops were used and insights from stakeholder consultation included key basin functions, priorities for water allocation, and critical vulnerabilities and drivers of change (Bhave and others, 2018).

Park and others (2014) present several case studies where workshops have been used, including the case study of Timor-Leste, where workshops assessed the impacts of a changing climate and evaluated possible strategies from an economic perspective. Questions for stakeholders related to identifying triggers for action to be taken as well as a discussion on thresholds/tipping points likely to result in implementation (Park and others, 2014). Park and others (2014) also referred to the Solomon Islands case study where community and government workshops were held, and potential pathways identified. Interviews were also used in this case study and the challenges faced by stakeholders discussed (Park and others, 2014).

Stakeholder workshops have also been used to review scenarios and improve them based on selected criteria (Vervoort and others, 2014). Tipping points have also been obtained through workshops (Schasfoort 2017).

8.1.3 Other engagement techniques (online surveys, meeting attendance)

In general, other techniques appear to compliment the 2 main methods of interviews, workshops and/or focus groups discussed above.

Surveys have been used with 2 main goals at different project stages. Some studies have used surveys to collect initial information during the development of pathway approaches, collating data on acceptable levels of risk for different stakeholders (Radhakrishnan and others, 2018a) or for evaluating different adaptation strategies (Park and others, 2014). Other approaches included field visits, questionnaires and in situ inspections carried out to understand perception and awareness of hazards and their impact with respect to adaptation strategies (Yang and others, 2015). In the TE2100 Programme, an extensive online consultation was used to collect stakeholders' views (Ranger and others, 2013).

Community meetings, expert advisory group meetings and a multi-stakeholder dialogue event have also been used as a way of engaging with stakeholders to understand the context of adaptation planning in London (Kingsborough and others, 2017) and guide management options (Lebel and others, 2018).

At a later project stage, surveys have been used to collect participant feedback to provide learning opportunities (Bosomworth and others, 2018). Obtaining participant feedback may also be done through observational notes, reflections, post-pilot interviews or post-workshop feedback (Lawrence and Haasnoot 2017; Bosomworth and others, 2018). Nikkels and others (2019) recommend creating space for social learning among stakeholders to facilitate cooperation based on shared meanings and practices.

8.1.4 Outcomes from stakeholder engagement

Experience of adaptation pathway projects within the literature suggests many positive outcomes resulting from stakeholder engagement. These include increased buy-in to projects, achieving consensus on the pathway selected and consideration of different options and pathways available which suit different stakeholder groups differently.

Stakeholder participants that have been involved in adaptation pathway projects are more likely to support the proposed actions and work to realise the goals of the project (Coulter 2019b). Groups of stakeholders and all levels of government can be included in discussions concerning the objectives and strategies of the project (for example, Delta Programme - Zandvoort and others, 2017). This helps to develop consensus on the objectives, acceptable levels of uncertainty and actions to be taken, thereby increasing stakeholder buy-in to the project.

Stakeholders are found to be less restricted by existing institutional, legal, and financial constraints when contemplating long-term planning horizons (Kingsborough and others, 2016). This supports creative consideration of a broader range of future scenarios, increasing the effectiveness of the adaptation pathway approach.

8.1.5 Challenges with stakeholder engagement

Many of the challenges of adaptation pathway projects (section 5.2) apply to stakeholder engagement. In particular, the literature has highlighted issues around perceptions and understanding of the complexity of the method and scenarios as well as ensuring that the length of engagement is appropriate.

A challenge of stakeholder engagement is conveying the information, with some stakeholders having difficulty understanding pathway maps (Zandvoort and others, 2017). This view has been supported by practitioners that were interviewed as part of this study. Furthermore, another challenge is the level of technical detail and understanding that is required. In the Delta Programme, there was disagreement between the different stakeholders about the climate scenarios that should be considered, with some stakeholders discarding scenarios and options based on monetary costs (Zandvoort and others, 2017).

The engagement must be long enough to capture all views of the different stakeholders. In one example, the causes of community vulnerability were not identified as the initial workshops used were too brief, thereby not providing enough learning for participants (Butler and others, 2016a).

9 Conclusions and recommendations

Although they have yet to be widely adopted, adaptation pathways have been shown to be effective tools for risk management. The most developed examples so far are for large, national-scale infrastructure projects that focus particularly on flood risk management in the context of rising sea levels. Nevertheless, the potential for using adaptation pathways is vast and applies to many settings. Research and project examples have shown that it is possible to overcome barriers, and these examples have highlighted the approaches that can be taken to enable the uptake of adaptation pathways more widely in risk management.

This section brings together the main themes from the published literature and expert insight to provide a critical review of the findings. It covers the context and characteristics of successful adaptation pathway projects, methodologies and approaches, potential benefits and outcomes and recommendations from these projects.

Knowledge gaps that have been identified during the process, and require further research, have been discussed. Finally, potential locations around the UK where adaptation pathways could be used in flood and coastal erosion risk management have been highlighted.

9.1 Main findings

The following 5 research questions were identified and investigated in this study:

- In what context do different adaptation pathway methods yield measurable outcomes which could support risk management authorities? This question is discussed in section 5.
- What are the primary barriers, enablers and limitations of adaptation pathways applied to flood and coastal erosion risk management and other industrial sectors? This question is discussed in **section 5.2**.
- How successful/transferable are different adaptation pathway approaches compared to conventional approaches and techniques? This question is discussed in **section 5.3.**
- What monitoring and evaluation approaches and/or techniques are required to realise potential benefits of adaptation pathways? This question is discussed in **section 7.**
- To what extent has stakeholder engagement been carried out to support the development of adaptation pathway projects (project inception – research question and objective definition, project delivery – co-design workshops and integrated modelling, project close – peer review of the developed pathways) and what were the outcomes? This is discussed in section 8.

