Coastal Erosion and Climate Change

Guidance for Policymakers, Planners and Stakeholders
August 2021

Jacobs

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A severe winter storm in 2013/14 attacks the coastline of Cornwall, UK, at Porthleven. An increase in more unsettled weather patterns is a predicted trend as a result of climate change. **Courtesy:** carlaregler.com.

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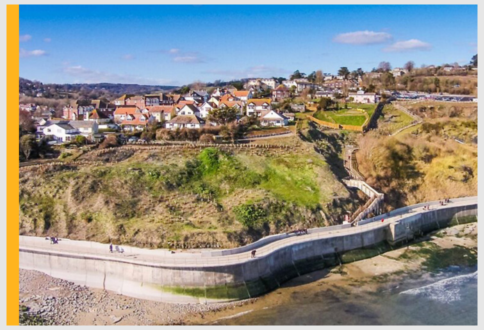
Main Picture: Storm Waves at Porthleven, Cornwall, winter 2013/14. Courtesy: carlaregler.com.

Images below (Left to Right): Knipe Point, Yorkshire, UK. Roger Moore; New coastal protection at Lyme Regis, Dorset, UK. Roger Moore; Malé, Maldives. Courtesy: Shutterstock Images/Klempa.

Knipe Point, Yorkshire, UK. Roger Moore;



New coastal protection at Lyme Regis, Dorset, UK. Neil Bigwood

Malé, Maldives. Courtesy: Shutterstock Images/Klempa.

Climate change, including the melting of the polar ice caps, is predicted to raise sea levels by over 1 metre, or significantly more, by the end of this century. **Courtesy:** Stephen Lee/Wight Light Gallery.

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Foreword

This guide fills an important gap in the toolkit of coastal managers and those responsible for the safety of coastal assets and communities. Coastal erosion and instability are often overshadowed by flooding in terms of profile and awareness as flooding tends to impact more people. However, the impact of erosion is catastrophic on those affected. Homeowners and businesses can lose everything, often uninsured, with knock-on impacts on the economy and welfare of affected communities.

I grew up on the Lizard Peninsula in Cornwall, just a few miles from Porthleven which provides the dramatic cover image for this report. Little surprise that I was drawn to coastal geomorphology and into a career in coastal risk management! The Lizard coastline is generally sparsely developed, but loss of clifftop land is an increasingly regular occurrence, with the heavily used coastal path frequently rerouted and built assets often impacted. Restoring the path and other affected infrastructure is a costly undertaking for the agencies and organisations responsible, but essential for access to the coast which is key to the local tourism economy.

This is a situation mirrored in coastal areas worldwide. Actions to prevent coastal erosion or instability are typically very costly, and often cannot be justified by the value of assets at risk and the potential negative environmental impact of protection structures. This leaves authorities, communities and individuals with the challenge of managing the risk which gradually increases over time. The safety and wellbeing of those potentially exposed to these hazards is of paramount importance, but in many jurisdictions, as discussed in this guidance, authorities have few tools with which to directly mitigate these hazards.

In the face of these challenges, it is vital that we support those potentially exposed to erosion and instability hazards with the best possible understanding of their exposure, to enable pro-active decisions on how best to manage the risks, leveraging all available tools and resources. In the UK, our work on Shoreline Management Plans provides a structured process whereby long-term coastal hazards are identified and risk management policies defined. These do an excellent job of presenting the science and engaging widely to raise awareness. However, there remains much to be done to best support those for whom the adopted plan identifies a long-term potential for coastal erosion to impact their home or business.

Regardless of our ability to reduce global emissions, we know that climate change and sea level rise are long term realities for coastal communities, which will increase the risks of erosion and instability. Ensuring policy makers, planners and all stakeholders are aware of these risks and taking early positive action to manage their impact is essential. This guide provides an excellent resource to inform that process and drive best possible outcomes for coastal businesses and communities.

Adam Hosking
Global Director for Water Resources and Resilience

Winter Storm Riley batters the eastern seaboard of the USA in September 2018. Courtesy: **Shutterstock Images/**Harry Andreson.

Preface

Climate change is one of the most significant issues affecting modern society. Jacobs recognises 'Climate Change' as one of the major global transformative trends challenging the status quo. As such, the aim of this guide is to share Jacobs' commitment to fully understanding the interplay of multifaceted variables shaping the future, ensuring that we conceive and deliver sustainable solutions that protect people, places and critical infrastructure, making an enduring, positive difference in the world.

In the UK, projections of future climate indicate hotter, drier summers and warmer, wetter winters combined with an increase in the frequency of extreme weather events, such as heavy rainfall, storms and heat waves; furthermore, sea level rise of up to 1 metre is predicted by the year 2100 for low to medium emissions scenarios, and up to 2.5m for extreme scenarios (e.g. UKCP18). These predictions will have serious consequences for cities, communities and infrastructure located at the coast due to the impacts of coastal flooding, erosion and cliff instability.

The adverse consequences of coastal hazards and climate change are a global issue. They pose significant challenges for jurisdictions and decision-makers involved in both planning and risk management and for affected communities and businesses. Escalating costs and financial constraints may mean that it will not be possible to fund mitigation measures for the increasing number of communities and infrastructure affected by natural hazard events. This will necessitate innovative approaches for the avoidance of risks through the implementation of adaptation strategies, future-proofing civil designs and sharing good practice advice and guidance for governments, policymakers, utilities, developers and local communities.

An appreciation of the physical and geological conditions affecting a state or territory can contribute to sustainable development by helping policymakers and planning officers understand the constraints imposed on developments by the physical environment; for example, as a result of the impacts of erosion, cliff instability, flooding and human activity in coastal zones. Background research has highlighted the vital importance of effective links between engineers and planning officers at regional and local levels in order to reduce the risks to people, development and infrastructure from natural hazards, such as coastal flooding, erosion and landslides.

The nature of problems relating to planning policy in local and regional government has been voiced to the authors at meetings with UK Coastal Groups and government planning officers. They report reductions in public expenditure combined with changes to planning policy guidance have weakened significantly both the technical and the planning input to sustainable policymaking and, hence, coastal hazard risk reduction in the face of climate change. Discussions with stakeholders at international conferences involved in coastal risk management and planning in France, Italy, the Netherlands and the USA suggest that this is a wide-ranging, worsening problem that is not exclusive to the United Kingdom.

Professor Roger Moore
Global Technology Leader
Geoscience & Engineering Geology - Jacobs

The Yorkshire coastline of north-east England at Skipsea lies within one of the fastest retreating coastal frontages in north-western Europe. Over the last thousand years the coast has retreated by over 2 kilometres with the loss of over twenty-six villages.
Courtesy: Shutterstock Images/Peter Yeo

Executive Summary

Many organisations involved in coastal management across the world have long-standing experiences of addressing the risks arising from coastal erosion, landsliding and inundation by the sea. However, the predicted impacts of climate change at the coast, that have long been anticipated, are now with us and are becoming increasingly severe. In fact, many regard climate change as potentially one of the most serious threats to humanity, with far reaching and devastating impacts on coastal communities, infrastructure, natural environments and economies. "Climate impacts affect all regions of the world and cut across all sectors of society. People who do the least to cause the problem, especially those living in poverty and fragile areas, are sometimes most at risk" (Global Commission on Adaptation, 2019[1]). In Europe alone, the economic value of coastal areas within 500 m of the sea amounts to up to €1,000 billion. The costs of doing nothing to mitigate the effects of climate change in coastal zones are estimated to be significantly higher than the annual costs of taking actions, whilst the net benefits of adapting to these changing conditions can often represent a far more beneficial approach in terms of sustainable coastal economies and environments.

In England, the predicted impacts of climate change on the coast include rising sea level of over one metre by the end of the century and, potentially, up to 2.5 metres (Edwards 2017[2]). The frequency of intense storm events might also increase and alongside rising sea level the consequence will be far more extensive coastal erosion, flooding and resulting impacts. In the UK, over half a million properties, including 370,000 homes, are located in areas of significant risk from coastal flooding, whilst nearly 9,000 properties may be at risk from coastal erosion; this figure could double by the end of the century. Apart from properties, critical infrastructure including nuclear, oil and gas terminals, ports and harbours, roads, railways, landfill sites and cultural heritage assets are likely to be lost unless appropriate actions can be taken. Along soft and unstable cliffs, a further 100,000 properties could become increasingly at risk from erosion and landslides (Jacobs, 2018[3]; Committee on Climate Change, 2018[4]).

Across Europe, the European Commission took the lead in promoting integrated coastal zone management (ICZM) in the 1990s, and this approach has since become well established in many countries (European Commission, 1999[5]; 2002[6]). The concept of shoreline management planning, aimed at providing a long-term, forward-looking strategy for managing coastal risks, has been developed and widely implemented in the United Kingdom; since then extensive technical and non-technical guidance has been published in support of these approaches (Burgess et al., 2004[7]; Defra, 2006[8]; McInnes & Moore, 2011[9]; 2014[10]). However, many of these coastal policy initiatives are non-statutory and provide guidance in contrast to planning systems, which are usually statutory. Globally, the rate and scale of change that is now being experienced, and which is widely expected to increase significantly in the next decades, demands closer integration between the coastal management and planning disciplines, both at the national policy level and, particularly, at the local government level.

Whilst the protection of cities, towns and key coastal infrastructure is likely to be maintained or enhanced in the face of climate change, it is becoming increasingly obvious that some coastal management policies, which have sought to manage risks through traditional approaches such as civil engineering measures, may prove to be unsustainable in the future. New strategies are, therefore, required which focus on adaptive management; this requires coordination between the coastal engineering and planning disciplines at the local level. For this reason, this new guide is aimed at those with an interest in coastal planning in local government, both councillors and planning officers, involved in the development and implementation of planning policy and development control. The setting of new policies and approaches to coastal risk management through close working with stakeholders is fundamental and this guide illustrates, through a range of international case studies, examples of approaches that can offer transferable opportunities, experience and lessons learnt.

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The coastline has formed a convenient location for the siting of important highway and rail infrastructure for over one hundred and fifty years. However, coastal routes are proving increasingly vulnerable to the impacts of coastal storms such as here on the coast of southern Thailand.
Courtesy: Shutterstock Images/Manun Tapkul

Key Conclusions and Recommendations

1. It is now widely accepted that climate change and sea level rise are already posing significant challenges for coastal communities in vulnerable locations across the world. The impacts of climate change necessitate even closer integration between coastal risk management, planning policy and development control particularly at the regional and local levels.
2. A thorough understanding of long-term coastal evolution, including the rate and scale of change, is necessary in order to inform planning policy-making. The shoreline management process supported by coastal monitoring programmes allow the identification of those frontages where coastal defence is likely to be a sustainable policy option and those parts of the coast where adaptive management or no intervention are the preferred alternatives.
3. In the UK, the Environment Agency's Shoreline Management Planning is undergoing a refresh and Jacobs is undertaking 'Health checks' of the individual SMPs. Jacobs is also developing specific guidance on coastal risk management for English and Welsh authorities which includes planning and engineering disciplines and relevant stakeholders. Explicit guidance on climate change, adaptation, management triggers and planning policy is being developed.
4. It is particularly important to continue to promote coastal research and to gather data of all kinds in order to better understand the potential for erosion, landsliding and flooding. This information will help to prevent disasters through the identification of trends and the development of appropriate early-warning systems, which should be embedded in coastal risk governance.
5. Greater resilience for coastal communities can only be achieved through continuous dialogue between local authorities, NGOs and stakeholders including businesses and residents.
6. Planning for coastal change must ensure that any new developments are located outside areas identified as being at risk from coastal hazards. Some modest and shorter-term development may still be possible in 'Coastal Change Management Areas' (as defined in planning policy).
7. The international case studies illustrate a range of approaches to adaptive management on the coast; these initiatives nearly always involve state financial support for regional/local funding initiatives.
8. Coastal hazards (erosion, flooding and landsliding) are increasing globally as a result of climate change and sea level rise. Closer links between coastal risk management and coastal planning policy are essential in order to ensure safe and sustainable development over the next decades.

Residents of Kiribati provide rudimentary defences against rising sea levels.

Courtesy: Alamy Images Ltd.

Jacobs has been working on an award-winning land reclamation and land use planning programme to protect developments against sea level rise up to the year 2200.

9. A thorough understanding of long-term coastal evolution is an essential requirement in order to support planning for coastal change. Full advantage should be taken of valuable historical data alongside a range of new technologies to better understand the potential for change over time.
10. For physical, economic or environmental reasons it may not be possible to continue to maintain or improve coastal defences. Along these 'Coastal Change Management Area' frontages planning policy should define acceptable usage of the land and impose time limits for land use as required.
11. A range of approaches to the management of coastal change have been described in the case studies. These include improved coastal defence measures, coastal realignment, natural defences and habitat creation, compulsory purchase and compensation, land banking and the relocation of small communities. The solutions described offer wide transferability value. Further information on each of the case study sites can be found in the references provided at the end of each chapter in this report.
12. Over the last decade as a result of the global economic downturn local government has seen significant reductions in funding and loss of specialist staff in the coastal engineering and planning disciplines in particular; this needs to be addressed.
13. Local authorities have often been supported by specialists from coastal consultancies who benefit from longstanding experience of all aspects of coastal management.
14. Jacobs will continue its commitment to fully understand the interplay of multi-faceted variables shaping the future, ensuring that we conceive and deliver sustainable solutions. In this way protecting people, places and critical infrastructure, making an enduring, positive difference in the world.
15. There is no doubt that the impacts of future sea level rise and climate change will see an increase in the frequency and scale of coastal hazard impacts. Effective mitigation will require action by governing bodies at global, national, regional and local levels. Critically, it is imperative that strategic coastal plans and decision making is based on a long-term (100+ years) view and is fully informed by appropriate technical studies and monitoring programmes. In this way decisions for development planning and building control will safeguard development, infrastructure and operations and coastal communities. In many cases this will require innovative approaches for the avoidance of risks through the implementation of adaptation strategies, future-proofing civil designs and sharing good practice advice and guidance for governments, policymakers and local implementation.
16. It is vitally important that effective links between engineers and planning officers at regional and local levels are fostered in order to reduce the risks to people, development and infrastructure from natural hazards, such as coastal flooding, erosion and landslides.

Part of the Undercliff, Isle of Wight, UK, which is the largest urban landslide complex in north-western Europe. Jacobs (formerly Halcrow has a longstanding involvement working with the local authorities at this site including the development and implementation of a Landslide Management Strategy.

1.0 Introduction to Coastal Land-Use Planning

Many of the world's major cities and towns are located within coastal zones including estuaries and floodplains and are occupying land less than 10 metres above sea level. Coastal populations, especially Small Island Developing States (SIDS), are highly vulnerable to the impacts of sea level rise, extreme weather events, coastal erosion, cliff instability and flooding. They are, therefore, at the front line in terms of coastal change impacts. As the global community negotiates, Carbon Dioxide continues to be emitted at an ever-increasing rate. Oceans across the world, as a result, have experienced an increase in acidity, warming, altered circulation patterns and sea level rise; weather patterns and precipitation events have also intensified. These changes will continue to escalate and are leading to a significantly increased frequency of hazards and risks for coastal residents, homes and commerce, infrastructure and economic prosperity in coastal zones more widely. Such impacts heighten the urgency to develop appropriate response measures, taking strong mitigation actions, and implementing innovative adaptation measures (Committee on Climate Change, 2018[1]).

In Europe, the challenge of coastal change is being addressed through integrated and ecosystem-based approaches and instruments, such as integrated coastal zone management (ICZM). These have proved crucial in terms of building the foundations for sustainable coastal management and development, supporting socio-economic development, biodiversity and ecosystem services. Integrated coastal zone management is, therefore, an acknowledged tool to address current and long-term coastal challenges, including coastal hazards and climate change and its impacts. In turn, this has led to the development of national integrated coastal management strategies, which have implemented different principles and tools to respond to these challenges; adopting a long-term perspective with precautionary principles, adaptive management, accounting for diversity of local conditions, working with natural processes and ensuring coherence between planning and management (Environment Agency, 2017[2]; Pontee & Parsons, 2010[3]).

Ecosystem-based adaptation approaches (e.g. World Bank 2017[4] and EWN network[5]), that encourage the preservation and restoration of coastal ecosystems as natural buffers, some of which are already being implemented as part of ICZM efforts in many coastal nations, must be strengthened and promoted to increase the resilience of coastal ecosystems and communities against the impacts of coastal hazards and climate change. However, many nations lack the capacity to implement adequate adaptive measures. Coastal local authorities, therefore, are faced with an increasingly complex task of balancing development interests and managing long-term coastal risks. Given the combined effects of further human development at the coast and impacts of climate change, coastal erosion, cliff instability and flooding, these problems are of growing intensity.

Across the world governments are increasingly committed to ensuring that planning policies help communities to adapt to the risks arising from climate change. Land use planning, therefore, has a vital role to play in helping coastal communities, infrastructure development and operations, and businesses to manage risk and adapt to these changing conditions.

The planning system, which is often a statutory function for local government, will, inevitably, have an increasingly important role to play in policy-making, strategic planning and day to day planning and development control on the coast.

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Introduction to Coastal Land-Use Planning

Figure 1.1
Stephen Lee/
Wight Light Gallery

Contrasting images of coastal zones with differing management requirements in France on its Atlantic and Channel coasts. The coastline at La Baule-Escoublac (Figure 1.1 above) has a fine 9 kilometre sandy beach backed by intensive holiday developments, whilst the Bay of Mont St Michel, Brittany (Figure 1.2 below), has retained its natural environment. A major project has seen the replacement of an access road and car park at this World Heritage Site with a monorail, which has allowed the restoration of natural sediment processes within the Bay.

Figure 1.2
Shutterstock Images/
jrossphoto.

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Introduction to Coastal Land-Use Planning

Figure 1.3
Medmerry, West Sussex, is the largest coastal managed realignment scheme on the open coast in the UK. It is sited on the west side of the Manhood Peninsula, which juts out into the English Channel south of Chichester. This is a flat coastline protected by shingle beaches, which are vulnerable to breaching and overtopping in storm conditions, resulting in regular flooding by the sea. Rather than building up the beaches to ever higher levels, as sea levels rise, the UK Environment Agency decided to work with nature.

The scheme involved building up some 7 kilometres of new earth walls inland, breaching the existing shingle beach and forming a large new saltmarsh habitat. This helps to absorb wave energy and manage flood risk for three hundred and fifty homes, two holiday parks, and a sewage treatment works. It also provides important compensation for loss of intertidal saltmarsh habitat elsewhere, allowing other flood defence schemes to be built around the Solent.

The new habitat is now a Royal Society for the Prevention of Birds (RSPB) Reserve with extensive walks and cycle tracks for people to enjoy, and benefits for local businesses. It is a model for win-win climate change adaptation, combining improved flood defences with new natural habitats and opportunities for recreation and business at the coast.

The £28 million Environment Agency scheme was constructed from 2011 to 2013. At all stages, the scheme was developed in close consultation with a stakeholder group embracing a wide range of local interests.

Source: www.gov.uk/government/publications/medmerry-coastal-flood-defence-scheme.

Image courtesy: Environment Agency.

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Introduction to Coastal Land-Use Planning

Figure 1.4
Fistral Beach at Newquay, Cornwall, UK, during a winter storm. Effective coastal management is essential in order to ensure sustainable futures for seaside resorts. However, such management can be a complex process involving engagement with a wide range of consultees as illustrated in Figure 1.5. (below).
Image courtesy: Shutterstock Images/ Helen Hotson.

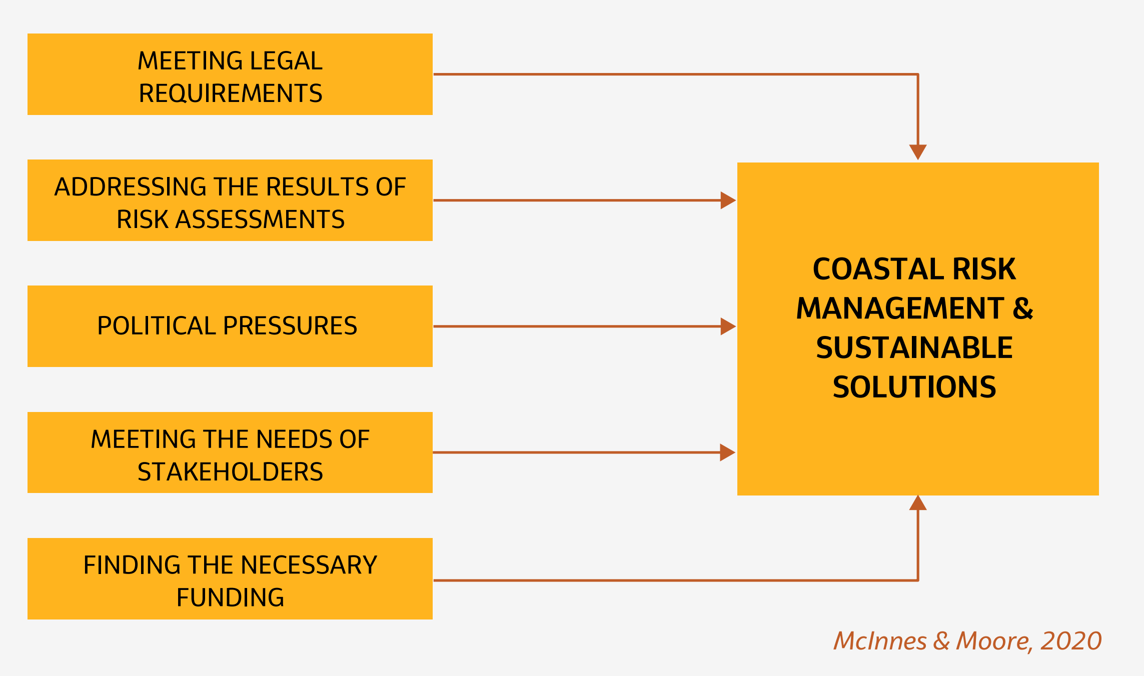

Figure 1.5
Effective coastal management involves the reconciliation of a range of demands including the legislative requirements, political pressures, the needs of the population and sourcing the necessary funding for implementation.

