Chapter One
Coastal Evolution, Behaviour and Climate Change

The varied geological conditions prevailing around the coastline of the European Union have resulted in the formation of a wide range of geomorphological features and have created a coast of enormous variety, scenic beauty and interest. The coastline has been formed over geological time with the diverse rock formations being created or deposited, uplifted during mountain-building phases, compressed, folded and faulted before being affected by processes including glaciation, inundation, coastal erosion, and weathering by wind and rain. An examination of the geological maps of many European countries illustrates a wide range of rock types exposed around the coastline. The nature of the coastal and seabed geology, as well as the structural form of the rocks (including the influence of joint lines, bedding planes and the angle of dip), together with other factors such as groundwater levels, natural sedimentary processes and the impacts of changes within the earth's crust have all had an influence on the appearance of the coastal zone.

Detailed mapping work has been undertaken by the Geological Surveys of a number of European member states and some of these have helped identify the inter-relationships between the terrestrial and sub-marine geology resulting in an improved understanding of coastal evolution. For example, in the Channel (La Manche) between England and France terrestrial mapping has extended to include the Continental Shelf, allowing the British Isles and France to be set within a European geological context illustrating many key structural features including major fault lines, sea basins and areas of higher ground.

The geological history does, therefore, dictate the present day structure and scenery of our coastal zones. Since their formation geological deposits have been eroded and weathered over millions of years to create our present landscape. Along the coast the most marked differences are often created through contrasts between those more resistant rocks, which form headlands and uplands, and the softer, usually sedimentary rocks, which form the lowlands and soft cliffline coastal frontages.

The coastline is constantly changing and factors such as wave size, wind speed, water depth, the strength of tides and the rates of relative sea level change, as well as rainfall and the frequency and intensity of storm events, are all influencing factors. By studying the geological maps of various countries it is possible to appreciate the overall geological structure and to identify rocks of geological Periods which, through their particular individual characteristics create major escarpments, valleys or other topographical features. Elsewhere the influence of glaciation has sculptured the geology whilst in other areas extensive deposits of more recent materials including clays, gravel deposits, landslide debris and alluvium form blankets masking the solid geology beneath. A particular influence has been the 'mountain-building' phases such as the Armorican and particularly the Alpine phase which led to the formation of the world's great mountain ranges, for example the Himalayas and the Alps. The outer ripples of these massive phases of crustal activity led to the formation of major features in north-west Europe, for example, by creating the Paris Basin and the North and South Downs of England. An examination of geological cross-sections and dip of strata, as shown on geological maps, illustrate the full extent of the folding, erosion and weathering that has taken place since the rocks were first deposited.

Many factors have led to the evolution and shaping of the coastline as we know it today. These include the changing rates in sea level rise which, in some locations, have been dramatic over the last 30,000 years. This, in turn, has influenced the nature and the severity of coastal erosion, a key factor in transforming the coastal landscape. The influence of climate is also particularly important on the coast as rainfall, and run-off carrying sediment from the hinterland down to the coast, is very significant, whilst along the coast itself the rates of erosion and transport of materials by waves, tides and currents have led to the formation of beaches and sediment sinks resulting in accretion in some places and depletion in others.

A wide range of climatic conditions including atmospheric pressure, temperature, wind speed and rainfall have all had their impact upon the geology of the coastline. These natural processes are not, however, uniform and even over the last 2,000 years particular phases of activity have been identified. Storm
events such as that striking southern England in 1703 and the coastal storms that affected the North Sea in 1953 resulted in the loss of lives of over 3,000 people in the Netherlands and 300 in eastern England and within the estuary of the Thames. Since then a considerable amount of research has been undertaken into the reasons why particularly severe storm events should occur and to establish whether this forms a pattern or whether they are random events. Studies of this kind and an improved understanding of coastal evolution and natural conditions generally are vital in order to prepare for a period of increasing change over the next 100 years as the impacts of climate change become increasingly serious.