The rapid evidence assessment (REA) investigated the above questions, with the main findings as follows:

• Adaptation pathways are the most effective tool available for dealing with uncertainty and risk management over long-term planning horizons. The

process increases collaboration, opens the decision space and improves understanding of uncertainty. They are an effective way of securing buy-in and commitment from local stakeholders.

- Methods for increasing the success of adaptive planning approaches include ensuring suitable governance procedures are in place, such as appropriate regulatory instruments and getting commitment from stakeholders.
- The main barrier to implementing adaptation pathways is the complexity associated with understanding uncertainty around future projections. The adaptation pathway approach intrinsically addresses this through flexibility, transparency, considering contingency actions and monitoring processes.
- Approaches to adaptation pathways can range from simple to complex, according to resource availability and funding arrangements.

Further details on the findings are provided in the following sections.

9.2 Context and characteristics of successful adaptation pathway projects

To date, the most successful and well documented adaptation pathways projects are associated with major infrastructure projects (for example, TE2100, Dutch Delta Programme). These projects have large budgets and national government support or control, ensuring appropriate governance procedures are in place. These types of projects provide a clear setting for successfully applying adaptation pathways projects, as they have a greater availability of resources, including technical knowledge on water management and forward looking approaches, people, institutions and finance. However, other adaptive plan projects are emerging, including local applications in Australia and New Zealand.

Transposing success features from large, exemplar projects (such as budget availability, governance procedures and technical knowledge) should also ensure the success of smaller adaptation pathway projects. From the outset of a project it would be critical to determine the governance procedures in place, including roles and responsibilities of key players within the project, which will also increase their support for the project. Secondly, setting an appropriate budget from the outset of the project, ensuring that it has appropriate allowances for all stages of the plan development, implementation and monitoring will overcome the challenges associated with not having a large budget. Once the budget has been established, decisions can be taken on the approach to be used (see section 9.3).

Based on pioneering studies of adaptation pathway approaches, stakeholder engagement has been deemed critical to the success of adaptation pathways techniques. Critical stakeholders should be identified at the start of the project and active engagement with them should be included within the plan development to gain their buy-in.

Adequate governance (including possible incentive structures) is required to support long-term planning. An overall long-term strategic vision will frame the development of the adaptive planning approach.

9.3 Methodology and approaches to successful adaptation pathways projects

The approach taken to developing adaptation pathways is generic and follows a simple step process. It can be adapted from a simple to a complex approach depending on the project constraints (for example, time, objectives, budget, resources) and the project phase. In some cases, using complex modelling and decision support systems (DSS) may help pathway development, however they are not necessarily a requirement.

General features that should be incorporated into all adaptation pathway projects to aid success are:

- Multiple climate scenarios should always be included, including the highend climate projections and socio-economic scenarios (for example, population growth, and urban migration) where possible. This helps explore possible future thresholds and is essential to ensure the flexibility of the pathway developed.
- An implementation plan needs to be considered from the outset to ensure actions are taken and implemented over the duration of the project. There is a tendency for management to go back to business as usual, but it is essential that the pathway is continuously monitored and adapted as needed to suit the changing conditions. This requires strong leadership and is assisted by policy supporting a long-term vision.
- Monitoring indicators should be decided at the onset of pathway development and should undergo an iterative review process during the implementation stage to ensure they are accurately detecting changes in conditions appropriate for the decision points on the pathway.
- Workshops with stakeholders are critical but care should be taken to plan these effectively, as they can be time/cost intensive and problematic to organise. They should target the right key individuals, include enough people to encourage discussion but not too many to hinder agreement, and be tailored to the task in hand.

High-level approaches to adaptation pathway development can be sufficient. Draft adaptation pathways that have been co-developed with stakeholders are showing promise as very effective risk management tools. This simple approach was taken in the Coastal Communities 2150 project (European Commission, 2015), which produced a draft adaptation pathway for Newhaven with little resource, and for Somerset to assist with flood risk in a state of climate emergency (Appendix C).

9.4 Benefits and outcomes

The main benefit of an adaptation pathways approach is its potential to broaden the debate around flood and coastal erosion risk management. The process provides greater understanding and appreciation of:

- tolerable levels of risk: increased understanding of stakeholders' risk appetite through the pathway development and option appraisal process will encourage a broader range of options to be considered. It will ensure a whole-system approach is taken and actions are prioritised based on stakeholders' interests
- awareness of risk management: the adaptive planning approach, when used in combination with successful stakeholder engagement, facilitates an

increased awareness of risk management and uncertainty by local stakeholders and decision makers. It also enables thinking about the need for long-term transformational change

 dealing with uncertainty: adaptation pathways represent the most realistic approach we have available at the moment for dealing with uncertainty. Adaptation pathways allow epistemic (known) and aleatory (random) uncertainties to be considered in a consistent analytical framework, and can be managed using a combination of qualitative, narrative-based and quantitative, complex-modelling approaches

9.5 Knowledge gaps

Adaptation pathways are an emerging concept in risk management and further research is required to further understand their potential, limitations and successful implementation. In particular, the review and discussions with experts through this project has highlighted the following knowledge gaps:

- Successful dissemination of available material on climate change projections so practitioners can consider and use it. Much of this information is available (for example, resources developed for UK climate projections, Met Office and others, 2015), however, guidance is needed on how to use this for developing adaptation pathways without expert insight.
- Further examples are needed of implementation (real or hypothetical) of lower cost adaptive planning approaches using adaptation pathways which do not have the barrier of high implementation costs and resource intensive processes. Examples of this type of study are emerging recently.
- Development of monitoring tools that help with detrending noise in natural variables and support decision makers, including making sufficient allowance for lag times.
- More information is needed on what indicators practitioners should target and how to identify when a trigger or threshold has been passed and a new pathway is needed. It is recognised that it will not always be possible to have a definite answer as to whether a trigger point has been reached to make a decision and it is therefore vitally important to have a clear and transparent decision-making process.
- Decision makers can decide to wait if they have a larger appetite for risk or decide to change if they have a lower one. These choices are personal and legitimate and should not necessarily be criticised for delaying or overspending, particularly if they result in risk reduction in the long term. Recognising this, there is still a need for better communication and this is where adaptation pathways can be particularly useful.
- Identifying critical thresholds from around the UK coast to determine where adaptation pathways such as TE2100 could be applied for future decisions. Several areas are highly exposed to storm surge effects, sea level rise and coastal erosion, and adaptation pathways would be appropriate for these.
- The methodology for adaptation pathways is more developed for slow onset hazards (for example, sea level rise). Further research is needed on applying this approach to rapid onset or stochastic (random) hazards such as surface water or pluvial flooding. This is because flexible decisions are challenged under rapidly changing prevailing conditions (both frequency

and severity). For this reason, finding the time for planning and implementation may be more problematic.

9.6 Recommendations for adaptation pathways

Recommendations have been developed from expert interpretation of best practices identified in the literature and case studies of adaptation pathways. These have been divided into recommendations for policy makers and practitioners.

9.6.1 Recommendations for policy makers

- Provide clear long-term strategic visions that support adaptive planning approaches over long horizons and provide appropriate support, governance procedures and financial backing for projects to evolve.
- Provide appropriate guidance to help overcome barriers with funding and resources. This guidance should help practitioners develop processes and/or reduce resource requirements (expert contribution).

9.6.2 Recommendations for practitioners

- Multiple future scenarios should be considered within the plan development. Where possible, it is highly recommended that a high-end estimate or scenario should also be included, at least to stress test the options against. This will increase trust from stakeholders, ensure the project is resilient, reduce concern regarding future climate information, and support low-regret investment.
- At the outset of the project, clear baseline conditions should be established with detailed documentation of the conditions, against which future trends, triggers and tipping points can be compared. This will be essential to support future decision points, especially when comparing monitoring indicators (for example, levels of sea level rise) against baseline conditions.
- Workshop sessions for stakeholders including an iterative process considering multiple futures to facilitate discussion and increase understanding of issues, establish co-creation of ideas and options and increase awareness of risk management. Using narratives around risk management can be used as a technique to engage stakeholders.
- Detailed plans should be developed that include clear definitions of roles and responsibilities, funding arrangements, a monitoring framework, definition of tipping points, records of decisions made and justifications, and an engagement plan for the duration of the project. Where resources are limited all these steps should be considered at least at a high level.
- The monitoring/evaluation framework must address the following questions:
 - What will be measured and how to analyse derived signals?
 - Are these indicators directly measuring the hazard or providing proxies for changes in the hazard? How does this impact the decision-making process?
 - What is the periodicity of monitoring (continuous or periodic reviews)?

- What is the periodicity of review cycles where the plan would be updated (as needed or regularly)? At what point would the passing of a threshold or trigger point lead to a full review of the plan?
- A relatively short review cycle of approximately 5 years or less is recommended to allow for updates to the monitoring and implementation plan, including ensuring that the adaptation pathway is still correct.

9.7 Summary

A comprehensive review of academic and non-academic (grey) literature covering the uptake and application of adaptation pathways in policy and practice was carried out. Results are analysed in the context of overarching research questions covering potential enablers, barriers and delivery models for adaptation pathways, including monitoring and evaluation as they relate to flood and coastal erosion risk management and other sectors and applications.

A range of methods and approaches are presented; these typically build on common principles and have historically been developed with direct reference to established high profile case studies in the UK and the Netherlands. A range of novel methods, tools and standards are being developed to further encourage the mainstream uptake of adaptation pathways in policy and practice, and these have been partially successful.

Adaptation pathways are highly relevant to flood and coastal erosion risk management and allow uncertainties about future climate change to be considered in a comprehensive, robust and flexible decision-making framework. When developed in collaboration with local stakeholders they can provide an effective means of ensuring the future viability and sustainability of flood defence projects and investments, ensure community buy-in and, at the same time, help to protect the environment.

Glossary

Adaptive planning approaches*	Approaches designed and implemented to be flexible and robust, which can anticipate and effectively respond to uncertain future changes by combining low-regret, short-term actions with long-term options to adapt, if necessary.
Adaptation or	Sequences of potential actions that are intended to anticipate
adaptive pathways*	and respond to evolving threats, risks and opportunities across
	multiple future scenarios. These actions are linked to specific
	thresholds or tipping points where a change in circumstances is
	reached and further adaptive action may be required. They are
	used to develop long term elimete adaptation plans
Indiantara	Used to develop long term climate adaptation plans.
indicators	Specific and measurable metrics which are objectively verifiable
	and can be tracked over time.
Low-regret	Measures typically associated with 'low cost' options which
	perform adequately or exhibit robustness across a range of
	future scenarios, while minimising potential trade-offs.
Risk management	Authorities that have a duty to manage risks from all water
authority	sources, including rivers and streams, reservoirs, the sea,
	eroding coastlines, surface water, groundwater or the sewer, in
	line with national policy.
Signals	Derived from the monitoring of indicators used to observe trends
_	and changes in the system. Signals trigger action.
Thresholds	A point in time where a change in circumstances (for example,
	higher sea levels or increased occurrences of flooding events) is
	reached and further adaptive action is required. Beyond this
	threshold, an unacceptable level of risk or loss of performance
	of the system could arise, and an alternative option is required.
Tipping points	See 'Thresholds'.
Triggers	Used for monitoring and occur when conditions change or are
	likely to change to an extent that they approach a threshold or
	tipping point.
Uncertainty	A situation or state of incomplete knowledge which can result
	from lack of information or disagreement about what is known
	and unknown
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*More detailed descriptions can be used for communicating adaptive approaches and adaptive pathways (for example consistent with the way they are described in the national flood and coastal erosion risk management strategy for England (Environment Agency, 2020). These are:

Taking an **adaptive approach** allows risk management authorities working with partners to better plan for and adapt to future climate risks. By considering climate change upfront, an adaptive approach enables practitioners and policy makers to plan to monitor and review how they are adapting to future flooding and coastal risks over time. Adaptive approaches should be proportionate and appropriate to particular places and circumstances, ranging from simple no regrets actions (e.g. avoiding inappropriate development in high flood risk zones or incorporating sustainable drainage into the design of new developments) to more complex activities (e.g. developing adaptive pathways plans to manage future flooding and coastal change over large geographies).

Adaptive pathways (also known as adaptation pathways) are a way of developing a long term climate adaptation plan for a place, often looking out to the end of the century (2100) or beyond. Adaptive pathways provide a range of actions that policy makers and

practitioners can take for better anticipating and responding to a range of future possible climate scenarios. This includes preparing for 2 degrees global warming but planning for higher scenarios including 4 degrees warming. These pathways are linked to specific thresholds or 'tipping points' where a change to our understanding of the impacts of climate change, the local environment or other socio-economic conditions may require further adaptive action. Adaptive pathway plans need to be regularly monitored and evaluated so that they can remain agile to managing future risks over time. A world leading example of a live adaptive plan in action is the Thames Estuary 2100 Plan.

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List of abbreviations

ADM	Adaptive delta management
APIS	Adaptation pathways in Somerset
BSI	British Standards Institution
DAPPs	Dynamic adaptive policy pathways
DSS	Decision support systems
FCERM	Flood and coastal erosion risk management
MERIL	Implementation, monitoring, evaluation, reporting, improvement and
	learning
NGOs	Non-governmental organisations
REA	Rapid evidence assessment
RMAs	Risk management authorities
ROA	Real options analysis
SCARP	Slopes Cluster Climate Change Adaptation Research Partnership
TE2100	Thames Estuary 2100

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Appendix A: The REA Methodology

A.1 Introduction and REA aims

This project has carried out a rapid evidence assessment (REA) of published literature, supported by stakeholder engagement and expert insights, to enhance the Environment Agency's, researchers' and practitioners' understanding, knowledge and guidance on adaptation pathway approaches. An REA aims to evaluate relevant studies on a specific topic in a rigorous, systematic, transparent way.

A structured and rigorous methodology was developed to ensure reproducibility and reduced bias. This section provides an overview of the methodology that has been used, including the REA questions, evidence sources, the screening and search criteria and evidence assessment (Figure 0.1).

The proposed REA protocol has been developed with the Project Steering Group to capture all aims of the Environment Agency and to ensure that the project output will be fit-for-purpose and directly relevant to the project and the Environment Agency's objectives. The REA results will be used to enhance the FCERM strategy, equip risk management authorities with the necessary knowledge and ensure they achieve their objectives.



Figure 0.1 Detailed methodology used within this project for the REA. Source: Wood, 2020

A.2 The REA questions

The objective of this project was to compile and assess evidence relating to the primary research question:

In what context do different adaptation pathway methods yield measurable outcomes which could support risk management authorities?

This question aims to broadly capture the Environment Agency's requirements of understanding the development and application of adaptation pathways in flooding and coastal erosion risk management and other relevant sectors. It will also allow evidence to be captured that showcases how adaptation pathways can be delivered in different contexts (including scale, geographies, flooding sources, socio-economic status) and the benefits that they yield.

To focus the REA search and ensure it was answered in full, the following secondary research questions were also defined:

- What are the primary barriers, enablers and limitations of adaptation pathways applied to flood and coastal erosion risk management and other industrial sectors?
- How successful/transferable are different adaptation pathway approaches compared to conventional approaches and techniques?
- What monitoring and evaluation approaches and/or techniques are required to realise potential benefits of adaptation pathways?
- To what extent has stakeholder engagement been undertaken to support the development of adaptation pathway projects (project inception – research question and objective definition, project delivery – co-design workshops and integrated modelling, project close – peer review of the developed pathways) and what were the outcomes?

A.3 Evidence sources

Evidence sources have been divided into 2 groups, namely academic literature from peer-reviewed sources and 'grey' literature produced by organisations and commercial publishers.

A.3.1 Academic evidence sources

Academic literature from peer-reviewed sources are available in journal articles from online electronic libraries and databases. Specialist electronic search resources, 'Scopus', was used to mine for published scientific literature by an experienced librarian. Expert judgement was used to determine that no additional print sources were needed in addition to the electronic sources.

A.3.2 Grey literature evidence sources

Grey literature sources produced by organisations and commercial publishers provide sector intelligence and case studies that may not be available within the academic literature. Sources can include conference proceedings, white papers, government documents, reports by research funders and working papers.

Our experienced project team, knowledgeable Project Steering Group members and key stakeholders were used to identify key grey literature sources. Internal references within the grey literature sources were investigated further where needed.