This guide has been designed and written in a non-technical style to assist those particularly in local government planning departments, who are incorporating policies for the management of natural and man-made coastal hazards within their planning frameworks and strategies, as well as supporting the assessment of coastal development proposals seeking planning consent. The guide will also be of value to politicians and councillors involved with planning matters, technical officers in local government, relevant non-governmental organisations (NGOs)

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Introduction to Coastal Land-Use Planning

and, importantly, affected coastal communities and businesses, who all have important roles in achieving successful coastal management (see Figure 1.6 below).

In many countries, the effects of the global financial crisis over the last decade has often led to a reduction in funds available for coastal risk management and adaptation initiatives. Together with escalating costs, this has meant that it has not been possible to fund mitigation measures for the increasing number of communities affected by natural hazard events; this situation may continue into the future. As a result, coastal management will necessitate more innovative approaches to the avoidance of coastal hazards and risks through the implementation of adaptation strategies and the sharing of improved tried and tested advice and guidance for policymakers for implementation at the local level.

Coastal hazards and risks have been addressed in some nations for over three decades. The Coastal Zone Management Act was adopted in USA in the 1970s, and in the UK preparation of shoreline management plans (SMPs) started in the 1990s, which have offered a long-term approach to the management of coastal risks. Through collaboration between coastal networks and groups, usually involving coastal engineers, environmental and heritage bodies as well as planning officers from local government, a more co-ordinated approach to risk management has been developed in some nations; in England, for example, the second round of SMPs are currently under review (Jacobs, 2018[6]). Notwithstanding the success of SMPs in the UK, it is evident that a more detailed and integrated approach to adaptive management around the world's shorelines will be essential to meet the coastal hazard and climate change challenges in the future.

The role of planning in local government should encourage a proactive approach to mitigating and adapting to coastal climate change, considering the long-term implications for coastal flooding, cliff instability and erosion risk. The development of policies that support future resilience of coastal communities and infrastructure to climate change hazard impacts, such as providing space for physical protection measures, or making provision for the possible future relocation of vulnerable developments and infrastructure, should be embedded firmly in local government planning policy. In particular, lessons should be learnt from past mistakes and development should be planned and designed in ways that avoid increased vulnerability to the range of coastal hazards and climate change impacts that have been described.

Figure 1.6

The seaside resort of Filey, North Yorkshire, UK, developed from the 1880s with visitors attracted by its fine sandy beach. Like many coastal towns it is protected by a seawall along its developed frontage. The maintenance and improvement of such coastal defences will be a necessity over future decades as a result of climate change and sea level rise. Jacobs has supported the Council in developing coastal strategy plans at Filey and elsewhere across the Borough (Moore et al., 2002[7]).

Image courtesy: Scarborough Borough Council.

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Introduction to Coastal Land-Use Planning

"The avoidance of risks through the development of adaptation strategies can bring multiple benefits for vulnerable coastal communities. These include the avoidance of losses and the ability of investments to reduce future losses, as well as positive economic benefits through reducing risks, increasing productivity and driving innovation all alongside the social and environmental benefits that can be gained from adopting adaptive coastal management" (Global Commission on Adaptation, 2019[8]).

A good example of the benefits of such an approach is provided by Hosking et al 2019[9], based on work in Belize commissioned to Jacobs.

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2.0 Coastal Erosion & Development - Key Considerations

Natural hazards have significant impacts on coastal zones across the world. The cost of emergency action, remediation and prevention can represent a significant burden to the state and communities affected, often local or regional authorities with limited resources, as well as for national governments. With the widespread evidence that the impacts of climate change and sea level rise are real, in particular posing increasingly serious risks to coastal communities and infrastructure, long-term policies are required to address the hazards of coastal flooding, cliff instability and erosion. Catastrophes resulting from these hazards are likely to increase also as a result of population and development growth in coastal zones, an increasing concentration of people and assets as a consequence of urbanisation, and the settlement and industrialisation of exposed coastlines. The future of some vulnerable coastal areas will become increasingly uncertain as sea level rise threatens, in some locations, to displace entire coastal communities and destroy their assets with severe disruption and economic impact to adjacent regions (see Figure 2.1).

At the highest level, the purpose of the planning system is to contribute to the achievement of sustainable development. Planning policies and decisions aim to promote the effective use of land in terms of meeting the needs of their nations, whilst safeguarding and improving the environment and ensuring safe and healthy living conditions. "Planning systems should also support the transition to a low carbon future in a changing climate, taking full account of the implications of coastal change. Planning should help to shape places in ways that contribute to radical reductions in greenhouse gas emissions, minimise vulnerability and improve resilience. Coastal planning should also take a proactive approach to mitigating and adapting to climate change, taking into account the long-term implications of flood risk, coastal change and their impacts on coastal environments" (MHCLG, 2019[1]).

Throughout the world governments are increasingly committed to ensuring that planning policies help communities to adapt to the risks arising from coastal flooding, erosion and cliff instability due to the impacts of sea level rise. Land use planning, therefore, has a vital role to play in helping coastal communities to manage risk and adapt to these changing conditions. In fact, land use planning is a branch of physical and socio-economic planning that determines the means and assesses the values or limitations in the way land can be utilised. Essentially, it involves studies and geo-spatial mapping, analysis of environmental and hazard data, and the formulation of land use decisions on differing geographical and administrative scales.

Figure 2.1
Key Terminology - Hazard, Vulnerability and Risk

Hazard - A threatening event, or the probability of occurrence of a potentially damaging phenomenon within a given time period or area.

Vulnerability - The degree to which a system is susceptible to, and unable to cope with, injury, damage or harm.

Exposure - The measure of potential future loss.

Risk - Expected loss (of lives, persons injured, property damaged and economic activity disrupted) due to a particular hazard for a given area and reference period. Based on mathematical calculations, risk is the product of hazard and vulnerability.

$$\frac{\text{Hazard} \times \text{Vulnerability} \times \text{Exposure}}{\text{Resilience or coping capacities}} = \text{Consequence Risk}$$

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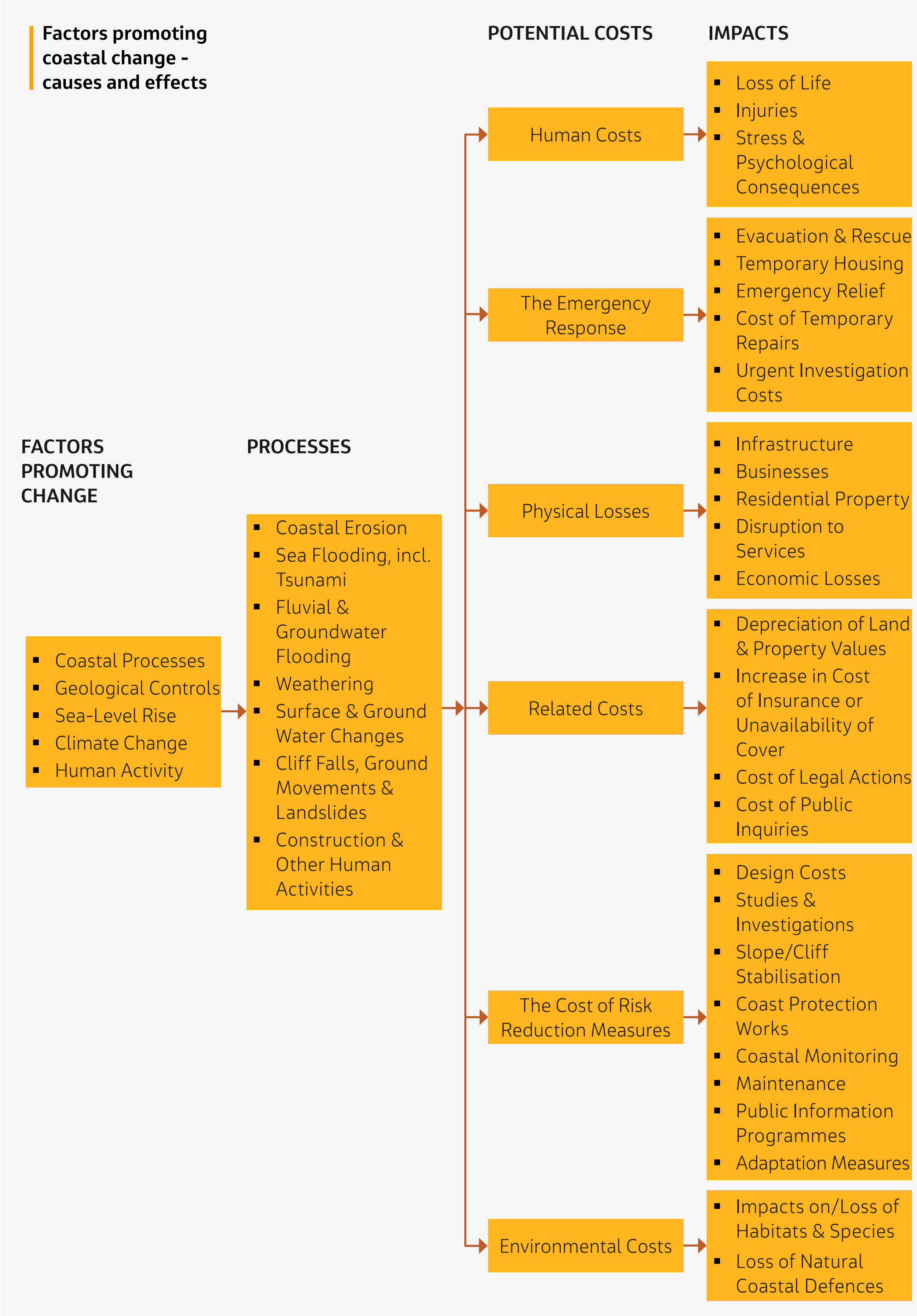
Coastal Erosion & Development - Key Considerations

Figure 2.2
Key Potential Human & Economic Consequences of Coastal Change, Hazards and Risks



2.0

Coastal Erosion and Development – Key Considerations

In order to reduce risks within coastal zones in the context of land use planning, assessments of hazard and vulnerability are essential tools to support improved standards and practice. Therefore, the introduction of natural hazard considerations into development, land use and urban planning reduces the accumulation of risk for coastal communities. The problems that communities now face across the world are largely a result of unsatisfactory land management and development, less resilient and poor construction practices, the increasing complexity of modern societies and inappropriate land use decisions in the past. If risk parameters are considered in development plans, then appropriate measures can be introduced to address the risks. This is equally important for large cities and other dense concentrations of population as well as for poor and marginalised settlements. In addition to ensuring better and safer use of land, the introduction of sound practices in land use planning and resilient construction will help to improve professional practice and ethics.

At the coast, planning is a systematic process that enables the identification and evaluation of hazards and the vulnerabilities of coastal settlements. Through the planning process, a programme of action can be prepared to initiate desired changes in the fabric and structure of coastal developments. In dynamic urban settings where fast-paced urbanisation occurs, together with economic progress, land use planning seeks to steer, or at least bring order to rapid land use changes by providing long-term goals and strategies and allowing inevitable changes to occur in a safe and sustainable manner. Planning supports coastal management because it focuses on modifying the vulnerabilities of developed areas instead of controlling the hazards, thereby supporting disaster mitigation, resilience and prevention.

A key issue of concern in areas affected by coastal hazards is the worsening of the situation as a result of climate change. Many coastal planning policy documents now support a risk-based approach towards managing the impacts of climate change by:

- ensuring proper consideration of the impacts of climate change in preparing regional and local plans, and in determining planning applications based on the use of an agreed evidence-base including, for example, rates of coastal erosion and sea level rise and potential changes in rainfall patterns as far as they are available;
- avoiding inappropriate development in areas that are vulnerable to coastal hazards and only allowing necessary development that is sustainable;
- implementing policies that can encourage much greater resilience to climate change for the future, including nature-based solutions wherever possible to enhance coastal ecosystems.

The varied geophysical and climatic characteristics of coastal zones make them susceptible to a range of extreme natural events. Natural hazards, such as erosion, flooding and cliff instability are common features of coastlines and have the potential to pose significant threats to the communities found within coastal zones. Operating on different timescales they present a varying degree of risk, coastal erosion being a relatively constant, low magnitude process, whilst flooding and landsliding are higher magnitude, episodic events that are relatively more difficult to predict and the consequences of these are potentially more costly as a result.

2.0

Coastal Erosion and Development – Key Considerations

Arctic	Northern Europe
▪ Temperature rise much larger than global average ▪ Decrease in Arctic sea ice coverage ▪ Decrease in Greenland ice sheet ▪ Increase in risk of biodiversity loss	▪ Temperature rise much larger than global average ▪ Decrease in snow, lake and river ice cover ▪ Increase in river flows to the coast ▪ Increase in damage risk from winter storms
North-Western Europe	**Mediterranean Region**
▪ Increased winter precipitation ▪ Increased risk of river and coastal flooding ▪ Increased rates of coastal erosion ▪ Increase in first time landslide failures and reactivations of dormant landslides	▪ Temperature rise larger than European average ▪ Decrease in annual precipitation ▪ Decrease in annual river flows ▪ Increased risk of desertification ▪ Increased risk of biodiversity loss

Figure 2.3
Different geographical regions will be affected in different ways by climate change. In Europe, for example, the observed and projected physical and environmental impacts of climate change for its coastal regions are described here. (*Adapted from European Environmental Agency, 2012*) Weblink.

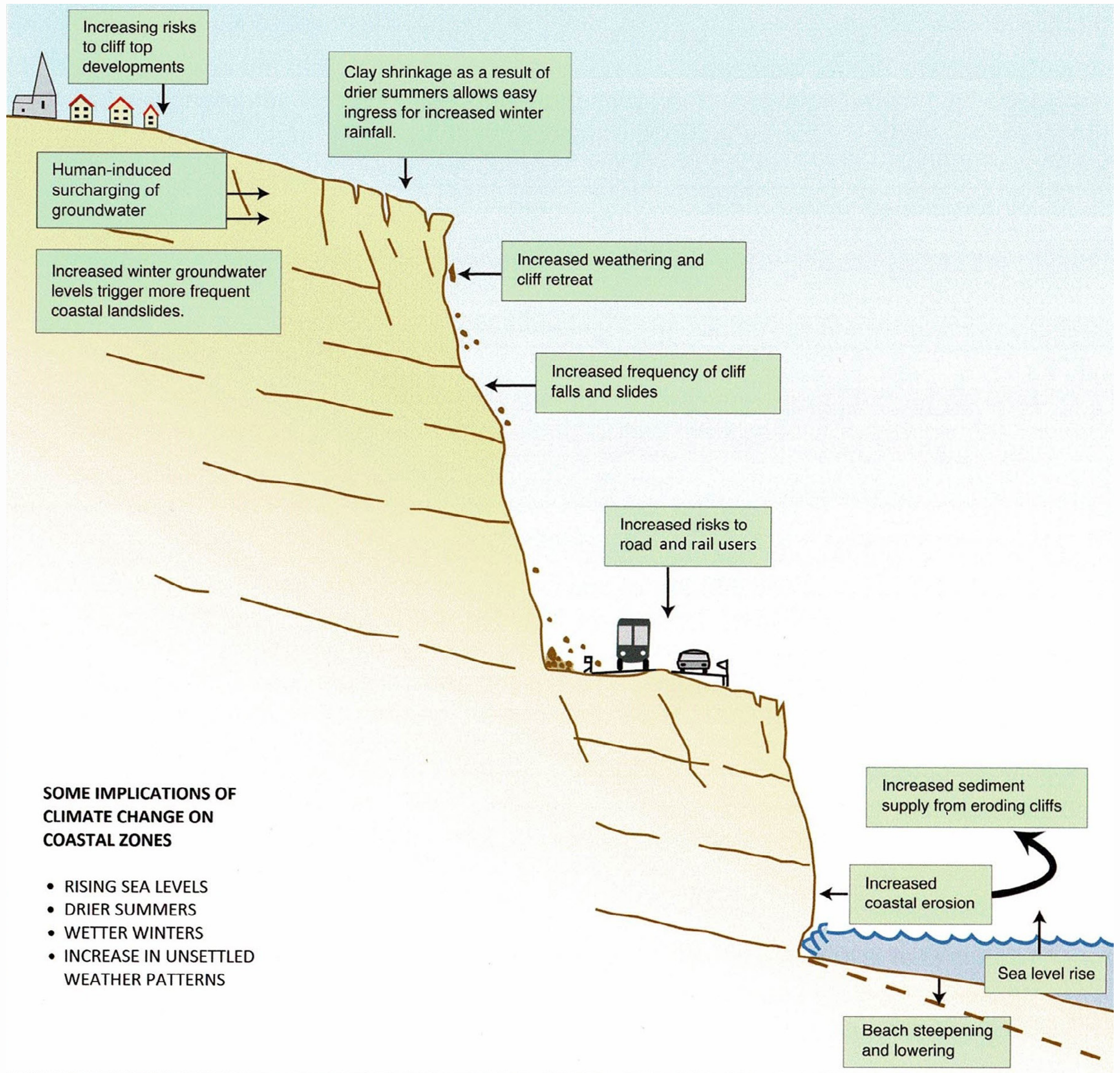


Figure 2.4
Some of the physical impacts of climate change on a developed coastal zone (McInnes & Moore, 2011).

2.0

Coastal Erosion and Development – Key Considerations

Figure 2.5
Regione Marche, on the east coast of Italy has faced problems of coastal instability for centuries. The slopes are affected by clay shrinkage, increasing winter rainfall, coastal developments, erosion and weathering. Coastal protection, drainage and other stabilisation measures have been built with a sophisticated coastal monitoring system.

2.1

Coastal Erosion

Coastal erosion is a natural and/or human-induced process, which is responsible for shaping the great variety of landforms we see around the coastline and is the process of removal and transport of material along the coastline. It's importance to the coastal environment lies in the fact that it provides a major source of sediment to a wide range of depositional features including beaches, salt marshes and sand dunes, which not only form very important natural defences, but also diverse natural habitats. However, the hazard of coastal erosion may result in a range of risks, including loss of life, property, infrastructure and land, and the destruction of natural and man-made defences, which may, in turn, result in flooding of the hinterland.

Figure 2.6
At Criel-sur-Mer along the Côte d'Albâtre, Normandy, France, rapid erosion posed a risk to cliff top properties. For economic and environmental reasons coastal defences were unsuitable, properties were demolished, and owners compensated under the provisions of the Barnier Law (see Case Studies 'France').

2.2

Cliff Instability and Landslide Hazard

Cliff instability and landsliding are significant and widespread problems around the world's coastlines. Often closely linked with coastal erosion, which can promote cliff instability or lead to the reactivation of historical landslide sites, such locations are likely to be increasingly affected by climate change through a combination of sea level rise and changes in weather patterns, including the volume of surface water and changing patterns of rainfall, which will raise groundwater levels (Moore et al., 2010[2]). In fact, the rapid expansion of coastal populations globally has increased the vulnerability of individuals and society as demand for housing and infrastructure spreads onto coastal slopes of marginal stability and this will, undoubtedly, continue. This is a particular issue for some developing countries where the availability of information, expertise, control of development and spatial planning may be weak or even non-existent. Even in developed countries there's a legacy of planned, unplanned or inappropriate development in coastal zones that are prone to, or increasingly at risk from ground movement and landslides (McInnes & Moore, 2014[3]).

Figure 2.7
The Dorset coast of south-west England, called 'The Jurassic Coast' and designated as a World Heritage Site on account of its outstanding geology and geomorphology, comprises long lengths of open coast where the natural processes of erosion and landsliding prevail. Smaller communities and important coastal resorts such as Lyme Regis benefit from coastal protection and stabilisation schemes (see Dorset Case Study).

Image courtesy: Roger Moore.

Jacobs

2.3

Coastal Flood Hazard

Around the world's coasts problems of nuisance flooding often result from a combination of peak sea levels, wave activity and storm surges. Sea levels are driven by tides, which are controlled by movements of the moon and planets, and surges result from air pressure changes and wind speeds on the ocean's surface. Tides, surges and wave action can be modified significantly by the shape and character of the sea bed in coastal locations. The worldwide expansion of the oceans caused by rising global temperatures and the melting of land-based ice are a significant concern in terms of increasing sea level in the future (IPCC, 2018[4], Karegar et al[5]).

Flooding can have severe impacts on people in terms of distress, injury or loss of life. Considerable demands are placed on the emergency and public services during such events. Coastal flooding can cause significant damage to property and developments, as well as disrupting businesses and other services. In England, for example, the challenge at the coast will be the need to adapt to at least 1m of sea level rise by the end of the century and managing flood risk when significant lengths of existing sea defences will be at risk of failure, overtopping or breaching over that timescale. The scale of the problem is illustrated by the fact that, in the United Kingdom, over 500,000 properties (including 370,000 homes) are located in areas potentially at risk from coastal flooding; this figure could triple by the 2080s (Committee on Climate Change, 2018[6]).

Addressing the Problem

Addressing the risks of coastal hazards and climate change in the future highlights the need for a significant level of expertise in terms of both technical officers and planners at the local government level. These increasing hazards and the resulting risks demonstrate the value of close collaboration between professionals both across local government and along longer stretches of coastline through collaborative networks and groups working in partnership with the key agencies involved with the full range of coastal management issues.

Figure 2.8

An aerial view of nuisance flooding caused by Hurricane Arthur on the Outer Banks, North Carolina, USA, on 4th July 2014. Arthur was the earliest hurricane ever to hit this location.

Image courtesy:

Alamy Stock Photos/ US Coastguard photo.

2.3

Coastal Flood Hazard

The planning system, therefore, has a key role to play in encouraging a proactive approach to mitigating and adapting to coastal change by introducing policies that ensure the resilience of communities and infrastructure to climate change impacts; thus, preventing consent of inappropriate development in high risk areas. Such measures can include the provision of physical protection, resilient design codes, the possible relocation of vulnerable developments and infrastructure, and, importantly, avoiding increased vulnerability to climate change impacts through the introduction of future-proof policies and adaptation measures.