In recent years a considerable amount of research has focussed on the time period between 13,000 BP and the present day, known as the Holocene Period. During the early Holocene a steady retreat of the ice sheets was seen which led to an increase in sea levels and a readjustment of the earth's crust following the relief of weight imposed by the huge mass of the ice sheets. These changes have had varied effects across the European continent. For example, in Britain, loss of the ice sheet resulted in settlement of the land mass in southern England and an increase in land levels in Scotland, roughly divided by a 'hinge' along the line of the Scottish Borders. An examination of the evolution of the European land mass over this period and an understanding of the inter-relationship between parts of the European coastline helps appreciate regional-scale coastal evolution. For example, in 10,000 BP Great Britain was connected to continental Europe by a land 'bridge' near the Dover Straits, whilst to the north, the east coast of England was separated from Belgium and Holland by the North Sea. By about 8,000-5,000 years BP, in what was known as the mid-Holocene Period, the rate of sea level rise was starting to slow down and the major erosion and weathering processes which had led to vast quantities of eroded material being transported from both fluvial and coastal sources was also reducing. During this period sea level rise was continuing much more slowly and this led to the creation of many low-lying, inter-tidal areas at the interface between the land and sea.

Coastal erosion resulted in the severing of the mass of land between the North Sea and the English Channel about 7,500 years ago helping to create the map of Europe much as we know it today. The severing of this connection resulted in much stronger currents and significant sediment transport around the Channel coasts before settling down to a regime similar to that of the present day. A progressive on-going rise in sea levels led to the flooding of many existing river valleys around the European coast forming features such as estuaries, creeks, mudflats and saltmarshes, and this process has been ongoing since then.

Plate 1.1: The chalk cliff lines of the Côte D'Albâtre have been eroded by the sea to form caves, arches and stacks such as those at Étretat, Upper Normandy, France.
Evidence drawn from palaeo-environmental and archaeological research has assisted the understanding of long-term coastal change in Great Britain and elsewhere (McInnes et al., 2000). This research has established a wealth of information about coastal evolution and change since the last glacial maximum. Palaeo-environmental evidence can also help us understand more about past fluctuations of climate for example during peak periods known in Europe as the Medieval Warm Phase and the Little Ice Age. These phases had their own lesser influences in terms of modifying and shaping parts of the European coastline. Incidents of rainfall over geological periods have also resulted in activity or inactivity in terms of geomorphological processes. The extent of coastal erosion and the amount of winter rainfall are two factors which can influence coastal landsliding activity and research has identified that the period from 1700 to 1850 was a particularly active one in southern England (Brunsden and Lee, 2000).

Over the last 100 years the influence of the Little Ice Age appears to have been much less significant and a general cooling trend now has been reversed. Many people have noticed a more rapid increase in temperatures in recent decades, although this has not necessarily been a steady rise but characterised by fluctuations and episodes. This trend of warming coincides with wide-ranging international concern over increased temperatures due to the human influences of climate change known as the ‘greenhouse effect’. Research has identified that the amount of sunshine reaching the earth is increasingly resulting in the acceleration of the pace of climate change. Since the 1990s there has been a widespread increase in the melting of glaciers and ice sheets, and a trend of ‘global dimming’ due to the interference of the sun’s rays by pollutants now appears to be reversing which, if continued, could have disastrous impacts for the human and natural environments in years to come.

It is not just the influence of climatic impacts and natural processes that has affected the coastal environment. Since human colonisation of the coast for reasons of trade, defence and recreation, particularly since the Roman period, the coastline has been altered significantly. This process was most dramatic during the mid-19th century and onwards when a huge increase in coastal development resulted from the popularity of sea bathing and following publicity on the benefits of the coastal climate for health. Such human intervention has resulted in many of the coastal estuaries being developed or reclaimed, as well as rivers being channelised, modified in other ways and dredged. Such changes not only have an impact on the formation and development of estuaries but can have significant impacts on adjacent parts of the coastline, which may include an increased frequency of coastal erosion or flooding.

In order to protect coastal developments, many of which were constructed on coastlines subject to significant rates of erosion, landslip and flooding, defences were provided particularly during the late 19th and early 20th centuries. In some locations this has prevented natural erosion of soft cliffs which, in turn, has reduced the amount of sediment supply entering coastal systems with knock-on effects such as beach depletion further along the coastline. In fact, along much of the European coastline, beach levels have declined as a result of human intervention, as well as other factors including sea level rise; the consequent beach lowering also often results in increased marine erosion.