The database of grey literature will be supplemented with evidence searches following the appropriate search terms, as defined in section A.4. The following websites of

relevant research and policy organisations and search engines were searched for grey literature sources:

- Environment Agency www.environment-agency.gov.uk
- Natural Environment Research Council (NERC) https://nerc.ukri.org/
- Defra https://www.gov.uk/government/organisations/department-forenvironment-food-rural-affairs
- Horizon 2020 https://ec.europa.eu/programmes/horizon2020/en
- CIRIA https://www.ciria.org/
- Chartered Institute of Water and Environment Management (CIWEM) https://www.ciwem.org/Professional networks and institutions, including:
 - http://www.deepuncertainty.org/category/recent-publications/
 - https://understandrisk.org/
 - BSI/ISO Working Group on Adaptation Pathway https://standardsdevelopment.bsigroup.com/projects/9018-01780
 - https://www.rockefellerfoundation.org/
- International financial institutions (IFIs), including multilateral and regional development banks, and national development banks with international objectives
 - World Bank https://www.worldbank.org/
 - African Development Bank https://www.afdb.org/en
 - Asian Development Bank (ADB) https://www.adb.org/
 - Council of Europe Development Bank https://coebank.org/en/
 - Development Bank of Latin America (CAF) https://www.caf.com/en
 - Eurasian Development Bank https://eabr.org/en/
 - European Bank for Reconstruction and Development https://www.ebrd.com/home
 - European Investment Bank https://www.eib.org/en/
 - Inter-American Development Bank (IADB) https://www.iadb.org/en
 - Islamic Development Bank https://www.isdb.org/
- Google www.google.co.uk

A.4 Search and screening criteria

A.4.1 Screening Criteria

All evidence sources identified were screened initially against the screening criteria in Table 0.1. This will limit the scope of evidence to those sources that are deemed most relevant to the project.

Table 0.1Screening criteria applied to all literature sources. Source: Wood,
2020

Торіс	Screening criteria	Rationale and limitations
Year	Post 2005 only	Removes outdated approaches that are not deemed 'current' while ensuring that recent developments, including UK Climate Projections first published in 2009, are included.
Language	English	Unlikely to introduce much bias as much of the academic literature is available in English, but may eliminate some international research especially in grey literature searches. Further refinements could extend this to include French, Italian and Dutch languages if necessary.
Content	Terminology for adaptation pathways	Focus placed on adaptation pathway approaches and therefore using a limited initial trunk search term of 'adaptation pathway' and a few select secondary terms.
Geographical context	Worldwide	No restrictions will be placed on the location to ensure all global adaptation pathway projects are captured.
Scale of research	Any	No restrictions will be placed on the scale of the adaptive pathway solution to span local, regional, national or international projects.
Flood source	Any	No restrictions will be placed on the source of flooding, for example, future sea level rise, fluvial flows, pluvial flows.
Sector	Excluding medical	A large number of evidence sources within medical research focus on 'adaptation pathway' approaches to individual medical plans. These and other medical references will be removed to ensure relevant information is captured in the REA.

A.4.2 Academic search protocol

The search protocol specifies the key search parameters that were used within searches of the evidence sources noted in **section A.3**. The search strategy is principled, planned, rigorous and grounded in the research question. This ensures a thorough review of all available evidence (local, regional, national and international) on adaptation pathways is achieved.

The search protocol is based on keywords that were used together to obtain results that are tailored to the REA questions. The key words will be used in a systematic way to reduce bias in the searching.

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Search terms were searched for in the title, keywords and abstract fields for academic databases. The search used operators to refine the key word searches, including:

- Boolean operators to combine various search terms (this includes the operators AND, OR, NOT)
- wildcards were used to search for alternative forms of key words, including words with different endings, pluralised words or alternative spellings of words (for example, *, \$ or ? symbols)
- clauses of key words were nested together using parentheses ((a OR b) AND c);
- quotation marks were used to specify terms that must appear together (for example, 'adaptive path*').
- key terms were extracted from the REA questions and synonyms were considered. These were then used to determine a search protocol as defined in Table 0.2.
- initial searches including 'adaptive planning' and 'adaptive management' yielded too many sources. It was felt that this would inhibit the project team's ability to capture the most important information, resulting in deteriorating quality of the REA. Instead it was decided that a trunk search term ('adaptive pathw* OR 'adaptation pathw*' OR "adaptive plan") would be used throughout. Secondary search terms detailed in Table 0.2 were used to refine the evidence searches.

Table 0.2Key search terms identified within the REA questions andcorresponding alternative search terms for academic literature sources. Source:Wood, 2020

Primary term	Secondary search terms
Adaptive/adaptation pathway	'Adaptive path*' OR 'adaptation path*' OR 'adaptive plan'
Risk management	'risk management' OR 'risk practice' OR 'local authorit*' OR 'lead local flood authorit*' OR 'public bod*' OR 'risk owner'
Context	Context OR background OR situation OR setting OR conditions OR circumstances OR perspective
Approach	Approach* OR method OR arrangement OR design OR mechanism OR plan OR practice OR process OR programme OR scheme OR system OR technique OR measure OR procedure OR structure
Barriers	Barrier* OR limit* OR hurdle OR impediment OR obstacle OR bottleneck OR deterrent OR difficult* OR disadvantage OR drawback OR restriction OR condition OR control OR restraint OR block OR constrain* OR weakness
Enable	Enable* OR facilitat* OR implement OR permit OR approve OR invest OR prepare OR aid OR ease OR expedite OR promote OR advocate OR benefit OR sponsor