In this respect, the close relationship between coastal risk management and the natural coastal environment is particularly important. Natural ecosystems are often the first line of defence against coastal changes, such as severe storm events and resulting flooding. For example, saltmarsh plants can reduce the height of storm surge waves by close to 20% (Möller, 2019[7]). Beyond this, the natural environment underpins economies and societies at many levels by providing food, water and supporting livelihoods, and removing carbon from the atmosphere to mitigate climate change.

A thriving natural coastal environment is, therefore, fundamental to the implementation of adaptation strategies. *"Maintaining a healthy coastal environment and avoiding environmental degradation reduces the vulnerability to climate change on the coast, particularly for those who depend directly on healthy ecosystems for their livelihoods. There is a significant opportunity to work with nature to build resilience and reduce climate change risk on all scales through adaptation initiatives, which are, typically, much cheaper than recovery and rebuilding"* (Global Commission on Adaptation, 2019[8]). To support such initiatives, Coastal Habitat Management Plans should be prepared to identify opportunities for nature-based solutions and habitat enhancements. These will also identify any requirement to protect designated habitats e.g. Natura 2000.

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3.0 Coastal Planning Policy and Risk Management - Guiding Principles

Globally, governments are increasingly committed to ensuring that planning policies help sustain communities to adapt to the hazards and risks arising from coastal change, particularly in the face of climate change. Land use planning has an important role to play in helping communities manage risk and adapt to these changing conditions. Being a branch of both physical and socio-economic planning, land use planning assesses the values or limitations in the way that coastal land can be used. This often involves a range of studies and baseline mapping, analysis of environmental and hazard data, formulation of land use planning options and design of a long-term plan for different geographical and administrative scales. Such plans should take a long-term view and proactive approach to mitigating and adapting to coastal change, considering the implications for coastal erosion, cliff instability, flood risk and the wider implications for landscapes and biodiversity. "*Planning policy should be developed with the objective of supporting appropriate measures to ensure the future resilience of communities and infrastructure to climate change impacts on the coast, such as coast protection measures or relocation of vulnerable development and infrastructure*" (MHCLG, 2019[1]).

In Europe, the European Commission has sought to improve the planning, management and use of Europe's coastal zones through integrated coastal zone management (ICZM). Many of Europe's coastal zones have faced problems of deterioration of their environmental, socio-economic and cultural resources. This led to a wide-ranging programme of studies and investigations, supported by the European Union, which embedded ICZM in national coastal policies and strategies (European Commission, 1999[2]; 2002[3]). Subsequently, as coastal and marine policies became more widespread, ICZM was developed further by coastal groups and networks involving local authorities and other stakeholders to try and ensure effective alignment across the land/sea interface and of the terrestrial and marine planning regimes.

Most local authorities are now taking coastal change into account when dealing with all planning applications within their geographical area (see Figure 3.1).

The approach generally involves:

- publishing clear policies for the coast alongside and incorporated within local development plans;
- publishing more specific advice relating to coastal change issues;
- developing policies that minimise vulnerability and provide resilience to climate change impacts at the coast;
- avoiding inappropriate development in areas threatened by coastal erosion, cliff instability and flooding directing development away from the areas of highest risk, or, where development is essential, making it safe without transferring the hazard elsewhere; and
- considering and identifying measures for managing any development at the end of its planned life, including proposals for removal of those developments before a site is threatened by significant changes and hazards.

The basic tools available for decision-making and risk management at the coast include:

- reducing the occurrence of potentially damaging events through active land management to lessen the magnitude and frequency of erosion, flooding and cliff instability;
- protecting against potentially damaging events using permissive powers to intervene and prevent coastal flooding and erosion or to protect cliffs and slopes through appropriate defence measures;
- avoiding vulnerable areas, such as through measures to control new development in areas of risk from natural hazards; and
- removing the risk by relocating developments away from higher risk zones.

In the United Kingdom the integration of coastal change policies in the planning system has been developed through an improved understanding of long-term coastal evolution and change. Well-established research has highlighted that the coastline consists of a series of interlinked physical systems, comprising both offshore and onshore elements (see Map 3.1). Sedimentary materials moved around the coast by waves and currents in a series of linked systems known as sediment transport cells. These generally comprise sediment source areas, such as eroding cliffs, rivers and the sea bed, areas where sediment is moved along the coast by natural processes, and sediment stores or sinks, such as beaches, estuaries or offshore sinks.

The mapping of coastal cells in England and Wales from the 1990s (Motyka & Brampton, 1993[4]) allowed the development of coastal groups or networks of local authorities and other interested bodies to oversee cell management in a co-ordinated way, and later saw the development of 'Shoreline Management Plans' (SMPs) (Defra, 2011[5]). Shoreline management plans in England and Wales, for example, have provided a framework for the assessment of the risks associated with coastal processes and have allowed the development of a policy framework for risk management in a sustainable manner.

Although non-statutory, the shoreline management plans have provided valuable advice to planning officers by identifying long-term policy aims, including those frontages that are likely to be susceptible to significant change looking ahead over the next century.

Jacobs is currently reviewing guidance for a further updating of Shoreline Management Plans (Defra, 2020[6]). By informing local development plans in this way, coastal policy-making and the development control processes are being made based on a scientific background (Figure 3.2). In Scotland, coastal cells have also been mapped and research has prioritised the need for Shoreline Management Plans in the context of climate change (Hansom et al., 2017[7]).

Shoreline management plans inform local government and the full range of stakeholders by providing information on coastal evolution and coastal risks and the suitability or otherwise for development on coastal land (Figure 3.1). In this way they can support the planning system, first at a sub-regional level by identifying those issues that need to be considered over a wider area than that of a single local authority, and, second, by informing the local planning authorities of areas at risk from flooding, coastal erosion and landslides over an extended timescale.

3.0

Coastal Planning Policy and Risk Management - Guiding Principles

Coastal Type	Local Plan Policy	Development Control
▪ Rapidly eroding cliffs ▪ Actively unstable slopes ▪ Unprotected low-lying areas ▪ Natural coastal defences (e.g. sand dunes) ▪ Very high-sensitivity coasts	Areas most unsuitable for development due to physical conditions. Planned development proposals subject to major constraints.	Should development be considered, it will need to be preceded by a detailed investigation, full risk assessment and/or environmental study. Many planning applications in these areas may have to be refused on the basis of potential physical problems.
▪ Eroding cliffs ▪ Potentially unstable slopes ▪ Low-lying areas with low standard of coastal defences ▪ Sand dunes ▪ Saltmarsh areas ▪ Foreshores in important sediment transport zones ▪ High to moderate sensitivity coasts	Areas likely to be subjected to significant constraints due to physical conditions. Local Plan development proposals should identify and take account of the nature of potential problems and address the requirements for suitable coastal defences.	A site reconnaissance study will need to be followed by a detailed site investigation, including a risk assessment and/or environmental study, prior to lodging a planning application.
▪ Areas behind eroding cliffs ▪ Problem ground conditions ▪ Estuaries ▪ Foreshores	Areas which may or may not be suitable for development, but investigations and monitoring may be required before Local Plan proposals are made.	Areas needed to be investigated and monitored to determine risks, sediment budget or sensitivity. Development should be avoided unless adequate evidence of suitable conditions is provided.

Figure 3.1
Generic planning policy guidance for different coastal types to support planning policy and development control (McInnes & Moore, 2011).

3.0

Coastal Planning Policy and Risk Management - Guiding Principles

Figure 3.2
A Sequential Approach to Coastal Risk Assessment, Planning and Management.

Coastal risk assessment, planning and management				
Risk appraisal & analysis	**Identify risk areas** →	**Coastal Risk Management Strategy**		
		Risk Avoidance	**Risk Mitigation**	**Risk Adaptation**
Hazard & Risk Zoning →	Planning Policy Guidance Maps	In light of Vulnerability Assessment	Engineering Measures (e.g. drainage or protection)	Strategies for adaptation (e.g. time-limited planning consents). Relocation of properties & assets

Figure 3.3
Coastal Risk Management and Planning – Tasks and Responsibilities (adapted from Communities & Local Government 'Development and Coastal Change Practice Guide' 2010)

Coastal, Risk Management & Planning - Tasks and Responsibilities

Policy Task	What is involved?	How is the task addressed?	Who is responsible?
Risk appraisal and analysis **Identify risk areas**	Undertaking geomorphological mapping, desk studies and reviews of historical data at appropriate scales and levels of detail. Preparing hazard maps illustrating potential risks to existing/future developments in the context of climate change.	Reference to geomorphological, ground behaviour and planning policy guidance maps.	Studies and investigations often commissioned from specialists by Coastal Groups and Local Authorities. Local Authority technical staff in liaison with their planning department officials.
Risk Avoidance	Ensure through the planning system that new development is prevented in areas at risk.	Carry out a vulnerability assessment using mapping data. Only consider approval of new developments of overriding economic or social importance.	Local Planning Authorities and their technical advisors.
Risk Mitigation	Measures to reduce current and future risks to communities affected by erosion, landslides or nuisance flooding.	Improve resilience of communities through civil engineering measures alongside advice and guidance for businesses and residents.	Local Authority technical departments and their advisors.
Risk Adaptation	Reducing or eliminating the risk to affected communities.	Identify land likely to become unsuitable for development as a result of increasing risks in the face of climate change. Implement strategies for transition, e.g. time-limited planning consents and programmes for relocation of property and assets.	Local Authority technical and planning departments in liaison with business, local communities and stakeholder groups.

3.0

Coastal Planning Policy and Risk Management - Guiding Principles

Figure 3.4
Damage to coastal properties caused by the tidal surge and flooding on 6th December 2013 at Hemsby, Norfolk, UK. Small coastal communities along undefended coastlines are particularly vulnerable to the impacts of cliff instability, erosion and climate change

Image courtesy: Alamy Stock Photo/Jon Gibbs.

Figure 3.5
The village of Borth near Aberystwyth on the west coast of Wales (population 1,500) has been at risk from both coastal erosion and flooding. A scheme of protection which provided physical, economic and tourism benefits has been developed with close engagement with the well-informed local community and is in progress.

Image courtesy: Alamy Stock Photo/Alan Hale.

Jacobs

3.0

Coastal Planning Policy and Risk Management - Guiding Principles

Roles of Key Partners in Coastal Management in the UK

The Department for Environment, Food and Rural Affairs (Defra) has the lead policy role for flood and coastal erosion risk management. Defra promoted its 'Strategy for Promoting an Integrated Approach to the Management of Coastal Areas in England' in 2009.

The Environment Agency (EA) is a non-departmental public body sponsored by Defra, with responsibilities relating to the protection and enhancement of the environment in England. The EA is one of the largest environmental regulatory and management organisations in the world and holds a supervisory role for flood and coastal erosion risk management in England. This includes the management of 35,000 km of river and 5,000 km of coastline. Work is currently in progress on a 'National Flood & Coastal Erosion Risk Management Strategy.

Local Authorities play a pivotal role in terms of coastal management. They are often major coastal landowners and their wide range of functions include coast protection, planning, countryside management and environmental health. Local authorities take the leading role in integrated coastal zone management and climate change response at the local level. Since the 1980s, local authorities promoted and established Coastal Groups (e.g. Southern Coastal Group), comprising coastal engineers, planning officers and other stakeholders with the objective of promoting sustainable coastal risk management, and encouraging a more sustainable approach to the management of their coastal frontages. Coastal groups also play a leading role in the co-ordination of the preparation of shoreline management plans in partnership with the Environment Agency and other stakeholders.

Coastal Partnerships provide local level engagement and delivery around much of the British coast. Established in 2006, the Coastal Partnership Network (CPN) provides support on a national focus for its membership (see Map 3.1). The objectives of the Network are to develop national approaches to common issues on the coast and to promote better integration of coastal management. The CPN also shares good practice and provides a collective voice at the national level seeking to influence the development of ICZM.

Natural England is a non-departmental public body sponsored by Defra. It is responsible for ensuring that England's natural environments are protected and improved. In Scotland, NatureScot is the public body responsible for Scotland's natural heritage, especially it's natural and scenic diversity. It advises the Scottish government and acts as a government agent in the delivery of conservation designations and all aspects of nature, wildlife management and landscape. In Wales, Natural Resources Wales is a Welsh government-sponsored body, which was established in 2013. Its objective is to pursue sustainable management of natural resources and apply these principles.

Historic England is a non-departmental public body sponsored by the Department for Culture, Media and Sport. It is tasked with protecting the historic environment of England by preserving and listing historic buildings and ancient monuments and by advising central and local government. In Scotland, Historic Environment Scotland is the body responsible for safeguarding Scotland's built heritage, whilst, in Wales, the Royal Commission on the Ancient and Historical Monuments of Wales is the responsible body.

The National Trust is an independent charity for environmental and heritage conservation in England, Wales and Northern Ireland. The Trust is one of the largest private landowners in the United Kingdom and owns extensive tracts of coastal land, as well as over 130 historic properties. The Trust has played an important role in the encouragement and promotion of adaptive management at a number of its sites (see case study). In Scotland, the National Trust for Scotland is a Scottish conservation organisation that protects and promotes Scotland's natural and cultural heritage. It also owns and manages extensive landholdings and numerous historic properties.

Royal Society for the Protection of Birds (RSPB) is a charitable organisation registered in England, Wales and Scotland and was founded in 1889. It works to promote conservation and protection of birds and the wider environment through public awareness campaigns and through the operation of some 200 nature reserves across the United Kingdom. It is the largest wildlife conservation charity in Europe.

The Marine Management Organisation (MMO) is a non-departmental public body established under the Marine and Coastal Access Act 2009. The MMO exists to make a significant contribution to sustainable development in the marine area, and to promote the UK government's vision for clean, healthy, safe, productive and biologically diverse oceans and seas.

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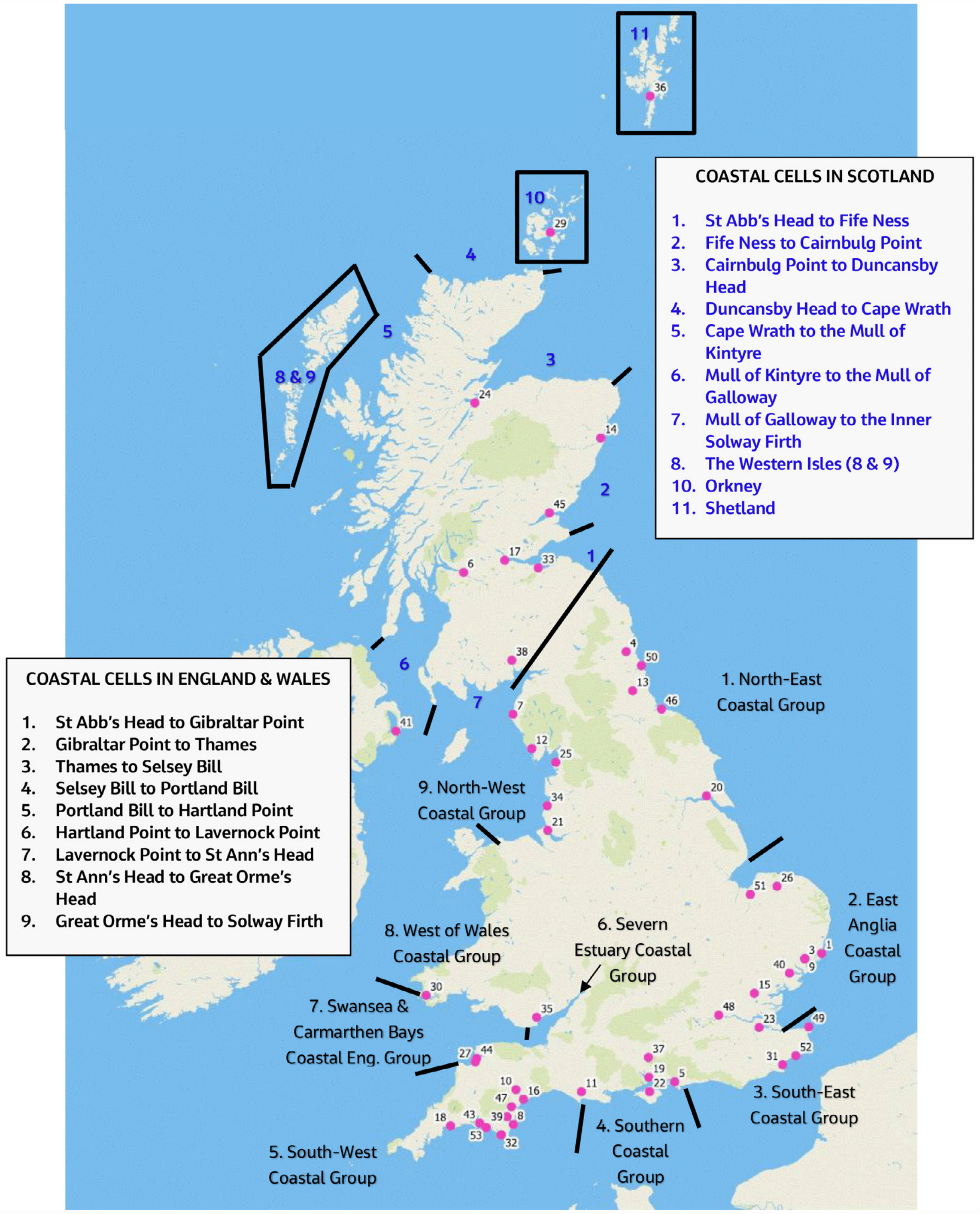
Coastal Planning Policy and Risk Management - Guiding Principles



Map 3.1 showing the location of the fifty-three UK Coastal and Estuary Forums/Partnerships and the coastal cell boundaries in England, Wales and Scotland. The cells represent practical sub-divisions of the coast that allow 'Coastal Groups' to consider coastal risk management issues at a strategic level. This provides a framework for the preparation of Shoreline Management Plans (SMPs). Coastal Partnerships data courtesy of the Coastal Partnerships Network.

3.0

Coastal Planning Policy and Risk Management - Guiding Principles

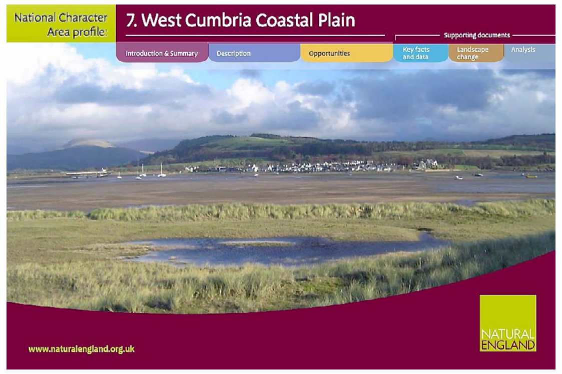


Figure 3.6 Natural England's series of 'National Character Area Profiles', which describe the whole of the English coast, provide comprehensive statements on the physical, environmental and cultural heritage issues affecting each frontage. Collectively they make a valuable contribution to coastal planning and management (Weblink).

Figure 3.7 Scotland's 'Dynamic Coast: Coastal Change Assessment' (2017) has provided a highly detailed review of the extent and rate of change over time. Highlighting current and potential erosion and flood risks, the vulnerable locations and social, economic and cultural assets that may be affected, the report will be invaluable for coastal planning in Scotland into the future (Weblink).

Where the local planning authority may be considering allocating coastal sites for development the SMP will provide information on the risks from natural hazards, as well as providing information on the acceptability of coastal defence policy options. In advance of considering planning applications in defined coastal areas, the SMP facilitates consultation between the relevant local authority engineers and planning officers on individual planning applications, especially with regard to planning conditions, planning obligations to mitigate risk or alterations to proposed designs. In summary, SMPs provide the necessary framework for area and local coastal strategy plans and scheme proposals that will ensure appropriate and sustainable decisions are made for future development and infrastructure proposals, management of natural hazards, the environment and other competing interests at the coast.

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4.0 The Identification and Recording of Constraints to Coastal Land Use

Sustainable development of coastal zones relies on a thorough understanding and effective management of the risks both now and in the future to mitigate impacts of climate change. Fundamental to this is the need to provide the tools to better inform planning policy and thereby improve risk management. An appraisal of future vulnerability, hazard and risk, as part of shoreline management, is most suitably based upon an assessment of the impacts of climate change on coastal landforms (McInnes & Moore, 2014[1]).

To address this requirement coastal risk management requires expertise, high quality data and information to support effective decision-making; it relies on a thorough understanding of coastal processes at work, the landform elements and the effect that these processes have on shoreline evolution (see Figures 4.2 & 4.3). In this respect, monitoring provides an invaluable data source for coastal scientists and engineers alike. It provides a basis for understanding coastal change, as well as for the design and development of coastal defence and landslide remediation works. Further requirements for remediation works can be predicted more effectively using long-term monitoring data, which may change the risk management philosophy from a reactive to a more proactive one; alternatively, data may suggest that an adaptive option is more sustainable.

Figure 4.1

Active coastal erosion after severe storms has created ongoing beach management problems for coastal authorities in Australia along the Gold Coast, Queensland.