The recognition of coastal change and practical experiences of the results of this over the last three centuries has clearly demonstrated that the coastal zone is an area that is naturally dynamic and prone to significant changes over time and geographical extent. The factors which result in coastal change do not always operate at the same frequency, whilst some factors are more intense than others. Understanding the coastal response may be complex; particular changes in the rate of erosion, landsliding or other factors may depend on certain thresholds being exceeded followed by periods of relative tranquillity until another threshold is exceeded. Some of the factors which lead to more dramatic coastal changes may have, therefore, been influenced by activities in past decades, whilst others may have swift reactions. All this emphasises the need for particular care to be taken when examining coastal processes and the need to draw evidence from longer term experiences rather than making decisions based upon data derived from a short timeframe. An understanding of the processes at work around the coast is, therefore, fundamental to effective risk management (Futurecoast, 2002).

All around the European coastline the influence of the geology on the coastal landscape is clearly illustrated through dramatic examples. On the Isle of Wight in southern England the more resistant chalk headland at its western end, which terminates in the famous Needles rocks, forms a marked contrast to the softer sediments to the north and to the south. In northern France the processes of coastal erosion
and weathering have created a dramatic coastal environment of textbook landforms including sea caves, stacks and arches along the chalk cliff frontage of the Côte d’Albâtre. Elsewhere sediment transport has resulted in the accretion of huge sand dunes such as those near Arcachon along the Aquitaine coast of south-west France.

In southern England the dramatic rise in sea levels between 10-6,000 BP, by as much as 100 metres, resulted in aggressive coastal erosion leaving many parts of the coastline in a vulnerable, over-steepened state. The effect of the erosion process has been to de-stabilise some coastal frontages resulting in a legacy of landsliding and instability problems. The largest urban landslide complex in north-western Europe is the Isle of Wight Undercliff which extends for 12 kilometres along the south coast of the Isle of Wight. A combination of coastal erosion and the effects of high ground water levels have promoted a series of landslide events within the complex which continue to this day.

In England and Wales the Department for Environment, Food and Rural Affairs (Defra), has provided funding for the development of coastal defence (shoreline management) plans (Defra, 2006) in order to contribute to wise coastal risk management. Following the completion of the first round of these plans for the whole of the coastline of England and Wales by the Millennium a review highlighted the importance of undertaking further research to re-emphasise the need for attention to be paid to the understanding of coastal evolution and natural processes to support decision-making. The result was a further major study (Futurecoast, 2002) which provided a wealth of supporting information in order to ensure that decisions, which may have an impact on the coast for a hundred or more years to come, are based upon the fullest possible knowledge of how the coastline may change. The LIFE ‘Response’ project aims to assist that process by illustrating the preparation of a sequence of maps which demonstrate a process of assessing the physical environment, coastal processes and the susceptibility of different coastal frontages to change, thereby allowing the development of hazard and risk maps which highlight those locations where particular problems are likely to be encountered in the future.

Plate 1.2: The more resistant chalk outcrop forms the Needles headland at the western end of the Isle of Wight, UK, whilst the softer sands and clays to the north, at Alum Bay, have eroded more rapidly.
For nearly 200 years geoscientists have provided evidence of coastal change. These include the records of lost villages, coastal structures such as forts, lighthouses and churches (McInnes, 2004) as well as important archaeological sites which may have been constructed thousands of years before. Some important or historic assets have been lost through coastal erosion whilst elsewhere sea ports have been stranded from the coast following the accretion of extensive mudflats and saltmarshes. A major tool to aid this process has been the use of radio-carbon dating by archaeologists (McInnes et al, 2000) which has helped provide a chronology of coastal settlements and in turn coastal change over the last 4,000 years.

With over 70 million people living within the coastal zones of the European Union, representing approximately 16% of the EU population, wise decision-making is vital. Along 20,000 kilometres of the European Union's coastline (about 20%) serious impacts arise from coastal erosion (EUrosion, 2003); 15,000 kilometres are actively retreating and nearly 5,000 kilometres are artificially protected. Coastal resilience is the inherent ability of the coast to accommodate changes induced by sea level rise, climate change, extreme events and occasionally human impacts, whilst maintaining the functions fulfilled by the coastal system in the longer term; this must be a key objective. The concept of resilience is particularly important in the light of the latest IPCC predictions of global climate change (EUrosion, 2003).

The impacts of climate change do, therefore, demand a more strategic and pro-active approach to coastal risk management in order to restore the sediment balance, allocate space necessary to accommodate natural erosion and coastal sediment processes and achieve a better understanding of coastal evolution. In most countries coastal erosion risks are not sufficiently assessed, so it is hoped that the information provided from the LIFE 'Response' project will provide common methodologies for coastal hazard and risk mapping. This objective formed a key recommendation from the European Commission's EUrosion project (2003). By incorporating coastal erosion hazards and risk mapping into long term plans, local and regional authorities can effectively divert new development from areas at risk and seek to modify or reduce risks in areas of existing development.