Primary term	Secondary search terms
Policy	Regulation OR strategy OR administration OR legislation OR guideline* OR governance
Outcome	Outcome* OR benefit OR success* OR delivery OR conclusion OR reaction OR result OR closure OR completion OR consequence OR development OR ending
Monitoring and evaluation	Monitor* OR evaluat* OR audit* OR advis* OR direct* OR review OR analysis OR check OR inspection OR report OR revision OR survey OR investigation OR study OR test OR examin* OR observ* OR instrument*
Stakeholder	Stakeholder OR collaborator OR colleague OR partner OR shareholder OR "interested party' OR participant OR beneficiaries OR facilitators
Engagement	Engage* OR workshop OR co-production OR consultation OR commitment OR discussion OR management OR co- develop* OR interview OR 'focus group'
Flood risk	Flood* OR 'coastal erosion' OR 'fluvial' OR 'pluvial' OR 'surface water' OR 'groundwater' OR 'sea level rise'

Table 0.3 Search protocol for academic literature sources. Source: Wood, 2020

Search No.	Search protocol	Number of academic results
1	('adaptive path*' OR 'adaptation path*' OR 'adaptive plan') AND ('risk management' OR 'risk practice' OR 'local authority*' OR 'lead local flood authorit*' OR 'public bod*' OR 'risk owner')	39
2	('adaptive path*' OR 'adaptation path*' OR 'adaptive plan') AND (context OR background OR situation OR setting OR conditions OR circumstances OR perspective) AND (outcome* OR benefit OR success* OR delivery OR conclusion OR reaction OR result OR closure OR completion OR consequence OR development OR ending)	165
3	('adaptive path*' OR 'adaptation path*' OR 'adaptive plan') AND ((barrier* OR limit* OR hurdle OR impediment OR obstacle OR bottleneck OR deterrent OR difficult* OR disadvantage OR drawback OR restriction OR condition OR control OR restraint OR block OR constrain* OR weakness) OR (enable* OR facilitat* OR implement OR permit OR approve OR invest OR prepare OR aid OR ease OR expedite OR promote OR advocate OR benefit OR sponsor))	433

Search No.	Search protocol	Number of academic results
4	('adaptive path*' OR 'adaptation path*' OR 'adaptive plan') AND (monitor* OR evaluat* OR audit* OR advis* OR direct* OR review OR analysis OR check OR inspection OR report OR revision OR survey OR investigation OR study OR test OR examin* OR observ* OR instrument*)	624
5	('adaptive path*' OR 'adaptation path*' OR 'adaptive plan') AND ((engage* OR workshop OR co-production OR consultation OR commitment OR discussion OR management OR co-develop* OR interview OR 'focus group') OR (stakeholder OR collaborator OR colleague OR partner OR shareholder OR 'interested party' OR participant OR beneficiaries OR facilitators))	268
6	('adaptive path*' OR 'adaptation path*' OR 'adaptive plan') AND (policy OR regulation OR strategy OR administration OR legislation OR guideline* OR governance)	149
7	Dynamic adaptive policy pathway	21

The protocol was refined through an iterative process during the searching process. This ensured that the evidence being identified was relevant and there was sufficient volume and variety of literature available to answer the research questions.

In total 7 individual searches were conducted, collecting a total of 1,699 results. Once duplicate sources were removed a total of 377 results were considered to be relevant.

A.4.3 Grey literature search protocol

Following the academic search protocol, the grey literature search of sources used the same truncated search term of ('adaptive pathw*' OR 'adaptation pathw*' OR "adaptive plan"). It was decided to not use any secondary search terms as these were found to limit the search results to a prohibitive number that would not address the REA questions.

This grey literature search was supported by results provided by expert team members deemed to be of relevance (

Table 0.34).

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 Table 0.4
 Search protocol for grey literature sources. Source: Wood, 2020

Search No.	Search protocol	Number of grey literature results
1	('adaptive path*' OR 'adaptation path*' OR 'adaptive plan')	24
2	Provided by team members	27

No duplicates were found in the results and therefore all 51 results were taken forward to the assessment phase (section A.5).

A.5 Evidence assessment

Following the searching and screening of the evidence sources, the content of the evidence was reviewed by technical experts to ensure it was relevant to the REA questions. The process was systematic and rationalised, with information and decisions recorded at all stages for transparency in a database. This database can be made available on written request.

A.5.1 Phase 1: Abstract consideration only

In the first phase of the assessment all evidence sources were screened based on the title and abstract/executive summary only. Limited information on the source was collected during this process, including information on the sector considered, the study design, and availability of case studies. This was used to inform a prioritisation assessment to determine how relevant the source was to the REA. Based on expert judgement the phase 1 assessment identified if the evidence source could potentially be relevant to the REA and therefore should be passed to a full review of the content.

Decisions were collected on a shared project document and included the following questions to collect relevant data (Figure 0.2):

- **Document reference**: this will have been defined at the sourcing stage and allowed for easy identification
- **Reviewer name**: to increase transparency and allow for quality assurance checks
- **Preliminary information** included in the report: this would help the phase 2 assessment but was treated as preliminary as it is understood that this information may not always be visible in the abstract alone. It was used to inform the priority assessment of the review. Information collected included:
 - study design, for example, conceptual, theoretical, applied, modelled
 - types of case studies, for example, pilot, widespread, measured, none

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1	Doc Reg.	Sectors Covered	Is the evidence relevant to adaptive pathways in risk management?	What term best describes the study design?	Are case studies included in the evidence?	Phase 1 assessment	Reason for exclusion (if applicable)	
5 S	copus_040	Climate change	Yes	Policy-Oriented	Yes - widespread studies	Relevant - further review required		
6 S	icopus_041	Flood risk	Yes	Theoretical	Yes - small scale studies	Relevant - further review required		
7 S	copus_042	Coastal erosion	Yes	Theoretical	No useful case studies id	Relevant - further review required		
3 5	icopus_043	Infrastructure design	Yes	Applied	Yes - unknown category	Relevant - further review required		
3 S	copus_044	Climate change	Yes	Theoretical	Yes - regional studies	Relevant - further review required		
0 S	icopus_045	Climate change	Yes	Theoretical	No useful case studies id	Relevant - further review required		
n s	copus_046 copus_047	Multi sector	No	Theoretical	No useful case studies id	Clearly not relevant - no further review	Focus on pathways for economic development not climate change Psychology experiment and adaptive pathway	
2		N/A - source is not relevant to REA	Yes	Theoretical	No useful case studies id	Clearly not relevant - no further review	individual approaches	
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Figure 0.2 Database used for collating phase 1 assessment results of the REA. Source: Wood, 2020