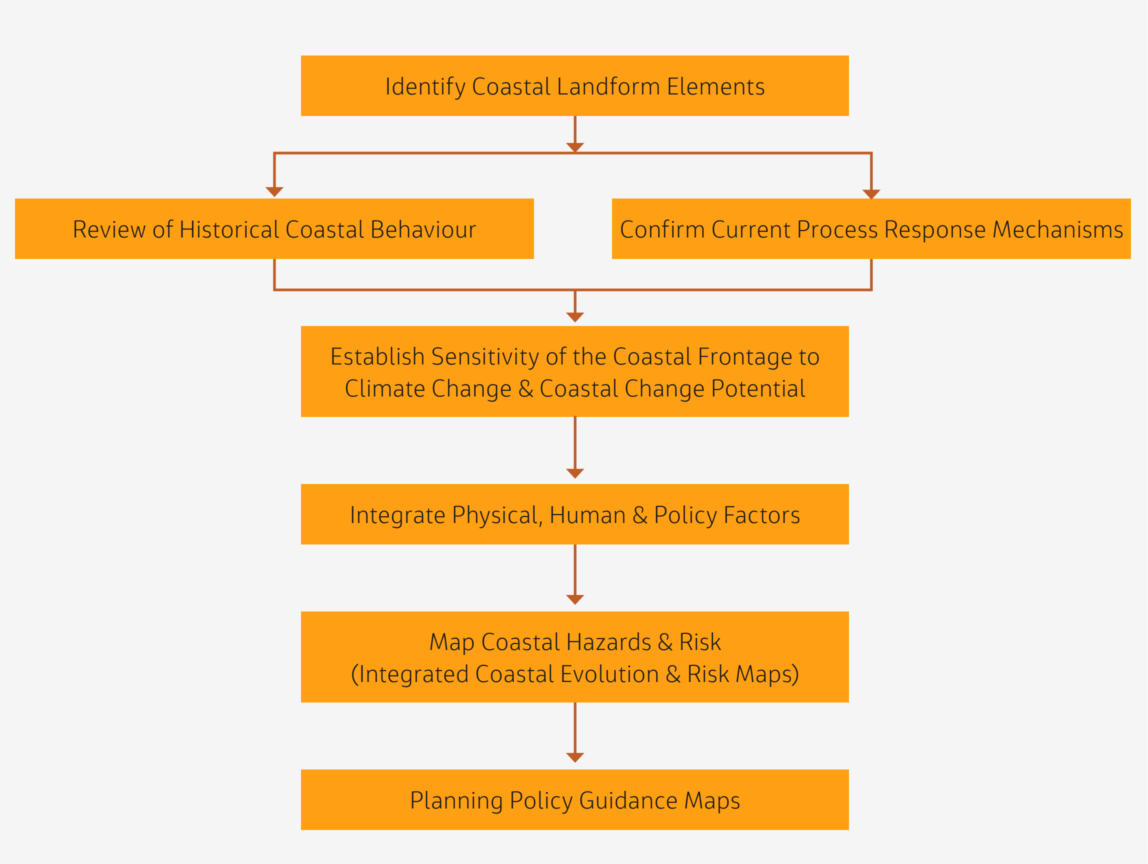
Courtesy: Alamy Stock Photo/David Morgan.

4.0

Figure 4.2
The hazard type encountered is dependent on the coastal geomorphology. An understanding of the geomorphology and coastal evolution is fundamental to good planning and hazard management.

Coastal Geomorphology Type	Coastal Hazard
Barrier beaches or spits	Breaching and flooding
Fringing barriers	Erosion and flooding
Sand dunes	Erosion
Saltmarshes	Erosion
Lowland areas	Flooding
Simple cliffs	Erosion & cliff instability
Coastal landslide systems	Ground movement & landslides

Figure 4.3
Methodology for development of 'integrated coastal evolution and risk maps' (adapted from Hosking et all, 2001[2])



Coastal archaeology and historical imagery can also form valuable additional tools that can support our understanding of long-term coastal change. They can provide a detailed insight of the coastline before human intervention, as well as informing us of the rate and scale of coastal change (see Figures 4.5-4.7).

4.0

The Identification and Recording of Constraints to Coastal Land Use

Figure 4.4
The partially submerged Neolithic stone circle on the shore of Er Lannic, Brittany, France, provides a clear indication of sea level change.
Image courtesy: Philippe Gouezin.

Figure 4.5 (left): Sidestrand Church Tower, Norfolk, UK. A photograph of the tower close to the cliff edge, c.1910. If the height of the structure is known, an assessment can be made from paintings and photographs of the distance to the cliff edge.

Figure 4.6 (below): Stranded oak trees on the beach near Ryde, Isle of Wight, UK, illustrate the location of a former shoreline. Steelplate engraving by E. W. Cooke RA, c1840.

4.0

The Identification and Recording of Constraints to Coastal Land Use

Figure 4.7
A highly detailed view of the beach and chateau of Dieppe, France, by Edouard Hostein, oil painting, 1854. The cliffs beyond the chateau have been affected by serious landsliding since 2012.
Image courtesy: © Musée de Dieppe

Figure 4.8
A major coastal storm on 8th February 2016 saw massive storm waves reach the top of the 60 metre high cliffs at Sennen, Cornwall, UK. Coastal monitoring programmes can record changes that have taken place after such events and improve our understanding of changing trends, coastal conditions and their impacts in the face of climate change.
Image courtesy: Alamy Stock Photo/ Mike Newman.

There are a wide range of monitoring techniques available to support improved understanding of coastal change. These can be airborne or spaceborne, as well as shipborne or ground-based. The categories of information needed to assess coastal change include data on waves, wind, tides, currents, coastal slopes and cliffs, geology, geomorphology, hydrogeology, ecology, vegetation, bathymetry and land use (Bradbury et al., 2007[3]).

A tried and tested approach to coastal monitoring has been undertaken in England and Wales where local authorities and the Environment Agency, with financial support from the UK government, implemented a national strategic monitoring programme that commenced in south-east England in 2002. This programme has provided a systematic approach to collection, management and analysis of data for strategic and operational management of coastal erosion and flood risk. The monitoring programmes are risk-based and integrate the requirements of local authorities with coastal defence responsibilities at both strategic and operational levels. Technical and financial benefits are evident at a range of temporal and spatial scales, tailored to the specific needs of Coast Protection Authorities.

Such strategic monitoring provides a basis for capturing the data required to make reliable assessments of coastal hazards, processes and to predict future changes. The accuracy of predictions improves dramatically with an extended length of records and hence long-term data sets (ideally 20-30 years duration) are required, with data collected at a variety of spatial and temporal scales to ensure optimal decision-making (Bradbury et al., 2007[3]).

Alongside strategic coastal monitoring, National Coastal Erosion Risk Mapping (NCERM) has been promoted by the Environment Agency in the United Kingdom, supported by Jacobs. The aim of this long-running project has been to build climate change projections into coastal erosion projections and to illustrate the possible extent of erosion for three time epochs, looking ahead for 20, 50 and 100 years. Such reliable projections are fundamental to coastal planning decision-making and shoreline management (Moore et al., 2010[4]).

The development of our understanding of coastal evolution alongside coastal monitoring provide the tools to support both the identification and recording of constraints to coastal land use, but also the information needed to manage coastal hazards and risks and to inform the planning system. The information will allow vulnerable areas to be avoided by:

- ensuring that measures can be put in place to control new development in areas at risk from coastal flooding, erosion or landsliding; (avoidance)
- reducing the magnitude and frequency of potentially damaging events through active land management; (reduce vulnerability)
- protecting against potentially damaging events through, for example, coastal protection, landslide stabilisation or other civil engineering measures; and (increase resilience)
- adapting to changing coastal conditions through relocation or retreat from sites at risk or potentially at risk. (reduce risk)

It is only comparatively recently that planning authorities in some countries have considered coastal erosion, flooding and cliff instability issues within the planning framework. This has been brought about by an increasing change in perception about the way risks and planning are being addressed. These changes reflect the growing appreciation that past approaches have not always been robust or in the best public interest. The assessment of physical conditions and the preparation of risk and planning policy guidance maps, together with shoreline management plans, are now assisting the implementation of more effective policies in many locations across the world.

Jacobs and its former companies, Halcrow Group Ltd and CH2M Hill, has been a world leader in integrated coastal zone management, strategic coastal planning and adaptation for more than three decades; this pioneering work, largely developed in the UK, sets the benchmark and approach which is being adopted all over the world.

4.0

The Identification and Recording of Constraints to Coastal Land Use

4.0

The Identification and Recording of Constraints to Coastal Land Use

Figure 4.9
A major coastal landslide at Totland Bay on the north-west coast of the Isle of Wight, UK, occurred in December 2012. A combination of coastal erosion and high ground water levels led to the slope failure which displaced the seawall 20 metres seawards. Options for management of the site are the subject of ongoing consideration.

Image courtesy: Isle of Wight Council, Coastal Management

Figure 4.10
Coastal adaptation at Steat Marshes, Bridgewater, Somerset, UK. This £21 million coastal management scheme allowed the existing seawall to be breached to enable sea water to flood a newly cut channel and create a 300 hectare saltmarsh nature reserve. The scheme will help protect homes and businesses from flooding resulting from climate change and sea level rise. The new habitat is owned by the Environment Agency and is managed by the Wildlife & Wetlands Trust.

Image courtesy: Environment Agency.

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4.0

The Identification and Recording of Constraints to Coastal Land Use

5.0 Adapting to Coastal Change and Engaging with Stakeholders

Coastal local authorities are faced with the increasingly complex task of balancing development needs and managing coastal hazards in the face of climate change. Given the combined effects of future development demands on the coast and the physical impacts of coastal erosion, flooding and cliff instability, these problems are growing in intensity. Despite this, the progress towards more sustainable coasts has been a relatively slow process in many parts of the world. In 1988, the United Kingdom House of Commons Agriculture Committee, in its report on '*Flood and Coastal Defence*', stated, "*We are of the opinion that flood and coastal defence policy cannot be sustained in the long-term if it continues to be founded upon the practice of substantial human intervention in the natural processes of flooding and erosion. Indeed, it is of concern to us that the legacy of flooding and erosional problems arising from this practice, and the likely increase in future climatological and other environmental pressures on the UK's ageing flood and coastal defence infrastructure, might combine to present flood and coastal defence local authorities with insuperable difficulties*" (House of Commons Select Committee, 1992[1]).

This report was responded to positively in the United Kingdom by the Department for Environment, Food and Rural Affairs (Defra), which worked with the Environment Agency, Coastal Defence Groups and other key organisations to help shape a sustainable shoreline management framework that would allow assets to be protected where economically justifiable, and where suitable technical solutions could be found without detriment to the environment. An active programme of research, together with funding to allow the development of shoreline management plans, also provided a framework that would allow decision-making to take place in a more sustainable way, taking account of the impacts of climate change and other factors (Defra, 2006[2]; Defra, 2007[3]). Jacobs has been at the forefront of developing the approach and guidance for shoreline management planning in the UK; this includes landmark research to fully understand coastal change processes e.g. Futurecoast, methods for the assessment of coastal risk e.g. National Coastal Erosion Risk Management (NCERM) and preparing guidance on the funding of coastal protection measures (Moore et al[4]).

Coastal studies, site investigations and other scientific assessments of coastal change scenarios and impacts can raise a range of concerns with different groups and individuals within coastal communities. Therefore, the dissemination of information to the community during and following coastal studies forms a vital part of a successful communications programme. "*The level of understanding, therefore, of coastal change can vary considerably amongst local residents, some who have acquired a detailed understanding of local conditions, whilst others have purchased properties for retirement with little perception of changes that might occur within their lifetimes*" (Joseph Rowntree Foundation, 2011[5]). There has been an increasing recognition in recent years that maintaining a dialogue with key coastal stakeholders from the commencement of studies and investigations to their conclusion is vital if the community is to understand and support the end results.

Residents living in coastal areas across the world are not only having to face the increasing challenges of climate change and sea level rise, but often such communities are also vulnerable because of socio-economic issues, including high proportions of older residents, transient populations, low employment levels and high seasonality of work, as well as physical isolation and sometimes poor transport links (Joseph Rowntree Foundation, 2011[5]).

Engaging with coastal communities over such issues on how to approach and adapt to changing coastal conditions involves the building up of trust and enduring relationships with the community between local residents and the local authorities. "Community engagement acknowledges that neither communities nor authorities always possess complete knowledge or experience of the problems that have to be faced in the future, or the means by which they might be solved. Rather, it involves a two-way exchange of information, which enriches both parties' understanding of the situation. Community engagement enables local people to act collectively to identify challenges and opportunities and allows them to respond effectively by themselves or in partnership with the authorities and by making appropriate demands of those authorities" (Sutton et al., 2013[6]).

In many countries a key government objective, through the planning process, is to support transition to a low carbon economy, taking full account of risks arising from climate change. In order to achieve this objective, the planning system should seek to:

- minimise vulnerability and provide resilience to impacts arising from climate change; and
- avoid inappropriate development in areas at risk by directing development away from such areas or, where development is essential, making it safe without increasing the hazard elsewhere.

To achieve these objectives, national governments and local government planning authorities often adopt proactive strategies to mitigate and adapt to climate change. "*Adaptation will be crucial in reducing vulnerability to climate change and it forms the only effective way to cope with the impacts that are inevitable over the next decades. Without early and strong mitigation, the cost of adaptation will rise sharply…governments have a role to play in making adaptation happen, starting now, providing both policy guidelines and economic and institutional support*" (Stern, 2006[7]).

This statement by Stern highlighted the importance of introducing adaptation as a tool to manage coastal change and is particularly relevant when addressing the question of natural hazards at the coast. First, in the context of new development, local government planning officials need to be satisfied that the developments:

- do not impair and, where possible, enhance the ability of communities and the natural environment to adapt sustainably to the impacts of climate change;
- will be safe throughout their planned lifetime (up to 50 or 100 years) without increasing risk to life and property or requiring new or improved coastal defence measures; and
- consider and identify measures for managing any development at the end of its planned life, including proposals for the removal of those developments, before the site is threatened by significant changes.

Coastal adaptation and risk reduction share the same ultimate goal: reducing exposure and vulnerability to hazardous events. There are synergies to be exploited in closely co-ordinating risk reduction and adaptation policies. Risk reduction and prevention in the short and medium term will primarily address socio-economic developments and climate variability to reduce the impacts of natural and technical hazards, while adaptation aims at developing longer-term planning to address climate change impacts (see Figures 5.1 & 5.2; Pontee et al 2012[8]).

5.0

Adapting to Coastal Change and Engaging with Stakeholders

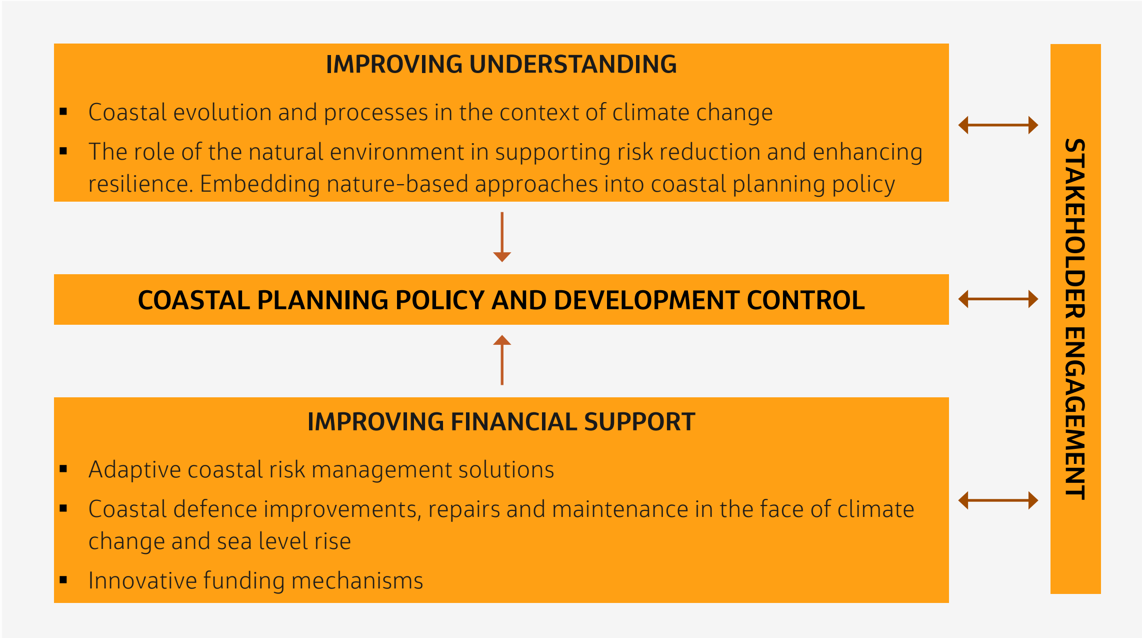

Figure 5.1
Key contributors to successful coastal planning and adaptive management.

5.0

Adapting to Coastal Change and Engaging with Stakeholders

Risk Planning	Risk Response	Risk Recovery
▪ Risk Identification & Assessment ▪ Land Use Planning ▪ Nature-based Solutions to Protect People & Assets ▪ Permanent Relocation	▪ Early Warning Systems ▪ Forecast-based Contingency Planning ▪ Strengthen First Responses ▪ Temporary Evacuation	▪ Insurance & Risk Finance Instruments ▪ Social Safety Nets ▪ Recovery Services including Health & Education

Figure 5.2
The components of Adaptation at the Coast.

"*It is important to note that uncertainty is inherent to coastal policymaking. Policymakers face deep uncertainties from a range of external factors, such as climate change, population growth, new technologies and economic developments. Adaptation policy is no exception. In addition to these 'external' factors influencing adaptation policy, other 'internal' influences on policy: societal preferences, stakeholders' interests, and stakeholders' evaluation of plans might also change over time. The end point is, therefore, not only determined by what is known or anticipated at present, but also by what will be experienced and learned as the future unfolds, and by policy responses to events*" (European Environment Agency, 2013[9]).

"*Traditionally, coastal scientists have used models that assume incremental change in the environment and in the social and economic context. However, the weaknesses of this approach are becoming more evident. Facing a deeply uncertain world, new approaches are needed to allow policy to adapt over time in response to how the future unfolds and changes in the environment and society*" (European Environment Agency, 2013[9]).

'Adaptation pathways' is the umbrella term given to the application of this flexible approach and delivers a selection of options that can be called upon as some uncertainty about future climatic and socio-economic developments decrease and new uncertainty appears. The adaptation pathways approach is iterative, relying on constant updating by information flows that deliver additional resilience in decisions. It stresses the importance of designing dynamic and flexible plans by creating a strategic vision of the future, committing to short and mid-term actions, and establishing a framework to guide future and longer-term actions (European Environment Agency, 2013[9]; Frampton et al., 2019[10]).

In certain situations, coastal hazards and risks may be so problematic that it is necessary to consider the relocation of a whole community or other assets, and to identify and allocate more suitable land within the development plan where a community may be relocated to (Siddle et al., 2015[11]). In the case of a coastal location affected by erosion, instability or flooding, 'rolling back' or relocation away from the area of active coastal change may be a practical option. Depending on the level of risk or the timeframe in which implementation is required, the planning authority may be in a position to approve some limited but modest developments, which can exist and operate within time-limited constraints. Planning conditions may be applied to such new developments where it is possible to manage the risk to the proposed development during its lifetime.

Such adaptive approaches aimed at trying to address potentially increasing levels of risk are part of a process that will be essential in order to address worsening coastal conditions aggravated by climate change. The definition of successful adaptation is likely to depend on the viewpoint of the stakeholders that are affected. A community facing permanent loss of assets or infrastructure may see things very differently to communities who are not immediately affected or at risk. Similarly, successful adaptation will depend on a wide range of socio-economic conditions. Some locations have high levels of social well-being, whilst other locations face much greater levels of deprivation. These impacts will set the tone for the challenge, and the process of proactively involving communities in preparing and planning for adaptation (Defra, 2010[12]; Defra, 2012[13]). A range of international approaches to adaptive coastal management are illustrated in Chapter 6.

5.0

Adapting to Coastal Change and Engaging with Stakeholders

Avoiding Potential Losses	▪ through improved understanding of the risks
Economic Benefits	▪ risk reduction ▪ improving resilience of coastal assets and driving innovation through new approaches
Social Benefits	▪ improved safety, security and well-being
Environmental Benefits	▪ working with nature through use of natural defences

Figure 5.3
The components of Adaptation at the Coast.

To achieve successful adaptation, communities need to be supported and to be involved in control of the outcomes that will shape the future of their community. There needs to be an open and honest debate on what coastal change may mean for their community, and agreement on the basic problems to be addressed in terms of infrastructure, buildings and livelihoods. The process of building a vision for the future is a long-term one, particularly when partnerships are genuinely community-based.

While consideration of risk should be taken into account at all levels of governance, it is often at the local community level where a coherent and acceptable response to managing the impacts of changing risks can be achieved most effectively. To be most successful this should bring together all sectors of a community, including homeowners, local businesses and landowners, as well as other parts of the whole community that contribute to the shape and functioning of the location, for example, heritage and natural assets that attract tourism. There is no definitive list of all the stakeholders that could be involved as this will vary from one location to another; however, these are likely to include local authority staff, local politicians and councillors, key businesses, utilities and infrastructure providers, alongside local residents.

The response to coastal change at the community level varies considerably across the world in terms of effective management action. Often local residents do not have clear and accurate information about coastal erosion, instability or flood risk to which they are currently exposed nor the impacts for the future. "*There is typically no insurance or compensation for losses from coastal erosion for homeowners to mitigate the risk of losing their properties. Consequently, homeowners at risk may not take action to relocate or consider strategies beyond trying to protect their existing asset*" (Committee on Climate Change, 2018[14]).

Whilst the case for adaptation at the coast is irrefutably strong, there are several fundamental reasons why the process has been slow to implement. In many locations, this is a result of short-term planning horizons, which fail to make proper consideration of the longer-term consequences of coastal change. In addition, governments often lack the resources to fund adaptation solutions although possible options may have been studied and agreed at the community level. Therefore, actions are required at government level to ensure that funding and investment is available to support adaptation initiatives. In parallel with this at the local level, local authorities and planners, in collaboration with affected coastal communities, need to raise awareness of the issues including, for example, the increasing evidence of accelerating coastal change.

The benefits for local communities working with their local authorities on adaptation are particularly important as their engagement will highlight:

- the value of a shared understanding of the nature and risks of coastal change, the problems to be addressed, and the basis for agreeing joint actions;
- the desirability of building adaptive capacity in coastal communities, which means they will be more resilient, creative and prepared for coastal hazards and accelerated rates of change; and
- the value of making good use of the local community's knowledge and resources to significantly improve coastal planning, particularly through developing governance mechanisms that enable areas to be managed in a holistic way (Scott Wilson, 2009[15]).

5.0

Adapting to Coastal Change and Engaging with Stakeholders

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Coastal Planning and Management - Good practice Case Studies

6.0

6.1

Isle of Wight, UK

Location

The Isle of Wight is located centrally along the south coast of England, facing the English Channel. With a coastal length of approximately 168 kilometres, the Isle of Wight has a wide variety of coastal scenery, including high chalk cliffs, eroding soft coastlines, coastal landslides, and low-lying frontages which are prone to flooding and at risk from sea level rise.

Map © Harper Collins, UK

Why was this Case Study site selected?

The wide range of geomorphological features within a relatively small geographical area make the Isle of Wight an ideal case study site. The coastline has been extensively studied over the last twenty years and has well-developed policies for linking coastal hazards and planning.

Summary of Geology, Geomorphology and Coastal Processes

The Isle of Wight is composed of rocks of Cretaceous age. The southern coastlines facing the English Channel are attacked by storm waves generated in the Atlantic Ocean, and these accelerate the processes of erosion and landsliding. The southern coast of the Isle of Wight, known as the Undercliff, is the largest urban landslide complex in north-western Europe.

Figure 6.1
The town of Ventnor on the south-east coast of the Isle of Wight lies within an ancient landslide complex called the Undercliff. The location has been the subject of detailed studies over the last thirty years. These have informed planning and management of such sites both in the United Kingdom and internationally (McInnes & Moore, 2014[1]).

Image courtesy: Stephen Lee/ Wight Light Gallery.

6.1

Figure 6.2
The open, relatively undeveloped coast of the western half of the Isle of Wight. This part of the coastline is undefended and erodes naturally. The cliffs are of international importance for the completeness of the geological succession and the rich fossil record. No defences are proposed, and planning policy involves adaptation to natural coastal change.
Image courtesy: Stephen Lee/Wight Light Gallery

Figure 6.3
The northern, mainly low-lying coastlines of the Isle of Wight are broken by creeks and estuaries flowing northwards into the Solent. The coastal towns including Yarmouth (Left), Cowes and East Cowes are likely to become increasingly vulnerable to flooding as a result of sea level rise.
Image courtesy: Andy Butler

6.1

Figure 6.4
A coastal landslide in 2012 at Totland Bay on the north-west coast has displaced the concrete seawall. Some coastal defences constructed in the past may not have been renewed for technical, economic or environmental reasons.
Image courtesy: Isle of Wight Council.

Figure 6.5
The eastern end of the Undercliff at Bonchurch. This coastline was protected in the 1980s to reduce the impact of coastal erosion on the toe of the landslide complex. The developed Undercliff will continue to be defended in the future because of the value of property and infrastructure along this frontage.
Image courtesy: Stephen Lee/Wight Light Gallery

6.1

Isle of Wight, UK

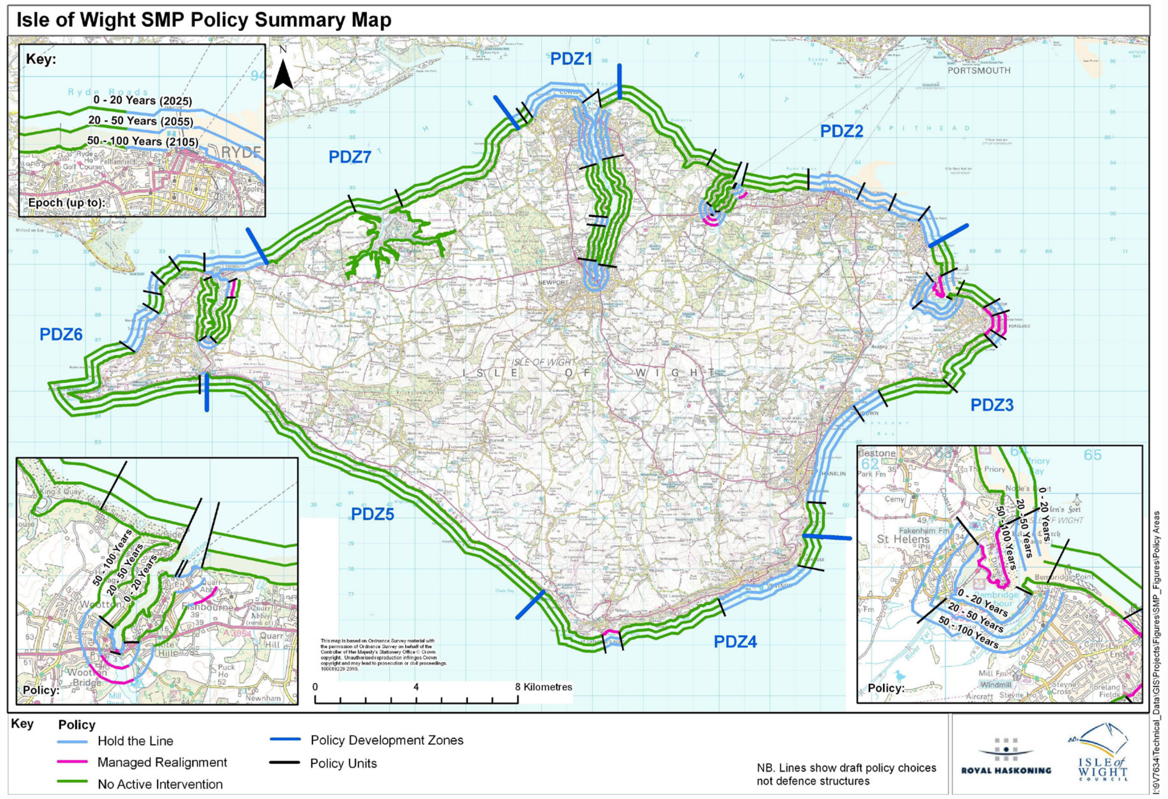
Policy Response to Coastal Change

The Isle of Wight Shoreline Management Plan is a strategic document that sets out policies for the management of the coastline, and the policy response to coastal flooding and erosion risks over the next 20, 50 and 100 years. Shoreline management plans provide a large-scale assessment of the risks to people and to the developed, historic and natural environments. This plan addresses the risk in a way that does not tie future generations to costly unsustainable management and attempts to balance potential conflicting interests along the coastline.

The map below shows, for each coastal frontage location, where a policy of *hold the line* (maintain coastal defences or replace where required, subject to funding), possible *realignment* of the coast (forwards or backwards) to help manage flood and erosion risk, and *no active intervention* where there is a policy decision not to invest in the provision or maintenance of any defences. These frontages are coloured blue, purple and green respectively. In line with the UK government's advice, the Council has developed policies for '*Coastal Change Management Areas*' (CCMAs) for those areas likely to be affected by coastal change over the next century. Most of the Isle of Wight coastal change management areas will lie within the green frontages indicated on the map. The draft policy framework for coastal change management areas is described in Box 6.1.

Figure 6.6
Coastal risk management policies set out in the Isle of Wight Shoreline Management Plan (2010)[2]. The blue lines indicate the frontages that are likely to continue to benefit from coastal defences (subject to the availability of resources). The green lines show frontages where management of natural coastal change is likely to be the preferred policy option.

Map courtesy: Isle of Wight Council.



This map is based on Ordnance Survey material with the permission of Ordnance Survey on behalf of the Controller of Her Majesty's Stationery Office Crown Copyright. All Rights reserved.

Box 6.1
Draft policy statements on 'Coastal Change Management Areas' from 'Draft Island Planning Strategy Development Plan' (Isle of Wight Council, 2018[3]).

Courtesy: Isle of Wight Council.

Coastal Change Management

Policy Overview

To enable the Council to manage development in coastal areas affected by coastal change, development proposals will be expected to demonstrate how they have taken a sustainable and practicable approach to coastal erosion and flood risk management.

To avoid inappropriate and/or vulnerable development within Coastal Change Management Areas (CCMAs), development proposals will be expected to be limited to:

1. Essential infrastructure, including Ministry of Defence installations.
2. Development directly linked to the coastal strip when within short-term risk areas.
3. Development more widely requiring a coastal location and providing substantial economic and social benefits within medium and long-term risk areas.

All development proposals will be expected to undertake a coastal erosion vulnerability assessment to demonstrate that it will be safe over its planned lifetime and will not have an unacceptable impact.

Permissions granted within CCMAs will usually be time limited.

Proposals for new residential development will not be supported within CCMAs.

A. As a first principle, new development should be directed away from areas vulnerable to coastal change, to avoid putting people at risk. Where there is development close to the coast in areas where there is a risk, a sustainable and well-informed approach will be taken.

B. For the purpose of this policy coastal change means physical change to the shoreline through erosion, coastal landslip, permanent inundation and coastal accretion. CCMAs are areas likely to be affected by coastal change over the next 100 years.

C. he CCMA is defined based on the policies and principles of the adopted Isle of Wight Shoreline Management Plan 2010, the adopted West Wight Coastal Flood and Erosion Risk Management Strategy 2016, and the latest studies into future coastal risks and defence requirements.

D. Ministry of Defence installations that require a coastal location can be permitted within a coastal change management area, provided there are clear plans to manage the impacts of coastal change. Where the installation will have a material impact on coastal processes, this must be managed to minimise adverse impacts on other parts of the coast.

E. In relation to point two of the policy, the types of development that would be considered as being appropriate include (but are not necessarily limited to) beach huts, cafes/tea rooms, car parks and sites used for holiday or short-let caravans and camping. Short-term risk areas are considered to be a 20 year time horizon from the time of development being permitted. Developers would have to refer to supporting evidence on future erosion rates for different epochs.

F. Medium-term is considered to be a 20 to 50-year time horizon and long-term is up to 100-year from the time of the development being permitted. The types of development the Council expects to see in these areas would be time-limited development, and could include uses such as hotels, shops, office or leisure activities requiring a coastal location and providing economic and social benefits to the community. Other significant development, such as key community infrastructure, is unlikely to be appropriate unless it has to be sited within the coastal change management area to provide the intended benefit to the wider community and there are clear, costed plans to manage the impact of coastal change on it and the service it provides.

6.1

Isle of Wight, UK

G. Proposals within the CCMA must be accompanied by a coastal erosion vulnerability assessment that assesses the degree of risk and the scale, nature and location of the development. The applicant will be expected to prepare this in advance in consultation with the Council, the Environment Agency and any other relevant stakeholders. The assessment must demonstrate that the development:

- Would not impair the ability of communities and the natural environment to adapt sustainability to the impacts of a changing climate;
- Will be safe through its planned lifetime, without increasing risk to life or property, or requiring new or improved coastal defences;
- Would not affect the natural balance and stability of the coastline or exacerbate the rate of shoreline change to the extent that changes to the coastline are increased nearby or elsewhere;
- Demonstrate how water can be discharged without exacerbating erosion and/or having an adverse effect upon the stability of nearby cliffs. This would typically preclude the use of soakaways;
- Consider whether any essential infrastructure which will support the proposed development is at risk from being lost to coastal change and demonstrate the proposal is sustainable over its planned lifetime; and
- Consider the management of the development at the end of its planned life, including proposals for the removal of the development before the site is immediately threatened by shoreline change

Landslide Management and Stakeholder Engagement

The Isle of Wight Undercliff has been recognised by the government as the most serious ground instability problem in Great Britain (Lee & Moore, 1991[4]; Lee & Moore, 2007[5], Moore, 2020[6]). The landslides are deep-seated and generally slow-moving, which has allowed the historical development of the area. A significant investment has been made over the years in developing a detailed understanding of the causes, with the aim of achieving long-term, sustainable solutions to the ground movement problems. This has involved leading-edge research into the fundamental causes of the instability and techniques for the management of large landslides in urban areas and has included the implementation of innovative and environmentally-friendly coastal and geotechnical engineering schemes to help to manage the risk (McInnes, 2007[7]; Moore et al., 2010[8]). As part of a co-ordinated Landslide Management Strategy the Council aims to:

- reduce the likelihood of future ground movement by controlling the factors that cause the movement, for example by controlling water in the ground and by improving coastal protection;
- limit the impact of future movement through the adoption of planning and building controls, in order to avoid inappropriate development on unstable land and to reduce vulnerability; and
- increase the awareness of landslide risk through monitoring, prediction of future movements and provision of early warning systems.

New property located within the Undercliff must be sustainable and be capable of withstanding ground movements and, importantly, any new development should not lead to a worsening of ground conditions. These measures are regulated by the Council through its planning and building control offices with support from its Coastal Management Team. An important element of the management strategy has been communicating with general public and professional organisations within the community.

6.1

Isle of Wight, UK

Figure 6.7
A model for a local authority landslide management strategy
(McInnes & Moore, 2014).

What lessons can be learnt from the Isle of Wight Case Study?

The Isle of Wight has long experience of seeking to address the range of physical problems that affect its complex coastline. Significant progress has been made in recent years through the development of its shoreline management plan and draft planning policy statements which provide a pathway for managing long-term coastal change. Risks arising from increasing

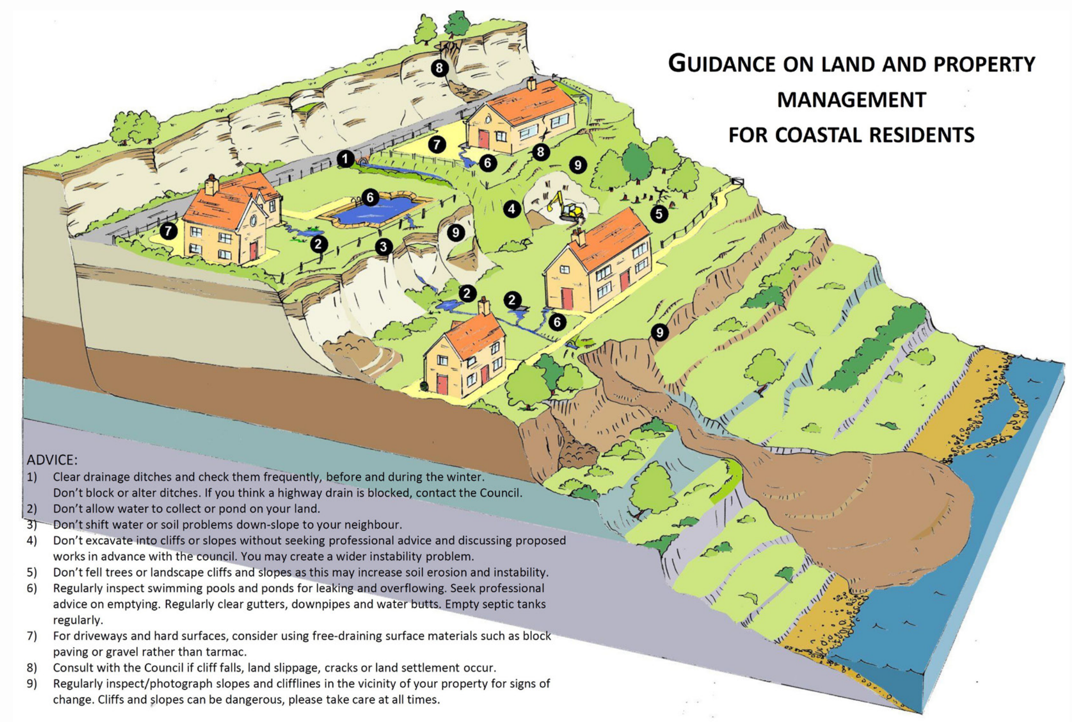


Figure 6.8
Advice for residents affected by coastal instability and landsliding
(McInnes & Moore, 2014).

6.1

Isle of Wight, UK

coastal hazards will prove particularly challenging and will require increasing levels of investment in terms of addressing both physical problems and day to day management. Research into coastal instability within the Isle of Wight Undercliff and on the Cowes to Gurnard frontage on the Island's north-west coast, has provided important data and publicly available information to support wise decision-making and to inform planning and development control.

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6.2

Portsmouth & Southsea, UK

Location

The city of Portsmouth is located on the south coast of Hampshire, overlooking the Solent and facing the north coast of the Isle of Wight.

The adjacent town of Southsea is a popular seaside resort abutting Portsmouth.

Map © Harper Collins, UK

Why was this case study site selected?

Portsmouth (population 205,400) is the only city in the United Kingdom where the population density exceeds that of London. Together with the adjacent town of Southsea, this part of the Hampshire coast is low-lying. The majority of the city is built on Portsea Island, with most of the surface area less than 3 metres above sea level. Although both Portsmouth and Southsea are protected by coastal defences, these structures are reaching the end of their life, yet fulfil a vital role in protecting large numbers of properties and businesses within the city itself. The case study illustrates how measures are being implemented to adapt to changing coastal conditions, including sea level rise and the impacts of more unpredictable weather patterns.

Summary of the Geology, Geomorphology and Coastal Processes

Portsmouth and Southsea are developed on an area of Cretaceous geology. Backed by chalk downs and facing the Solent the frontage is prone to wave attack, particularly from the English Channel, as well as storm waves generated within the Solent itself. With sea levels predicted to rise by up to 1 metre by 2100, this low-lying region is particularly vulnerable to an increasing risk of flooding. Following serious damage in recent winter storms to some of the coastal defences, which date back to World War II, a major scheme has been developed to improve the standard of protection for Portsmouth and Southsea.

Figure 6.9
A view of the great maritime city of Portsmouth, looking north over the entrance to the harbour.
Image courtesy: Shutterstock Vittorio Caramazza

6.2

Portsmouth & Southsea, UK

Policy Response to Coastal Change

With current coastal defences reaching the end of their existing life, the local authority has recognised the importance of adapting the coastline at Portsmouth and Southsea to reduce flood risk for the future. Over 10,000 homes and 700 non-residential properties are at risk of flooding from the sea. Current defence levels only offer limited protection from coastal flooding and many of the existing defences have a residual life of less than ten years, with two major failures occurring in recent years. The Council, therefore, aims to mitigate the increasing risks of flooding from the sea and high tides and winter storms through a major flood and coastal defence scheme. The proposed design for the Southsea frontage, which extends from Old Portsmouth eastwards, comprises a sloping seawall revetment and a setback defence, which will offer the necessary standard of protection, as well as the opportunity to enhance the seafront and maintain the location's unique heritage. Beach management will also be an integral part of the coastal defence plans. The estimated total cost of delivery of the coastal defence scheme is £130 million. This scheme was developed following completion of the North Solent Shoreline Management Plan (SMP) in 2010 (New Forest DC, 2010[1]) and the Portsea Island Coastal Strategy (East Solent Coastal Partnership, 2012[2,3]) the following year. It concluded that a hold the line policy for the frontage was imperative in order to protect the population of the city and its infrastructure from the risk of flooding by the sea.

Engagement with Stakeholders

This project, which is being led by Portsmouth City Council, is being delivered by Coastal Partner[3], with support from the Environment Agency and the UK government. Throughout the development of the scheme there has been extensive consultation with the wide range of stakeholders, including a major consultation in 2014 when coastal defence options were considered. During 2017 nearly 700 people attended a series of engagement events and their feedback, along with the advice from statutory bodies, enabled the creation of a suitable scheme that will provide the necessary standard of protection for the future.

Figure 6.10
The Southsea frontage showing the Castle in the foreground. The low-lying nature of Southsea and the city behind can be seen clearly.
Image courtesy: Shutterstock/ John Morley

Lessons learnt from this Case Study site

In terms of adapting to climate change and sea level rise, the densely developed and low-lying city of Portsmouth, and adjacent Southsea frontage to the east require upgrading of coastal defences in order to ensure their protection for the future. Other adaptation options for this particular case study site are inappropriate. The case study illustrates how a thorough investigation of existing and potential problems has led to the most appropriate scheme design, taking advantage of a well-managed extensive consultation and ongoing engagement with a wide range of coastal stakeholders.

Figure 6.11
The North Portsea Island Scheme to the north of Portsmouth city centre covers 8.4 kilometres of coastline. Most of the area is low-lying and many of the current coastal defences were approaching the end of their effective lives. A phased programme of construction works to manage the flood and coastal erosion risk has been undertaken since 2015, and includes the provision of concrete curtain walls, as well as rock revetments and earth embankments to manage the flood risk. This northern section of the scheme was completed in October 2019 and included the creation of three tidal pools.
Image courtesy: Knights Brown.

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Jacobs

6.3

Dorset, UK

Location

The county of Dorset is located on the south-west coast of England facing the English Channel. The study site focusses on the picturesque seaside town of Lyme Regis overlooking Lyme Bay.

Map © Harper Collins, UK

Geology, Geomorphology and Coastal Processes

The case study site lies within the Jurassic Coast World Heritage Site and contains some of the most spectacular coastal scenery and landslide complexes to be seen in Europe (Badman, 2000[1]). The coastal geology in the vicinity of the town of Lyme Regis is comprised of mudstones and limestones of the early Jurassic Period. These include the Blue Lias and other formations which are overlain by Cretaceous Chalk and Upper Greensand formations. The Gault Clay outcrops give rise to extensive rotational and translational landslides, whilst deeper horizons contain thin clay layers that also promote landslide activity. Lyme Bay is situated in an exposed location prone to attack by storm waves generated in the Atlantic Ocean. The natural processes of cliff instability and erosion have maintained this unique, distinctive and diverse landscape, whilst also leading to the loss of coastal properties, roads and farmland (Brunsden & Moore, 1999[2]).

The county of Dorset has been actively involved in a wide range of coastal management initiatives since the early 1990s. In 1995 the Dorset Coast Forum was established as a strategic coastal partnership with the aim of improving understanding of long-term, broad-scale issues facing the Dorset coast and its inshore waters. The overriding aim of the Forum has been to promote the sustainable approach to the management, use and development of Dorset's coastal zone. This is being achieved by encouraging co-operation and dialogue between the different interests and users of the Dorset coast, as well as gathering knowledge and undertaking necessary research in relation to the physical processes, natural environment and human use of the county's coastal zone.