- Phase 1 assessment of the evidence source: this ultimately determined whether the source was reviewed in phase 2 and was informed by the following questions:
 - is there evidence of the source addressing the key research question?
 - is the evidence source relevant? (relevant Phase 2 assessment required, clearly not relevant – no further assessment will be carried out)

Evidence sources that were determined to be highly relevant were progressed to the phase 2 review. Sources that were not relevant were not assessed any further and not used to inform the REA results.

Where an evidence source did not have an abstract or executive summary, a best expert judgement was made based on the available information in the document log. Throughout phase 1, reviewers took conservative decisions. This ensured that relevant sources of literature were not overlooked at this early stage or discarded in error.

All team member sources of grey literature were assumed to be relevant given their recommendation by experts involved in the project. These were therefore automatically passed to the phase 2 assessment.

In total 113 academic sources and 43 grey literature sources were deemed to be highly relevant and were taken forward for further assessment.

A.5.2 Phase 2: Full evidence source review

In the phase 2 assessment the full evidence source was considered. The main aim of this assessment was to determine whether the evidence source was relevant to the REA. The phase 2 assessment consisted of 3 sub-components that were carried out in sequence if the evidence source passed the above stage. Reviewers therefore read the whole document, and then assessed the evidence source for:

- relevance to the REA
- quality of the evidence source

• metadata extraction of the evidence

To assess the relevance of the evidence source to the REA, reviewers considered:

- the sector covered (for example, flood risk, forestry, health, infrastructure design)
- inclusion of case studies and the type of case study presented (for example, widespread, pilot, theoretical, modelled
- geographic location of the study
- scale of the adaptation pathway approach
- details of measurable outcomes of adaptation pathway approaches
- information on stakeholder engagement carried out during the project

Ultimately, this was used to determine whether the evidence source was relevant to the REA question. Only sources relevant to the REA were considered further.

To assess the quality of the evidence source, reviewers considered:

- the independence/authority of the author
- whether there is evidence of peer review or acceptance of criticism in the source
- whether underlying assumptions are explained and justified
- whether the methodology of the study is explained and repeatable
- the uncertainty of the results and how this has been included

Ultimately, this provided an assessment of the quality and robustness of the evidence source. The REA process favours appropriate sources of evidence that are transparent, robust and high quality. This assessment therefore determined which evidence sources should be considered as more authoritative in the final assessment.

Finally, for sources that were deemed relevant, metadata was collected from the evidence source. This was used to inform the critical appraisal and evidence synthesis. Information collected included:

- details on adaptation pathway approaches and their measurable outcomes
- details on barriers, enablers or limitations of adaptation pathways
- comparison of adaptation pathway approaches compared to conventional techniques
- details on monitoring or evaluation of adaptation pathways
- content specific to flood or coastal erosion risk management
- specific case study details of adaptation pathway approaches
- examples of stakeholder engagement within the adaptation pathway project

Quality assurance reviews were carried out by experts in adaptation pathways on ~10% of identified relevant sources. The metadata extraction was determined to pass the quality assurance checks.

Appendix B: Interviews

B.1 Introduction and interview aim

To support the rapid evidence assessment (REA) a series of interviews was carried out with experts in adaptation pathway approaches. These interviews supported the appraisal of information provided in the REA and filled gaps in knowledge where published literature did not exist.

The interviews targeted a cross section of academics, practitioners and policy makers to seek representative views from different sectors (Table 05). Note some of the interviews included multiple stakeholders who were grouped in their profiles to maintain anonymity. The experts were drawn from the project team, SME wider professional network and supplemented with contacts provided by the Environment Agency.

ID	Sector	Position	Reason for targeting
1	Practitioner	Project manager	Experience of implementing an adaptation pathway project within the UK (Climate Ready Clyde).
2	Policy maker	Policy manager	Experience as a stakeholder in the TE2100 Project and also experience of policy making on adaptation strategies.
3	Industry	Programme manager	Pioneering adaptation pathway approaches in industry strategies for a major water company.
4	Community stakeholder	Project beneficiary (charity)	Experience as a stakeholder in Adaptation Pathways in Somerset (APIS) Initiative.
5	Academia	Knowledge exchange manager, independent body providing advice to government	Recent experience of research on adaptation pathways with a policy focus for governments.
6	Practitioners	Project advisors	Experience of implementing an adaptation pathway project within the UK (Thames Estuary 2100). Involvement in the review and monitoring phases.
7	Practitioner	Engagement advisor	Experience of implementing an adaptation pathway project within the UK (Thames Estuary 2100). Involvement in the engagement process for project stakeholders.

 Table 0.5
 Interviewees targeted for expert insight into adaptation pathways

ID	Sector	Position	Reason for targeting
8	Policy maker	Strategy advisor	Experience of strategy development for adaptation pathway approach at a national level, including work with local governments and NGOs.
9	Researcher	Researcher on adaptation pathways	Experience of acting as a knowledge broker to involve stakeholders in projects and experience of developing policy at a national level offering guidance on adaptation pathway approaches.