A focus for considerable study has been the town of Lyme Regis, which developed in the mid-nineteenth century on an ancient coastal landslide system. Over the last twenty years a detailed understanding of the ground behaviour of this site has been gained and a programmed upgrading of coastal defences protecting the toe of the landslide complex has been successfully completed (Clark et al., 2000[3]; Lee et al., 2000[4]). The final phase of coast protection works at Lyme Regis was completed in 2015 and was one of the largest and most complex coast protection schemes undertaken in the UK (Davis et al., 2015[5]).

Coast protection and associated drainage measures to reduce the impact of landsliding on the town and its infrastructure was the only possible sustainable solution for this site. A new seawall has provided long-term protection for over 480 properties, including the main highway accessing the town from the east. Considerable efforts were made to minimise the footprint of the new seawall, which extended to a length of 390 metres and which replaced an existing dilapidated structure. The scheme was developed following extensive consultation with both statutory bodies, including nature conservation interests and community organisations, landowners and residents over many years (Davis et al., 2015[5]; Moore et al., 2017[6]).

This part of the Dorset coast comprises long stretches of open coast where natural processes prevail, interspersed by coastal development including Lyme Regis, and Seatown and Charmouth to the east.

6.3

Dorset, UK

Figure 6.12
The Jurassic Coast World Heritage Site looking westwards towards Lyme Regis.
Image courtesy: Shutterstock/Martin Kemp.

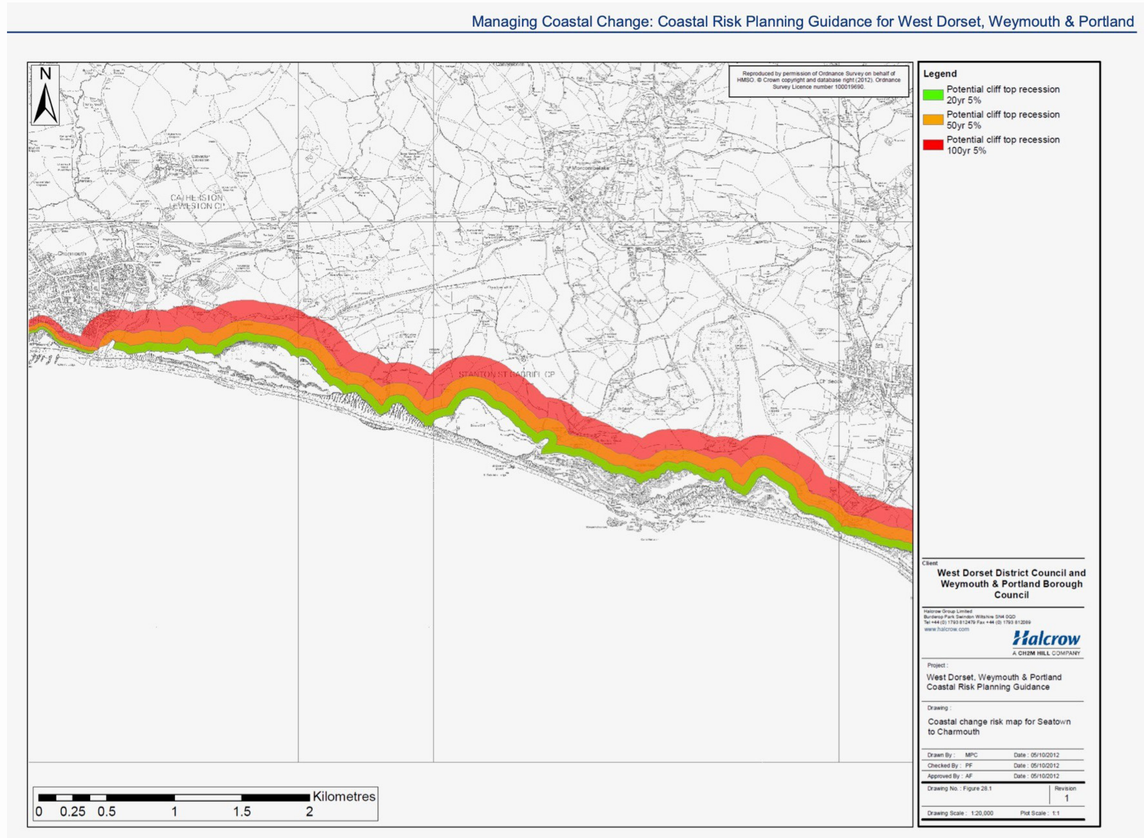

Figure 6.13
Example of a Coastal Change Risk Map for part of the Dorset coast near Charmouth illustrating potential cliff top recession over the next 20, 50 and 100 years.
Image courtesy: Jacobs (formerly Halcrow)/ Dorset Council.

6.3

Dorset, UK

Coastal Management Policy

The coastal risk management policy for this part of the Dorset Coast was set out in the Shoreline Management Plan (Halcrow, 2010[7]), which identified those frontages where coastal defence measures were deemed to be necessary and suitable in technical, economic and environmental terms.

Coastal risk planning policy guidance for West Dorset was published in 2013 (Halcrow, 2013[8]). This 'Guidance on Coastal Change' identified the nature of risks posed to the coastal frontages and set out consistent advice on planning applications and to inform the future development of 'Coastal Change Management Areas' along this part of the Dorset coast. Dividing the coast into thirty-three separate sections, for each of these a map was provided showing coastal risk zones arising from erosion, landsliding, flooding or a managed realignment policy, along with a description of the section's coast. The document also describes the nature of coastal change risks including the hazards and timing and frequency of the risk occurring based upon a desk study review and expert assessment of all the data. Recommendations for management included, for example:

- development restrictions setting out where different types of appropriate development should or should not occur based on the risk zones.
- requirements for geotechnical appraisals for any construction, including proposals for discharge of water in the vicinity of a risk zone.
- a vulnerability assessment to demonstrate that the development is unlikely to be at risk from coastal change within the period for which time-limited planning consent is being sought.

The Dorset guidance also addressed wider coastal change management issues and opportunities, including:

- the development of community partnerships in areas at risk of coastal change, building on the work of studies undertaken on the Dorset coast (Dorset Coast Forum Council, 2011[9]). This approach aimed to prepare community-led coastal change adaptation plans with clear objectives and steps that would be taken to respond to coastal change in the future.
- providing advice to land/property/business owners about actions they can take in areas at risk of coastal change in order to improve individual's resiliency.
- undertaking education activities to raise awareness of coastal change risk and to increase the capability of communities to participate in future coastal change planning decisions and the definition of coastal change management areas.
- appointing a local 'Coastal Change Champion' within the local planning authority to lead on coastal change issues and planning.

What lessons can be learnt from this Case Study site?

Coastal change management policy for the Dorset coast has evolved from the long experience of the local authorities in coastal zone management and planning. The significant coastal instability problems have necessitated detailed study of the coastal geology, geomorphology and processes, and these are now embedded into shoreline management and coastal change management policy for the County. The long-standing experience of the Dorset Coastal Forum and coastal engineers within the local authority in terms of engagement with stakeholders affected by coastal change has been a particularly strong feature of the management response for many years (Davis & Cole, 2002[10]). The coastal change policy for the county has recognised that there is considerable sensitivity over the provision of coastal defences within the Jurassic Coast World Heritage Site and for most of this coastline natural processes will prevail. However, areas affected by coastal landsliding, such as at Lyme Regis (and at Ventnor Undercliff on the Isle of Wight – Case Study 1) necessitate civil engineering solutions that involve both coast protection and drainage measures, as well as monitoring of ground conditions.

6.3

Dorset, UK

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Figure 6.14
The East Cliff coast protection scheme at Lyme Regis, completed in 2015, involved replacement of the dilapidated existing seawall, slope stabilisation and extensive environmental mitigation works. The scheme protects 480 homes and the route into the town from the east. (Moore 2017)

Image courtesy: © Neil Bigwood.

6.4

Knipe Point, UK

Map © Harper Collins, UK

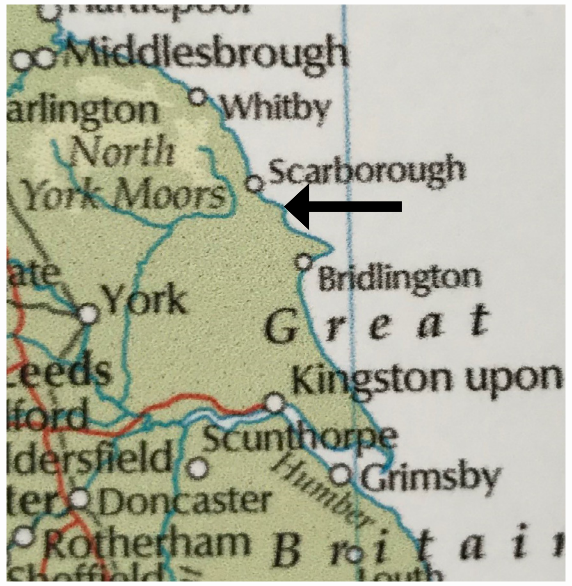
Knipe Point, Yorkshire, UK

Location

Knipe Point is located on the coastline of North Yorkshire, 5km south of the major seaside resort of Scarborough. The settlement was developed on the northern headland of Cayton Bay from the 1950s.

Geology, Geomorphology and Coastal Processes

This part of the North Yorkshire coast is characterised by high cliffs composed of sandstones and clays overlain by glacial till. Geologically, this coastal frontage comprises rocks of the Jurassic Period. Erosion and cliff instability have, historically, impacted on the coastal towns and villages of North Yorkshire, and these are protected from coastal erosion by a variety of coastal defence structures following a substantial investment, particularly over the last twenty years. Problems of erosion are compounded by coastal instability arising from groundwater flows from the fluvial-glacial materials within the cliffs. In addition, removal of material at the toe of the cliff by marine erosion, the saturation and remobilisation of previously failed material and weathering all contribute to the instability of this coastal zone. This part of the Yorkshire coast demonstrates a clear link between climatic patterns, groundwater levels and cliff instability (Clark & Guest, 1994[1]; Lee, 1999[2]; Fish *et al.*, 2006[3]).



Knipe Point

The development at Knipe Point originally comprised a holiday camp and, later, fifty-six bungalows were constructed, in the 1980s. The location has a long history of landslide activity and this became more evident by early 2008, when the local authority, Scarborough Borough Council, commissioned investigations (Halcrow, 2009[4]). Prior to completion of the 2009 study, three properties had become dangerous and these were subsequently demolished. In the winter of 2012/13 three more properties at Knipe Point had to be demolished following a sustained wet summer and early winter period, resulting in the build-up of antecedent rainfall, which triggered reactivation of the landslides (Siddle et al., 2015[5]).

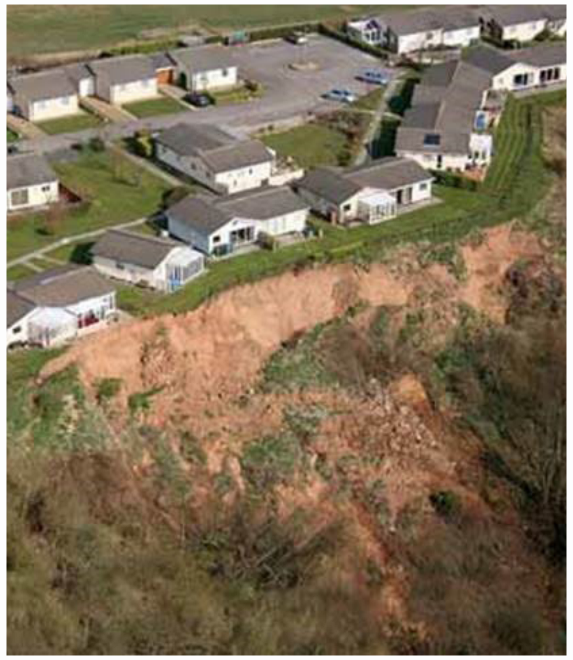
In 2009, the UK Department for Environment, Food and Rural Affairs (Defra) invited calls for bids under the '*Coastal Change Pathfinder Programme*' to test '*new and innovative approaches to planning for and managing coastal change*' (Regeneris Consulting, 2011[6]). Scarborough Borough Council, on behalf of the Knipe Point community, successfully obtained funding of over £1 million to trial an adaptive management scheme for the Knipe Point community in the absence of an alternative viable civil engineering solution.

Figure 6.15
The significance of groundwater in the failure of cliffs was clearly demonstrated in the failure at Holbeck Hall at the southern end of the Scarborough frontage in June 1993 (Clark & Guest, 1994[1]; Lee, 1999[2]).
Image courtesy: Scarborough Borough Council.

6.4

Knipe Point, UK

Figure 6.16
Development on the coast at Knipe Point, Cayton Bay, North Yorkshire.
Courtesy: Scarborough Borough Council.



Figures 6.17. & 6.18 (left): Coastal landslide impact on residential properties at Knipe Point.
Images courtesy: Moore (bottom left); Scarborough Borough Council (bottom right).

6.4

Knipe Point, UK

The Pathfinder project involved sourcing and purchasing suitable land as a form of land-banking, in order to relocate residents and properties to a site in the vicinity that was not at risk from coastal erosion or ground instability; affected residents would then use their own insurance pay-outs to construct their new homes.

This was the first time that the concept of land-banking adaptation and homeowner building had been attempted in the United Kingdom. The scheme involved the valuation, sourcing and negotiations to purchase land to relocate the fifteen properties at most immediate risk and involved working closely with affected residents in order to try and progress this imaginative scheme.

Lessons learnt from the Knipe Point Study Site

There were a number of obstacles to this proposal including finding suitable land in the vicinity and overcoming reluctance by some of the homeowners to accept the risk of their property loss and an unwillingness to move, particularly as some of the residents were elderly. Negotiations with residents became protracted and are continuing. Many obstacles and lessons have been learnt, developed and overcome through the lifetime of this project and it is believed that the principle of land-banking, to allow for relocation of small communities at risk, is a potential solution in the face of coastal climate change.

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6.5

National Trust Sites, UK

Site Locations

The case study sites are drawn from the National Trust's extensive coastal landholdings, which extend to a length of approximately 1,260 kilometres. They include locations along the central south and south-west coasts of England, and on the Essex coast facing the North Sea.

The Role of the National Trust

The National Trust is an independent charity and membership organisation for environmental and heritage conservation in England, Wales and Northern Ireland. The Trust was founded in 1895 and has acquired land by gift or by public subscription and appeal over the last one hundred and twenty-five years. The Trust owns over five hundred heritage properties and 248,000 hectares of land.

'Shifting Shores' – Supporting Coastal Policy Change

Over the last twenty years the National Trust has played an increasingly important role in helping to shape coastal policy. Jacobs was commissioned by the National Trust to assist the preparation of the Shifting Shores policy which was published in 2015. The wide variety of its coastal landholdings, including hard and soft cliffs, dunes and saltmarshes, as well as wide range of coastal defence structures, have presented ongoing challenges in terms of sustainable Moore R, Davis G, Stannard M, & Browning N 2017 Stabilising Lyme Regis: a strategic Approach. Proceedings of the Institution of Civil Engineers, Civil Engineering 170 Issue CE2; 63–70. Weblink

An assessment by the Trust of its coastal frontages found that one hundred and sixty-nine sites (60%) of their coastline would lose land through coastal erosion, and 10% of this loss could see between 100-200 metres of coastal retreat. 5% of coastal land would retreat by over 200 metres and over 4,000 hectares are currently at risk from tidal flooding, whilst a further thirty-three low-lying sites would be at increased risk from a combination of tidal and river flooding over the next century.

The policy being implemented by the National Trust has, therefore, been to ensure that long-term sustainable plans are in place and that coastal adaptation is seen as a positive force for good. The Trust recognises also that working closely with coastal communities is essential, as is forming partnerships with other key coastal interests and stakeholders. It believes that these approaches will fulfil its aspiration for a healthy coastline that is shaped by natural processes (Dyke, 2015[2]).

Figures 6.19 and 6.20
Two influential publications by the National Trust in 2014 and 2015 promoted the case for a more sustainable approach to coastal management and adapting to natural coastal change.

Image courtesy:
The National Trust.

6.5

National Trust Sites, UK

Case Study Summaries

Birling Gap, East Sussex

Birling Gap is an important National Trust owned site in East Sussex on the south coast of England, facing the English Channel. It receives an estimated 350,000 visitors a year and enjoys spectacular views towards Beachy Head in the east and the iconic Seven Sisters cliffs to the west. The near-vertical chalk cliffs along this frontage are retreating rapidly at an average rate of 0.7m per annum and, as a result, the Trust has implemented a policy of managing realignment along this frontage, as well as seeking creative ways to adapt to coastal change. Land-based facilities such as the café are being relocated further back from the coast, whilst the flight of cliff steps leading down to the beach have been adapted to allow them to move back as the cliff line retreats. The site provided an important test case heard at public inquiry for geoscience conservation versus coast protection of a small community (Moore, 2001[3]).

Figures 6.21
Birling Gap, East Sussex, looking westwards along the Seven Sisters chalk cliffs.
Image courtesy: Roger Moore.

Studland Beach, Dorset

Studland Bay is located on the Dorset coast of south-west England to the west of the popular seaside resort of Bournemouth. Despite some protection from storms by a headland, which terminates in the famous Old Harry Rocks at the southern end of the bay, this coastal frontage has experienced rapid rates of change over the last decade; this has made the maintenance of defences at this location impractical and unsustainable. The Trust recognised that a number of the coastal defences were reaching the end of their life and were having a detrimental effect on the beach itself. After detailed consultations with the local community and beach users, an adaptation plan was agreed in 2017. It was recognised by the National Trust that whilst northern parts of the bay accumulated large quantities of sandy sediment, continuing erosion of the cliff and beach to the south presented an ongoing and increasing threat to the bay's temporary built environment, including beach huts, a visitors' centre and car park, as well as the amenity value of the beach itself. Some buildings will have to be relocated further inland in the longer term, whilst continued monitoring of the frontage in the face of increased sea level rise and storm surges will be essential.

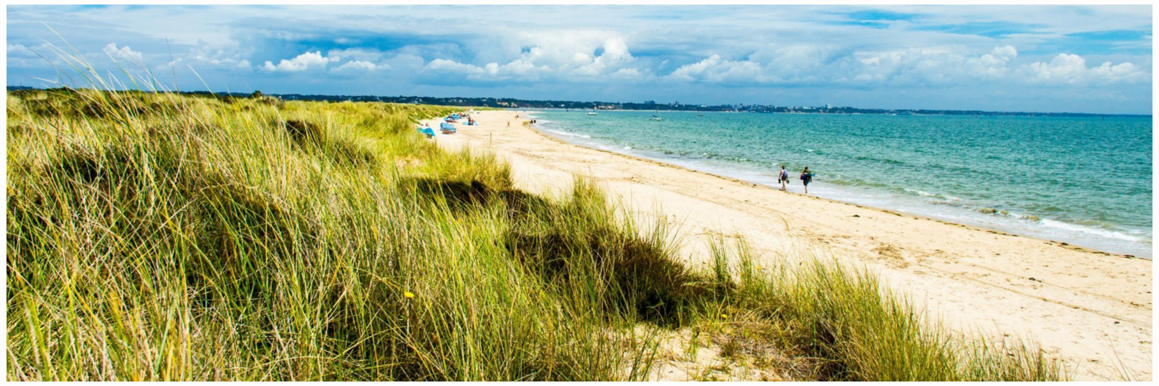

Figure 6.22
Studland Beach, Dorset, looking north.
Image courtesy: Shutterstock Images/ Suxxes Photo

Brownsea Island, Dorset

Brownsea is an island located within Poole Harbour on the Dorset coast, between Studland and Bournemouth. This small (202 hectare) island attracts over 100,000 visitors each year. Its interest lies in its exceptional wildlife and heritage value and the tranquillity of the location.

In the 1970s and 1980s the National Trust sought to reduce the rate of coastal erosion by construction of a line of defences along a 2.5 kilometre length of its southern shoreline. Defence measures included sections of wooden palisade defences, gabion rocks or baskets and sheet pilings which, over the years, have become increasingly unsightly and ineffective in terms of coastal protection. The coastal policy for this frontage recommended 'no active intervention', and after extensive consultations it was agreed that the 'ad hoc' and failing defences should be removed and the works were completed in 2011. The works undertaken have provided a positive improvement to the visual and natural environment of Brownsea Island and have provided valuable experience for assessments of other Trust sites facing similar problems with aging coastal defences (Flux, 2012[4]).

6.5

National Trust Sites, UK

Figure 6.23
The shoreline of Brownsea Island and Poole Harbour, Dorset.
Image courtesy: Shutterstock Images/ David Young

6.5

National Trust Sites, UK

Northey Island, Essex

Northey Island is located in the County of Essex on the east coast of England. The study site is located within the highly designated Blackwater Estuary, and has presented an opportunity to implement integrated and sustainable solutions for adapting to coastal change. Northey Island was the location of England's first managed realignment scheme undertaken in 1991. The existing defences on the island are in poor condition and sea level rise is resulting in the loss of saltmarsh habitats around its coast (Leggett et al., 2019[5]).

Figure 6.24
Northey and Osea Islands, Essex, 2017.
Image courtesy: Geograph © Chris/ Creative Commons.

A phased programme of adaptation has been implemented, including the creation of saltmarsh and transitional marsh/grassland habitats, which add to the biodiversity of this internationally important habitat. Collectively the coastal adaptation measures on Northey Island will work together so that adaptation to sea level rise and climate change happens around the margins of the island, thus allowing space for the main estuarine channels to widen and maintain mudflat habitat, whilst not causing the loss of the central saltmarsh area. This approach will also help to reverse some of the impacts of sea level rise and climate change, which have been resulting in a loss of vegetation biodiversity. The Trust hopes that the managed realignment that has been implemented at this site, will contribute to coastal adaptation in estuaries more widely, both in terms of their strategic approach and measures that are applied (Leggett et al., 2019[5]).