The interviews followed a semi-structured format allowing for open discussions led by topics of relevance to the experience/knowledge of the interviewee, with the questions asked tailored to the interview situation and context. To ensure consistency, and to capture relevant details for the project, a framework was developed to highlight key themes that should be explored within the interviews. Example questions were provided to interviewers to be used as prompts.

Interviews were conducted via telephone/Skype meetings between 24 February and 12 March and lasted approximately 40 to 60 minutes.

The framework (section B2) provides a list of topics and example questions that the interviewer aimed to cover during the interview. It should be recognised that the interviewer could deviate from the guide where appropriate at their discretion.

B.2 Introduction and interview aim

B.2.1 Qualitative interview introduction

Interviewer should introduce themselves.

Interviewer should introduce the project: The purpose of this project is to conduct a rapid evidence assessment (REA) to assess the current state of knowledge and best practices covering adaptation pathway approaches applied in risk management. The results of this project will provide robust evidence to inform future policies, including providing evidence to underpin the implementation of the Environment Agency's flood and coastal erosion risk management (FCERM) strategy.

Interviewer should state the goal of these interviews: This interview forms part of a series of expert interviews designed to capture insight and knowledge based on practical experience from those involved in adaptation pathway projects. The interviews will be used to supplement the results of the REA and help with the critical appraisal of information obtained from the published literature.

B.2.2 Verbal consent

Interviewer should obtain verbal consent from the interviewee that they consent to be involved in the project and for their views to be used in the project report.

Interviewer should obtain verbal consent from the interviewee that they consent to the interview being recorded and used by the project team only. The recording will be deleted on completion of the project. An interview summary will be included in the publicly available report, although this, and all references to the interview, will be anonymous. We will share the interview summary with the interviewee before publication.

B.2.3 Background information

Invite the interviewee to briefly tell you about themselves.

Prompts questions include:

- Please provide some general information about your background and experience of adaptation pathways
- What are your perspectives on adaptation pathway approaches?

B.2.4 Experience of adaptation pathway projects

Invite the interviewee to discuss their experience of adaptation pathways, referring specifically to case study examples that they have been involved in.

Prompt questions include:

- Was the experience positive or negative?
- What was your expectation of using adaptation pathway approaches before the start of the project and were these realised during the design and implementation of the project?
- What were the advantages and enablers for using adaptation pathway approaches in your project? Was there a benefit compared to conventional approaches?
- Did you identify any barriers associated with adaptation pathway approaches? What were they and how were they overcome?

B.2.5 Gaps in the published literature

Invite the interviewee to provide insight on issues that have been identified as gaps in the published knowledge. These issues include (prompt questions are provided):

Extreme climate scenarios were often found to be excluded from adaptation pathway future scenarios analysed

- What is the most extreme climate scenario you used?
- Why was this value/year/scenario selected as the extreme? Does it represent the most extreme value that could realistically occur?
- Would you consider more extreme values in future projects, why/why not?
- What processes are in place through the monitoring phase (or other) of the project for dealing with more extreme climate scenarios in the future should they occur?

Enablers of adaptation pathway techniques

- What factors would encourage people to use adaptation pathway approaches?
- Do facilitators of adaptation pathway approaches need any additional information to encourage uptake of adaptation pathway approaches?

The role of policy in driving adaptation pathway techniques

- Could policy play a role in increasing adoption of adaptation pathway techniques?
- If so, how and what types of policy? What level would the policy need to be (local, national), would it be statutory or non-statutory? Would guidance be needed?
- What support do facilitators/participants in adaptation pathway projects need, for example, guidance, training, financial support, monitoring support?
- Should policy mandate the climate scenarios that are considered in adaptation pathway approaches?

Contexts and settings where adaptation pathway approaches are effective

- The literature had a bias towards coastal, urban areas. Do you think there is a reason for this bias?
- Are there specifications in terms of context (geography, hazard, population, and governance) required for adaptation pathway approaches to be successful?

Monitoring and evaluation approaches

- What are your experiences of monitoring and evaluation approaches?
- Were there challenges setting up monitoring and evaluation approaches?
- What are the challenges associated with monitoring complex variables, often with a lot of variability?
- How effective is the monitoring approach likely to be in terms of determining adaptation options and selecting new pathways?

B.2.6 Stakeholder engagement

Invite the interviewee to share any thoughts on stakeholder engagement within the projects that they have been involved in. This line of questioning will depend on their role in the project as either a facilitator or stakeholder.

Prompt questions for facilitators:

- How were stakeholders identified and when were they engaged?
- What value did the stakeholder bring to the project and decisions made?
- Will the stakeholders be engaged throughout the project?
- Do you believe there was buy-in to the project from the stakeholders?
- Do you feel the engagement was successful?

Prompt questions for stakeholders:

• How did you become aware of the project and at what stage of the design?

- Do you feel the engagement was successful, why/why not?
- What value did you add to the project?
- Do you feel the engagement was successful?
- Could anything have been done differently to increase your involvement or buyin to the project?

B.2.7 Conclusion

Ask whether the interviewee has anything else to add that hasn't already been discussed.

Thank the interviewee for participating.

Reiterate how this interview series will feed into the rest of the project.

Explain that the results are expected in spring 2020 and will be published on the Environment Agency's website. Once available, the final report will be made available to all interviewees.

B.2.8 Interview summaries

Following the interview, the interviewer should note any impressions, extra details or thoughts that stood out.

All relevant information discussed should be written up into an anonymised interview summary.

B.3 Interview summaries

This **technical annex** is available from the Environment Agency on request and with the authors' permission.

Appendix C: Somerset Project report

This **technical appendix** is available from the Environment Agency on request and with the authors' permission.

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