Lessons Learnt from the Case Study Sites

The National Trust faces a wide range of challenges in the face of climate change and sea level rise along its extensive and varied coastline. Through its varied coastal management initiatives, the Trust has successfully implemented good practice, which has been undertaken through close dialogue with local residents and the full range of other coastal stakeholders. More widely, the approaches being promoted and adopted by the Trust have been noted by local authorities and other bodies with responsibilities for flood and coastal erosion risk management, thereby helping provide solutions or potential solutions to their own particular coastal problems.

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6.6

Normandy Coast, France

Location

Two of the case study sites (1 and 2) are located on the coast of the Seine-Maritime Department at Criel-sur-Mer and at Pourville near the city of Dieppe. The third case study site is located on the Calvados coastline at Villerville between Honfleur and Trouville.

Map © Harper Collins, UK
1. Criel-sur-Mer.
2. Pourville.
3. Villerville

Geology, Geomorphology and Coastal Processes

The 130 kilometres of coastline of the Côte d'Albâtre in the department of Seine-Maritime comprises high, near-vertical chalk cliffs, which have a long history of coastal erosion and instability. A combination of erosion at the base of the cliffs and infiltration of rain decreases cliff stability, resulting occasionally in massive failures which have had a serious impact on coastal properties and infrastructure at some locations.

On the Normandy coastline to the west of Dieppe massive failures have taken place where a large clay-sandy pocket within the chalk cliffs collapsed in December 2012. A total of 100,000 cubic metres was displaced and further movements have been ongoing since then. A detailed understanding of the coastal geomorphology and processes has been gained over the last 20 years, and adaptive coastal management policies have been implemented in order to address ongoing current and future coastal change (Costa et al., 2019[1]; Pannet et al., 2015[2]).

Figure 6.25
A massive failure from the 130 metre high cliffs on the Normandy coast at Varangeville near Dieppe. There is a long history of erosion and landsliding along this coastline as illustrated in three case study sites at Dieppe, Criel-sur-Mer and Villerville.
Image courtesy: Professor S. Costa, University of Caen.

6.6

Normandy Coast, France

Case Study Sites

Dieppe, Seine-Maritime

Immediately to the west of the city of Dieppe a major failure took place in December 2012; this caused a retreat of the coastline of up to 40 metres within a few months. The landslide resulted in the loss of one property and the evacuation of two others. Other houses located close to the coast, the coastal highway and sports stadium, were also put at risk. A detailed study was conducted by the French Geological Service BRGM and the Departmental Direction of the Territories and the Sea of Seine-Maritime (DDTM76) led to recommendations for managing the coastal landslide risk.

As a result of comprehensive site investigation and monitoring programmes, a more detailed understanding of the processes of failure was gained (Pannet et al., 2015[2]). It was recognised that further failures along this cliff line were likely in the future and, as a result, a policy of coastal retreat has been implemented. Coastal properties have been acquired under the provisions of the Barnier Law (République Française, 2019[3]) and the owners have been compensated to the pre-disaster market value of their properties. The highway, which had been closed, has been relocated further inland, away from the area of risk, and the sports facility has also been moved back from the coast (see Figures 6.27 & 6.28).

Figure 6.26
View of the cliff failure looking north-east towards Dieppe.
Image courtesy: © Thomas Dewez, BRGM.

Figure 6.27
Shows the landslide in December 2012. This led to a failure of over 100,000 cubic metres of sands and clay and cliff retreat of over 40 metres. Since then landslide activity has continued. Coastal residences at risk were purchased with funds provided through the provisions of the Barnier Law.

Figure 6.28
The local authority had adapted to coastal change by relocating the coastal road and the sports ground further from the coast.
Image courtesy: (Top) Thomas Dewez © BRGM; (bottom) Professor Stephane Costa, University of Caen.

6.6

Normandy Coast, France

Criel-sur-Mer

Criel-sur-Mer is a popular seaside resort located on the high chalk cliffs of the Seine-Maritime coast, close to the town of Le Tréport.

This part of the French Channel coast consists of high near-vertical chalk cliffs, interspersed with deep valleys. There is a long history of erosion along this coastline, which can result in spectacular cliff collapses, leading to damage and loss of infrastructure, as well as posing risks to local residents and visitors. Detailed studies of the mechanisms of cliff failure along this frontage have been undertaken in recent years and the rate and scale of coastal change is now much better understood. Depending on the durability of the chalk horizon, the rate of cliff retreat can vary from less than 10 centimetres a year at Étretat to up to 50 centimetres a year (Deboudt, 2010[4]; Graff et al., 2019[5]).

Because of the height of parts of the cliffs and the scale of movements, coastal defences are often impractical and would also adversely affect the coastal environment. Historical development along the cliff edge has led to the loss of a number of properties, whilst elsewhere private residences have been acquired by the Mayor under the provisions of the Barnier Law, the owners being compensated and the properties subsequently demolished. A row of bungalows on the seaward side of the coast road at Criel-sur-Mer were acquired in 1996 and subsequently demolished between 2004 and 2006 to create an open space along the cliff top (see Figure 6.29) (Debouldt, 2010[4]).

Figure 6.29
Criel-sur-Mer showing the cliff edge site where properties were acquired by the Mayor, the owners compensated, and buildings demolished in 2006.
Image courtesy: 123RF/Milacroft.

Villerville, Department Calvados, Normandy

The study site is located at Villerville, a village on the coast road between Honfleur and Trouville. The coastal frontage lies on the south side of the mouth of the River Seine, facing the English Channel.

The coastal frontage at Villerville comprises complex cliffs of the Cretaceous period, which are affected by deep-seated rotational-translational landsliding (Costa et al., 2019[1]). The location has been monitored since the early 1980s following a major landslide event in 1982. More recently, further detailed assessments and monitoring has been undertaken, allowing seasonal displacements to be measured and groundwater fluctuations could be observed (Lissak, 2012[6]). Over the last century over forty properties have been lost as a result of coastal instability, including many fine villas of the 'Belle Epoque' style (Figures 6.30–6.32). Evidence of ongoing damage is visible, affecting both coastal properties lining the highway and within the carriageway itself, which is frequently affected by cracking and displacements.

Numerous properties on the coastal slopes below the highway have been demolished over the decades and the land has been cleared and managed as a nature reserve and open space. Where properties have been demolished on both sides of the public highway, the sites have been vacated and their redevelopment is not proposed. Where practical, some of the properties, which include some buildings listed as being of architectural importance, have been repaired as far as practicable.

Monitoring of the Villerville site is ongoing and repairs to the highway are undertaken frequently, required warning signs and traffic lights advising motorists of uneven surfaces. Attempts to undertake large-scale drainage and slope stabilisation works at this location are not planned at the present time.

Figures 6.30 & 6.31
Damage to properties alongside the coast road west of Villerville illustrating rotational failure (left) and cliff falls (right).
Image courtesy: (Left) Robin McInnes; (right) Professor O. Maquaire, University of Caen

Figure 6.32
Damage to coastal villas near Villerville as a result of landsliding.
Image courtesy: Professor O. Maquaire and Dr C. Lissak.

6.6

Normandy Coast, France

Coastal Risk Management and Adaptive Planning

In France there are close links between coastal risk management and adaptive planning. For most sections of the coast and for many individual communities '*Plans for the Prevention of Risks*' (PPRs) have been prepared, which categorise the levels of risk. The PPRs form an appendix to the Local Plans for the communities concerned. *The Barnier Law* (République Française, 2019[3]) has, for over twenty years, offered an alternative option for managing coastal risks by supporting the retreat from risk zones and the acquisition and indemnification of property owners affected by hazards such as shoreline retreat and coastal landsliding. This initiative, the Barnier Fund, is financed by a contribution based on a percentage of home insurance and motor insurance premiums, currently set at 12%. An improved understanding of coastal hazard and risk around the French coastline, together with the implementation of the Barnier Law, has provided a mechanism to support adaptive management in the face of coastal change and climate change. Finance for the Barnier Fund is not received direct from the government but through finances based on contributions from the property insurance premiums. This approach does provide a workable mechanism for the management of such developed coastal frontages in the face of climate change.

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6.7

Small Island Developing States

Small Island Developing States (SIDS) is a term given to a group of developing island countries with unique but challenging characteristics, primarily focused on their limited size, low physical elevation and isolated locations, which prevent social and economic development at a normal rate. Currently fifty-two states are categorised as SIDS, eleven of which are among the least developed countries (UN-OHRLLS, 2011[1]).

Coastal Policy Framework

The ocean is crucial to global climate regulation, including uptake of CO_2. This causes changes to ocean chemistry and physiology including sea level rise, ocean acidification and more frequent and extreme storm events (IPCC, 2014[2]). These impacts are already taking effect, and the first regions to be impacted are low lying and equatorial regions, predominantly SIDS (Nurse et al., 2014[3]). As well as the physical impacts of rising seas, the natural resilience of these environments is also reduced; e.g. ocean acidification causing coral reef bleaching and death, leading to increased inundation by the sea and declines in economically important fishery resources (Ferrario et al., 2014[4]).

Sustainable development goals set out by international convention e.g. UNFCCC (1992), Stockholm Convention (1972), and Kyoto Protocol (1997), promote the development of all States in a way which reduces fossil fuel dependency and emissions without impeding societal and economic development. This includes an obligation on developed nations to provide financial support to less developed nations, in particular SIDS (UN, 1994[5]), along with documents such as the Mauritius Strategy.

Incorporating development with softer nature-based engineering can increase resilience, longevity, and bolster sustainability simultaneously. Soft adaptation methods - non-constructive alterations, including capacity enhancement, ecosystem-based adaptation (EBA), community engagement and policy development- are becoming seriously considered methods due to their cost effectiveness, resilience building, provision of ecosystem services and improved sustainability (Ferrario *et al*. 2014[4]).

Small Island Developing States (SIDS)
(28 States)

Note: The boudaries and names shown and the designations used on this map do not imply official endorsment or acceptance by United Nations.

Figure 6.33
Distribution: Pacific, Caribbean and AIMS (Atlantic, Indian Ocean, Mediterranean and South China Sea) in predominantly equatorial latitudes.
Source: United Nations.

Jacobs

6.7

Figure 6.34
Economic, environmental and social vulnerabilities of SIDS in the face of the impacts of climate change (Moosa *et al.*, 2007[6]; Ratterm *et al.*, 2019[7]).

Economic	Environmental/Physical	Social
Volatile economy	Limited space	Growing populations
Dependency on external, remote markets	Narrow resource base	High costs for essential social infrastructure: transport, energy, communication, services
Dependent on imports: materials, non-renewable energy and sustenance	Isolated locations	Limited private sector opportunities
Reliance on international financial aid for development progress	Fragile, economically important, and rare or highly endemic ecosystems	Political instability
Few opportunities to develop private sector industries and economic activities	Low lying	Reliance on irregular tourism industry
Economic activities concentrated in the coastal and inshore zone	Soft sediments/geology	Development of coastal zone concentrates residential and economic activities in coastal zone
High costs of transport, insurance and communication access	Extreme storms and other climatological events including droughts, landslides and flooding	Hierarchical governance structures and power balance between national-local authorities
Not well represented at WTO	Erosion	Internal migration and rehabilitation needs
Constraints on sustainable development progress	Sea Level Rise	Specific vulnerabilities dependent on the community and location
Dependence on few income sources including volatile tourism industry	Ocean acidification	Constraints on sustainable waste management
Potential for tourism and other economic activities to degrade environmental quality	Saline intrusions into groundwater	Sanitation issues regarding freshwater resources and poor water quality

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Small Island Developing States

Responses to Coastal Climate Change – Case Studies: Kiribati and the Maldives

The following specific case studies provide examples of hard and soft adaptation responses that have been implemented to improve SIDS resilience to the impacts of climate change hazards. These are examples of SIDS in different locations, at different stages of development, but that are experiencing similar vulnerabilities, set to increase into the future.

Kiribati

The Republic of Kiribati is highly isolated and one of the least developed island states, located in the Pacific Ocean and consisting of thirty-three islands spread over 3.5 million km^2 of coral atolls (Frankland et al., 2012[8]).

Vulnerabilities: Kiribati is low lying (3-4 metres above Sea Level), experiences storm surges and droughts relating to extreme heat, has dense population concentration on inhabited islands (average 4000/m^2), increasing coastal development, degrading environmental quality, susceptibility to coastal erosion, inundation and impacts of ocean acidification.

Adaptation: This case study demonstrates how hard engineering solutions with some softer adaptation methods can provide immediate, cost effective and reasonably long-term solace from the effects of climate change in SIDS.

A. An integrated coastal assessment has been developed to reduce vulnerability on the islands of Kiribati in the face of climate change (UN, 1994[5]), focusing on Tarawa where over half the entire population resides. Despite considering softer solutions, including unfeasible options of relocation or retreat, the preferred solution was a version of a commonly used sandbag wall, improved to include foundations, double walls, a geotextile toe, headwall and drainage through-out. The outcome of this project enhanced well known techniques, for quick implementation and immediate protection, alongside development of an assessment tools to identify "at risk" sites.
B. The 2019 IEMA award-winning Temaiku Land and Urban Development in Kiribati overseen by Jacobs (Jacobs, 2019[9]) combines land reclamation and land use planning on a pioneering scale for SIDS. Reclamation of 300 hectare of swampland will provide essential space for development, and safe residency, which in-line with IPCC prediction models, is intended to protect the island against sea levels predicted for 2200.
C. Coastal mangrove rehabilitation (Wong, 2019[10]) - soft adaptation approach increases resilience to storms, inundation and provides many ecosystem services to local communities.

Advantages of hard engineering methods	Disadvantages of hard engineering methods
▪ Effective as soon as construction is complete. ▪ Provides additional space for social and economic development. ▪ Develops and improves an already well-known and locally understood initiative. ▪ Scalability and reproducibility on other islands.	▪ Time limit of effectiveness. ▪ Life time is based on predictions with uncertainties. ▪ Storm damage may reduce life expectancy of structures. ▪ Building against nature instead of with it.

Figure 6.35
Flooding on the outskirts of Tarawa, the capital of the nation of Kiribati, an island nation in the Central Pacific Ocean.
Image courtesy: iberdrola.com

6.7

Small Island Developing States

The Maldives

The Maldives, an atoll system in the Indian Ocean, consists of 1190 islands (Khan et al., 2012[11]) – 358 of which are inhabited- spread over 298 kilometres. It is the flattest country on Earth (Toll, 2007[12]), lying across the equator from 07.06'N – 0.42'S, and in 2004 was acknowledged to be in extreme danger from climate change, with the IPCC predicting 75% of the country will be submerged by 2100 (Nurse *et al.*, 2014[3]).

Vulnerabilities: 80% of land mass is less than 1 metre above current sea level, 62% of inhabited islands report coastal erosion, saline intrusion into water supplies, tropical monsoon climate, inundation, degradation of coral reefs, ad-hoc nature of existing protection methods, political inconsistency (Harris, 2015[13]), and large-scale destruction of several islands during extreme storm events.

Adaptation: Hard engineering schemes dominate, however softer methods including traditional practices are also used - and preferred by local communities (Ratter et al. 2019[7]) - particularly over more radical solutions including relocation or mass migration (Bogardi & Warner, 2009[14]). As a high-profile luxury resort destination, there is more impetus and funding available for coastal protection and it was the first SIDS to raise awareness to the international community of this crisis (Petherick, 2015[15]), and has been leading the way with policy development (NAPA) and innovative adaptation solutions.

A. The Assessment of Coastal Protection Methods (2016) identified a range of methods already in use in the Maldives (Jacobs, 2019[9]; Shaig, 2011[16]).

B. Island scale land reclamation creating artificial islands (Water Solutions, 2013[17]) – eight existing and three in planning phase. Hulhumalé – The City of Hope – began construction in 1997, reclaiming a total of 244 hectare enclosed by 3 metre fortified sea walls, second phase to be completed by 2023 creating space for 130,000 inhabitants
Advantages: Creates higher elevated space for economic and social development;
Disadvantages: negative impact of dredging and dumping on fragile but economically important coral reef systems.

C. Floating islands – The 5 Lagoons Project (Dutch Docklands, 2014[18]). The Maldivian Government and Holland based consultancy Dutch Docklands are developing a joint project which will ultimately create five floating islands increasing space, at higher elevations, with a mixture of housing and economic activity types to encourage development and tourism, thereby increasing available funds for further adaptation.

D. Soft Adaptation - The need for more original and innovative coastal protection has been identified, to increase effectiveness and sustainability of adaptation. Using public perception studies (Ratterm et al., 2019[7]), it was highlighted that local communities would prefer soft solutions, to be actively involved, and to be able to trust political leaders. The main pathways identified to develop moving forward were:

- Openness to innovation,
- Political support for local communities,
- Shared responsibility between decision-makers and communities,
- Nature based solutions – re-establishing natural environments, use natural materials, restoring keystone habitats e.g. Mangroves, sea grass beds, reefs and artificial reefs,
- Combining social science, economics, finance and coastal engineering for a holistic solution (Hinkel et al., 2018[19]).

6.7

Engineering Type	Method	Advantages	Disadvantages
Hard	Sea walls, groynes, breakwaters	Immediate protection from erosion, flooding and other extreme events	Overtopped can exacerbate negative impacts, limited lifespan of installations depending on actual rates of SLR, erosional processes can reduce effectiveness, not cost effective in long term
Soft	Land reclamation, beach nourishment	Creates additional space for economic and social development, natural materials	Requires ongoing maintenance, effectiveness may take time to establish
Ecosystem Based	Coastal vegetation protection and enhancement, raised ridges and artificial bio-rock reef construction	Building with nature, many already implemented as traditional practices, more sustainable, opportunity to share responsibility with local community, low costs and low risks involved	Requires continuous maintenance, few existing pilot studies, requires innovation

Figure 6.36
Coastal Protection Methods in use in the Maldives.

Figure 6.37
Aerial view of Malé, capital of the Maldives. The land rises to a maximum elevation of 3 metres above sea level but with 80% of the area 1 metre above sea level.
Image courtesy: Shutterstock Images/ Klempa.

6.7

Small Island Developing States

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6.8

New Zealand

Location

New Zealand is an island arc archipelago, formed on the collision boundary between the Pacific and Australian tectonic plates. The North and South Islands are the major inhabited islands lying south-east of Australia bordered by the southern Pacific Ocean and the Tasman Sea at 41º S, 174º E.

Geomorphology & Processes

New Zealand's volcanic formation and active tectonic processes have created unique and dynamic geomorphological conditions on the islands and around their 18,200 kilometre coastline (Rouse et al., 2003[1]). North Island is smaller, heavily influenced by volcanism, with pocket beaches, estuaries and loose erodible Holocene sediments (Healey, 2005[2]). A greater proportion is at low elevations with 77% of New Zealand's 4.8 million inhabitants residing here (Stats NZ, 2017[3]; World Bank, 2020[4]). South Island's west coast is dominated by mountains, steep glacial valleys and fjords, whilst the eastern coastline is low-lying and agriculturally fertile, with long sandy beaches (Gillingham, 2008[5]). On both islands much of the population is concentrated within the coastal zones.

Response to Coastal Climate Change

Although effects have been mild so far, it is recognised that climate change will exacerbate all environmental risks currently occurring in New Zealand. It has also been suggested that despite robust national plans, some societal and political structuring has led to barriers to efficient progress towards adaptation to climate change and its associated hazards (Manning *et al.*, 2014[6]).

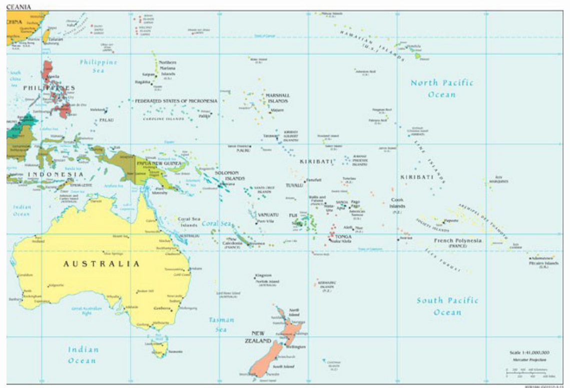

Figure 6.38

Location maps for New Zealand.

Figure 6.39

Limestone cliffs at Cape Kidnappers, Hawke's Bay on the east coast of North Island. The Bay comprises over 350 kilometres of open coast, estuary shoreline and developed coast, including the city and sea port of Napier.

A long-term strategy for the Bay is being developed through collaboration between the Regional and Local Councils.

Image courtesy:
K. Ireland/Shutterstock Images.

6.8

Figure 6.40
Environmental and socio-economic vulnerabilities and policy approaches in the face of coastal climate change in New Zealand (see references 2, 6, 7, 8, 9, 11, 12, 13,15, 20)

Environment / Processes[8,9,2]	Socio-Economic[6]	Policy[6,15]
Coastal erosion – South Island beaches (east coast), estuarine environments, and loose Holocene sediments of North Island exacerbated by SLR.	Increasing population (1.4-2%/yr), concentrated in coastal regions, and significant quantity of critical infrastructure in the coastal zone[10].	Establish consistency in the perception of risk to communities from climate change hazards.
Geomorphology of coast-facilitates erosion from some areas, but limits sediment transport elsewhere, in high energy system of Pacific/Southern oceans.	Uneven wealth dispersal leading to inequity in regional capability to invest in adaptation against future climate change hazards.	Balance the need for hard engineering measures and soft/adaptive responses.
Low lying land elevation – densely populated North Island and east coast of South Island particularly vulnerable to SLR and flooding.	Risk exposure estimated at $3-19 billion (NZL$) in the 0.5-1.5m coastal zone[11].	Focus on adaptive approaches to risk reduction and seeking to avoid costly post-disaster recovery.
Shift in rainfall patterns causing flooding, droughts, and increased significant landslide events.	Expectation of communities to be protected indefinitely is embedded in social values.	Development of uniform approaches to management of risks where practical and sustainable.
Coastal flooding, exacerbated by rising sea levels, increasing frequency and intensity of storms and Influence of El Nino Southern Oscillation and Inter-decadal Pacific Oscillation.	ENSO events recognised cause of economic recessions in past (1990s[12])	Build improving understanding of the rate and scale of coastal change into Planning policy.
Increased tidal prism caused by SLR, deepens harbour channels and increases impact of storm surges and tsunamis impacts in densely populated harbours around NZ's coast.	Strengthen relations between regional councils, social and cultural groups, to build consensus[13].	Embed coastal science and monitoring data into planning policy up to 2100 and onwards.
Other natural hazards – tsunamis, earthquakes and volcanic eruptions can reduce the resilience of communities in the face of additional impacts of climate change.	Intensive mono-culture farming in the coastal zone, degradation of environmental quality, and loss of connection to nature in some communities.	Implementation of national DAPP plans at the local level.

Jacobs

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Policy

New Zealand has national and regional level governance policies and plans for environmental hazards and the Resource Management (Energy and Climate Change) Amendment Act gives local authorities the statutory requirement to consider and plan for the effects of climate change (Resource Management Act, 2004[14]). The Ministry for Environment's Coastal Hazards Guidance (MFE, 2017[9]) details the dynamic nature of hazards and climate change effects, and the need for frameworks that include multiple risk scenarios, environmental thresholds and management options, shifting focus to reducing long term risk. It is also acknowledged that protecting the built and natural environment requires an holistic approach.

Dynamic Adaptive Policy Pathways (DAPP) - A novel methodology integrated into national level guidance to facilitate decision-making (Lawrence et al., 2018[15]). Decision "trees" have a common starting point, and multiple pathways plan out future directions and decisions, incorporating consideration of uncertainty types and scales as well as community input into planning and adaptation to climate change.

Auckland City Council has created a robust set of non-statutory plans including the Unitary Plan and Coastal Management Framework from which regional Coastal Compartment Management Plans (CCMPs) comparable to the United Kingdom's Shoreline Management Plans (SMPs) have been developed (Auckland Council, 2017[16]; Millar et al., 2020[17]).

Social Resilience and Adaptation Tools

There are some aspects of adapting to the effects of coastal climate change that strong policy alone cannot achieve. Including communities in the complex and emotive decision-making can increase understanding of the processes occurring, option viability, and improve acceptance of the pathways ultimately chosen; enhancing the capacity of communities to adapt to sometimes difficult changes made necessary by current and future risks.

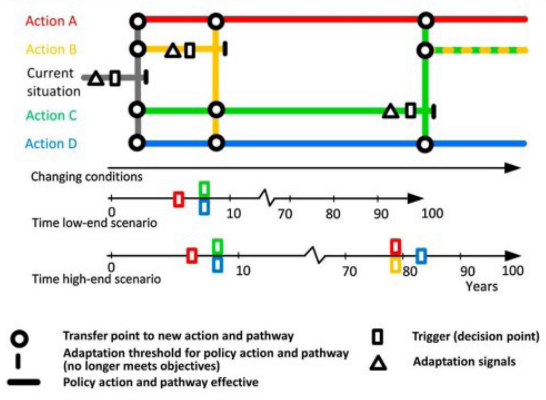

Figure 6.41
Decision pathways of DAPP visualised (Lawrence *et al.*, 2018[15]).

Living at the Edge, Hawkes Bay – A joint initiative between the local council, urban and Maori communities used Multi-Criteria Decision Analysis to develop an interdisciplinary strategy plan together, to build holistic resilience to coastal hazards, drawing together the concepts of DAPP and holistic community involvement (Kench et al., 2018[18]).

Cape Cod Coastal Planner – An interactive tool developed for Massachusetts, USA. Its accessibility and concept provide an excellent example of an effective tool to explore and test risk and management scenarios, providing long term impact metrics for several key factors including habitat loss/gain and infrastructure value (Cape Cod Planner[19]).

Jacobs & Christchurch City Council, NZ have collaborated on a tool to guide decision-making, promote communication and community engagement into the future management of the regional coastline. This successful prototype App has applicability to any coastal region encouraging decisions to manage risks from climate change through sustainable adaptation.

Maori Culture instills a cultural and spiritual connection to Earth, which engenders respect for nature; this ethos could be promoted to demonstrate best practices in the wider population and to build natural resilience within communities (Manning et al., 2014[6]).

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New Zealand

What can we learn from this case study?

Statutory and non-statutory policy frameworks and plans need to be dynamic to facilitate current decisions and overcome the various sources of future uncertainty which are intrinsically linked to climate change and its impact on society.

- Community engagement and involvement are fundamental in decision-making to achieve sustainable adaptation, considered with High Confidence by IPCC.
- Good communication networks between local authorities and their communities can engender a sense of shared responsibility and develop sustainably.
- Different factors should be considered by asset valuation in urban and rural communities.

Tools such as the Cape Cod Coastal Planner[19], developed by Jacobs and other participatory mapping methods can greatly enhance local-level policy development and implementation, and should be:

- **Simple** to use and understand.
- **Flexible**, including trigger thresholds and multiple scenarios.
- **Holistic** – physical environmental change, ecosystem services, economics, social impacts.
- **Tangible**, with understandable metrics of impact or change – economic value, loss/gain.
- **Facilitate** discussion between decision-makers, technical experts, and affected communities.
- **Compare** management pathway options, and reassessment of future decisions in dynamic process.
- **Updated** with best available science.

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6.8

New Zealand

Figure 6.42

A view along the city of Napier coastal frontage at the southern end of Hawke's Bay, North Island. The bay faces hazards from tsunami, erosion and flooding and a 'Coastal Strategy 2120' seeks to address these hazards and the management of risks into the next century.

Image courtesy: Ramunas Bruzas/ Shutterstock Images.

6.9

East Coast of the USA

Location

The USA has one of the longest continuous coastlines in the world, spanning the Atlantic and Pacific Oceans. For the purpose of this guide, the USA case study will focus specifically on the 3,300 kilometres of east coast, from Maine to Texas, where its characteristics make this coastline particularly vulnerable in the face of climate change and associated coastal hazards.

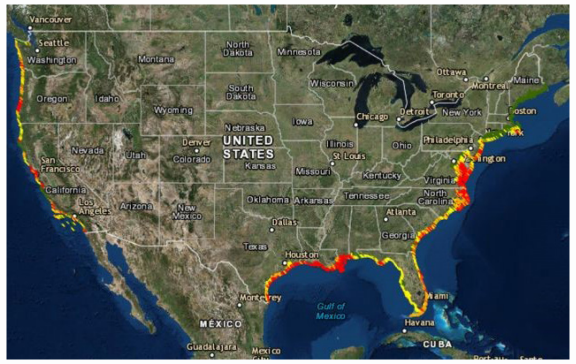

Figure 6.43
Map depicting susceptibility to coastal change on the USA East Coast. USGS, 2020.

Summary of Geomorphology and Processes

The USA has an extensive and dynamic coastline. The east coast is characterised by low-lying estuaries, bays, wetlands and barrier-island chains, whose tidal extents increase the coastal length to 46,150 kilometres (Sherman, 2005[1]). It is typically much lower in elevation than the western coastline and is dominated by mud, silt and sand-based sediments (USGS, 2020[2]). A unique feature of this coast is that sea level rise is occurring three to four times faster than the global average (Sallenger, et al., 2012[3]). Figure 6.43 indicates the prevalence of change on the east coast, with Texas, Louisiana and North Carolina experiencing the most significant changes. Part of that geomorphological change is a result of its exposure to anti-cyclonic storms and hurricanes impacting the coast (Figure 6.44), along with a range of other factors, which make this coastline vulnerable to the impacts of climate change (see Figure 6.45). Coastal storm risk management measures on the Texas coast around Houston, including nature-based defences, enhancements of the existing ecosystems, and improved levee and floodwall systems costing $1.9 billion, are being designed by Jacobs and Stantec (Galveston Coastal Services) for the US Corps of Engineers.

Figure 6.44
Map of Hurricane Prone Regions.
Source: FEMA, 2013[4].

Figure 6.45
Wells, Maine, 09 Sep 2019.
Image Courtesy: Arthur Villator/ Shutterstock Images.

6.9

Environmental/Physical[4]	Social	Economic/Policy [7,8]
Coastal flooding, exacerbated by impact of storms and sea level rise.	Densely populated residential areas directly adjacent to coastline. Highly populated and high risk areas include New York, Boston, Baltimore, and Philadelphia [2,9].	Poverty/differing economic status within and between States – affects ability of communities to recover and build resilience, and level of response capability and protective/mitigation measures.
Low-lying topography, with varied coastal geomorphology including less resistant depositional features, such as deltas and barrier islands.	Coastal population density is increasing – pressure on resources including emergency services & aid during and after hazards.	Current legal framework – discriminates against innovation in coastal hazard solutions - complex permitting process having to consider each case individually.
Coastal erosion, facilitated by less resistant geology dominated by mud, glacial deposits, and sand based sediments.	Differing attitudes towards acceptance of climate change[5,6].	No single guidance document setting out specific actions required for coastal management and adaptation.
Extreme weather events- Nor'Easters and hurricanes hit this region more than any other. Associated impacts with hurricanes include storm surges and strong winds, beach erosion, nuisance flooding.	House Bill 819 – North Carolina legislation temporarily banned coastal policies being based on SLR models which indicated accelerated SLR, in favour of historical linear predictions[6].	Individual States have different legislative priorities and local policy. Cross State-lines challenges for continuity, different data collection efforts.
Land subsidence 3-4 times faster than global average rate on the East coast, enhancing relative sea level rise rates[3].	Prioritisation of economic growth over acceptance of coastal change and investment in a more sustainable future[5].	Ad-hoc investment in coastal engineering schemes.
Sea level rise – exacerbate impacts of hurricanes and other extreme weather events.	Public response to risk communications before and during extreme weather events is unpredictable and advice is often ignored[10].	Policy loopholes and enforcement issues, and lack of incorporation of scientific reports and assessments into policy.
Sea surface temperature increase linked to increasing frequency and intensity of extreme weather events.	Resistance to retreat to stable, mainland areas. Instead fighting erosion and SLR with long term use of unsustainable methods such as sandbag walls meant for short term mitigation[9].	Preference for hard engineered methods of holding the line in rapidly eroding areas, reducing natural replenishment[9].

Figure 6.46
Environmental, socio-economic and political factors which increase the East Coast's vulnerability to coastal hazards and climate change. (USGS, 2020[2]; Sallenger *et al.*, 2012[3]; FEMA 2013[4]; Glass & Pilkey, 2013[5]; Waldman, 2017[6]; DEQ, 2009[7], 2011[8]; Oskin, 2012[10]; Abramson & Redlener, 2012[9])

6.9

East Coast of the USA

Response to Climate Change

North Carolina

North Carolina is one of the most vulnerable frontages on the eastern seaboard (USGS, 2020[2]). In recent years progress has been hindered by political rejection of climate science (Waldman, 2017[6]), but has since produced some of the most comprehensive strategic management plans along the eastern seaboard. These plans are progress towards accepting the necessity to adapt, utilising a combination of hard engineering protection, land elevation/reclamation, and managed retreat (NCCF, 2017[11]). Strict rules have been introduced for construction including a ban on hardened oceanfront structures, the requirement for "buffer zones" between new developments and Mean High Water, and flood resilience incorporated into building and foundation design (FEMA, 2013[12]). Policies are recommended to be updated at regular five yearly intervals; for example, erosion setback for structures using the best available science.

Hurricanes

The hurricane season occurs between June and November each year, peaking in September, where an average of 2-3 major hurricanes will make landfall. History shows that one extreme event can devastate vast swathes of the coastline including densely populated cities. The last two decades has produced particularly damaging storms including Hurricane Florence (2018), Sandy (2012), Irene (2011), and Katrina (2005). Their unique characteristics fuelled unprecedented impacts, including severe storm surges, which inflicted immense damage, particularly in low-lying areas (Oskin, 2012[10]) and underground transport systems, causing widespread nuisance flooding and cutting off aid supply chains. These impacts continue to highlight how extreme weather events will only be exacerbated by sea level rise and other climate change impacts, which reduce natural coastal resilience (Arkema et al., 2013[13]). The need for better co-ordination in response to unavoidable events is also recognised, despite well-rehearsed response efforts and strategies existing, (Abramson & Redlener, 2012[9]).

Figure 6.47 & 6.48
Before and aftermath of Hurricane Sandy in New Jersey.
Image Courtesy: © Google/NOAA National Geodetic Survey.

6.9

East Coast of the USA

Managed retreat

This can be a drastic and sometimes unpopular option, but one which may represent the only safe mitigation action against sea level rise and coastal erosion. The Riggings community in North Carolina has been utilising sandbag walls to keep back the encroaching sea since 1985 rather than move, despite the offer of large Federal grants (Riggs et al., 2009[14]). The barrier islands in Chesapeake Bay are disappearing one by one. Here, sea level rise has enveloped thirteen islands including Holland Island, which was abandoned in 1918 (Gibbons & Nicholls, 2006[15]), and the currently inhabited Deal Island is now facing a similar fate within the next twenty years (Waldman, 2017[6]). Isostatic subsidence is causing relative sea level rise at a greater rate than the rest of USA. Coupled with deltaic, marshland environments which have prevailed since the last Ice Age, this creates a dynamic, mobile environment (Karegar *et al.*, 2017[16]).

What can we learn from this Case Study?

The greatest challenges here originate from the extent of the eastern coastline, combined with dense population hotspots and large investments of critical infrastructure plotted against an increasing prevalence of extreme weather events. The following are identified actions that will facilitate overcoming these issues.

- Data collection - is crucial to underpin effective adaptation strategies. Efforts must be consistent across States, up to date, robust data sets.
- Use of "big data" has the potential to improve social resilience in the face of extreme coastal weather events, particularly in densely populated areas (Shelton *et al.*, 2014[17]).
- Developing an improved understanding of the dynamic processes at work to support management of coastal hazards.
- Accept flexibility in planning and policy; the coastline is in a state of flux and plans should reflect this.
- Natural coastal features provide some of the best protection against coastal hazards (NCCF, 2017[11]). Coastal protection schemes and new developments should aim to harness and work in synergy with natural processes.
- Holistic coastal zone and shoreline management plans, which consider effects down-drift of developments, are essential to prevent a hazard being shifted down the coast or across a border.
- Make use of the range of tools now available for planners and decision-makers that exist, e.g. Digital Coast, USG's DSAS, and Coastal Change Hazard Portal, StormSmart Coasts and localised Shoreline Mapping exercises (FEMA, 2013[4]). The Cape Cod Coastal Planner is a communication and decision support tool intended to educate users on the climate change hazards impacting Cape Cod's coastline, the adaptation strategies available to address them, and implications for local infrastructure and ecosystems. You can choose your location and zone of impact to begin planning. It is possible to view planning layers and test adaptation strategies for three coastal hazards via this weblink.
- Community engagement is crucial to ensure stakeholders' understanding of hazards and risks and to build resilience from the bottom up in the face of changing climate.

Figure 6.49 (left)
Riggings Community, barrier island, Maryland.
Image Courtesy: Ashley Evans, WCU, 2017/ Shutterfly

Figure 6.50 (right)
Last house on Holland Island, Chesapeake Bay, 2009.
Image Courtesy: baldeaglebluff/ Wikicommons.

6.9

East Coast of the USA

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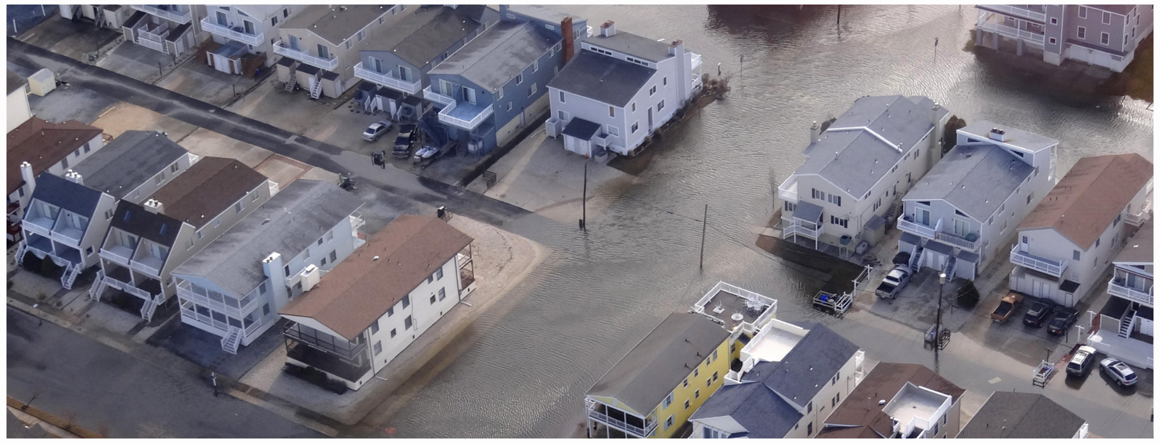

Figure 6.51
The aftermath of a severe winter storm at Ocean City, New Jersey, in March 2013.
Image courtesy: US Coastguard/ Alamy Stock Photo.

6.10

Case Studies - Discussion

The case studies described in this chapter, which are drawn from twelve locations in the United Kingdom, France, the USA, New Zealand and the Small Island Developing States, demonstrate that the adverse consequences of coastal hazards and climate change represent an issue of global proportions. There is no doubt that they provide significant challenges for decision-makers involved in both planning and risk management particularly at the local government level, as well as for those communities and businesses directly affected. The increasing pressures imposed on coastal locations through this century and beyond will be particularly challenging and will require innovative approaches to avoidance of risks from coastal erosion, nuisance flooding and landslides including the implementation of adaptation strategies and the sharing of good practice advice and guidance, such as through this publication.

Coastal local authorities, therefore, and the communities they represent are faced with an increasingly complex task of balancing development needs and managing long-term coastal risks. Given the combined effects of further human development at the coast and climate change impacts these problems are of growing intensity. Increasingly, central and local governments are becoming committed to ensuring that planning policies help communities to adapt to the risks arising from climate change. The authors firmly believe that land use planning has a vital role to play in helping coastal communities, infrastructure development operations and businesses to manage risks and adapt to these changing conditions. The planning system at the local government level is already having an increasingly important role to play in policy-making and day to day planning for the coast. The case studies provide illustrations of how a thorough understanding of long-term coastal evolution along affected frontages, and the availability of scientific evidence, can support the planning framework and ensure the implementation of sustainable policies.

In the United Kingdom, for example, the preparation and implementation of shoreline management plans (SMPs) has enabled the identification of *'Coastal Change Management Areas'*, which are those coastal frontages most likely to be affected by coastal change over the next 100 years. This information allows planning departments within the local authorities to set out policies for adaptation to changing coastal conditions and provide a framework for engagement with affected coastal communities. In France, the preparation of 'Risk Prevention Plans' (PPRs) provide detailed information to support wise decision-making within many of the communes around the French coast (see Case Study 6.6).

In some locations where communities face particular threats from coastal erosion, landsliding and nuisance flooding, and where economically justifiable and environmentally acceptable, coastal protection, landslide management and flood defence measures are being implemented, for example at Lyme Regis on the Dorset coast, the Ventnor Undercliff of the Isle of Wight and Portsmouth and Southsea, Hampshire (Case Studies 6.1, 6.2 & 6.3). On the north Yorkshire coast of north-east England, government funding has supported the testing of new and innovative approaches to planning for the management of coastal change through the UK Department for Environment, Food and Rural Affairs (Defra's *'Coastal Change Pathfinder Programme*'). Here, the task involved sourcing and purchasing suitable land as a form of land-banking in order to relocate residents and provide replacement properties on a site in the vicinity of their existing homes that was not at risk from coastal erosion or instability. This was the first time that the concept of land-banking adaptation and homeowner building had been attempted in the United Kingdom (see Case Study 6.4).

The role of national conservation and cultural heritage bodies can be particularly influential, as illustrated through the work of the National Trust in the United Kingdom. The work of the Trust over the last ten years has encouraged adaptation to coastal change, particularly in locations where significant environmental gains can be achieved (see Case Study 6.5).

Engaging with coastal communities over adaptation in changing coastal conditions involves building up enduring partnerships between local residents and often local authorities.

6.10

Case Studies - Discussion

The impracticality of defending some coastal communities for physical, economic or environmental reasons is naturally an issue of significant concern and a focus for much discussion. The French case studies illustrate an approach whereby funding can be made available for the compulsory acquisition of properties at risk and the owners fully compensated at pre-damage market values. Such an approach, which is funded by a contribution based on a percentage surcharge on home insurance and motor insurance premiums provides a mechanism to support adaptive coastal management (see Case Study 6.6).

The vulnerability of the Small Island Developing States, where often land levels are less than 5 metres above sea level, has proved particularly challenging for their governments and a range of both soft and hard engineering solutions have been implemented at locations such as the Republic of Kiribati in the Pacific Ocean and within the Maldives Atoll in the Indian Ocean. An innovative scheme on Kiribati, overseen by Jacobs, has combined land reclamation and land use planning on a pioneering scale for such a location; the scheme will provide essential space for development and safe residency with the intention of protecting the Island up to 2200 (see Case Study 6.7).

On the North Carolina coast of the USA, one of the most vulnerable frontages on the eastern seaboard, strict rules have been introduced for construction, including a ban on hard and ocean front structures, the requirement of buffer zones between new development and Mean High Water and flood resilience being incorporated into building and foundation design (see Case Study 6.8).

The impacts of hurricanes and severe storm surges, which have caused widespread damage in recent years, continue to highlight the need for development of a thorough understanding of the dynamic processes at work on the coast. This includes acceptance of flexibility within coastal planning policy, recognising the crucial importance of community engagement to support understanding risks and hazards and the building of resilience from the ground up in the face of our changing climate and coast (see Case Study 6.9).

The case studies illustrate a range of approaches to adaptive management and demonstrate how coastal science can provide essential information to inform planning and development control in the face of climate change. The authors hope that the case studies and the references cited will prove to be of real practical value to those in the process of developing their own planning policy documents to meet the challenges of coastal hazards and climate change.

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