Plate 1.3: The dramatic coastal sand dune system on the Aquitaine coast of France near Arcachon.
References


Plate 1.4: Dense development of the coastal zone at Biarritz, south-west coast of France.
Chapter Two
What are the nature and scale of coastal risks?

Natural hazards have significant impacts on coastal zones throughout Europe. The costs of emergency action, remediation and prevention can often represent a significant burden to the communities affected, often local or regional authorities with limited resources as well as for national governments. It is now accepted that the impacts of climate change are real and sea level rise, in particular, poses serious risks to coastal communities. In order to identify risks to assets in coastal zones it is necessary to establish first the current level of risks and then to seek to identify the increasing level of risk resulting from climate change in order to implement sustainable policies to reduce or manage those risks.

Europe’s diverse geophysical and climatic characteristics make it susceptible to a wide range of extreme natural events. Natural hazards such as coastal erosion, flooding and instability are a common feature of coastlines in the EU 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 gradual process whilst flooding and landsliding are more spontaneous, episodic events that may be relatively more difficult to predict and are potentially more costly as a result (European Environmental Agency, 2004).

In 2005, Europe suffered 648 natural catastrophe loss events (a loss event being an earthquake, tsunami, volcanic eruption, windstorm, flood, temperature extreme or mass movement). These resulted in 336 fatalities, and overall losses of US$ 16,002 million of which US$ 4,875 million represented insured losses. There are clear signs that there has been an increase in the number of westerly weather conditions and a significant rise in flood catastrophes such as those on the Elbe and the Danube (2002), and in the northern Alps in 1999 and 2005 as well as on the coast. In 2005 there were three instances of serious flood conditions within the space of just six weeks, a clear sign that climate change is already happening in central Europe. Evidence suggests that changing weather patterns will result in more frequent and more severe events and, as a result, more losses and damage, to which the insurance industry and society as a whole must devise an effective response.

Catastrophes will continue to affect Europe’s coastal zones and hinterland. The reasons for this include population growth, an increasing concentration of people and assets as a consequence of urbanisation, the settlement and industrialisation of exposed areas such as coasts and river basins, the greater susceptibility of modern societies and technologies and, especially, hazardous changes in the climate and the environment (Munich Re, 2006). The future of some coastal areas is particularly uncertain as rises in sea level will threaten to displace entire coastal communities and destroy their assets with severe disruption to adjacent regions and the finance sector.

Coastal risks arise when the hazards associated with the physical environment such as flooding and erosion or instability interact with society. Risk-based decision-making is seen to provide the means of addressing the challenges put forward by climate change and sea level rise. This is because it is based on a view of the world that recognises uncertainty rather than presenting an over-confident ‘this will happen’ view of what is known (ie. the so-called ‘deterministic’ perspective). The approach provides a framework for combining possible hazard events and their consequences along with a way of considering uncertain events and outcomes. It recognises that although current understanding may be limited, decisions still have to be made. It also supports the notion that management measures may reduce risks but they generally cannot eliminate them. Risk-based approaches allow an appreciation of the degree of risk reduction and the residual risk that must be borne by society or individuals after mitigation measures have been implemented (Lee et al, 2004).

Risk evaluation is a judgmental process designed to determine just how significant the estimated risks are and to establish the best course of future action, including the nature of risk management required. Risk management strategies generally accept that there must be a degree of acceptable risk. Above a certain threshold the risks might be considered intolerable or unacceptable. It is widely accepted that between these two conditions the level of risk should be reduced to a level which is ‘as low as reasonably practicable’, the so-called ALARP principle (Lee, 2004).
Coastal erosion risk

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 can be defined as the process of removal and transport of soil and rock by weathering, mass-wasting, and the action of streams, glaciers, waves, winds, and underground water. Its importance to the coastal environment lies in the fact that it provides a major source of sediment to depositional features such as beaches, saltmarshes and sand dunes, which not only form natural defences but which often form ideal habitats for a diverse flora and fauna as well as being important recreational amenities. However, the hazard of coastal erosion may result in a range of impacts or risks including:

- loss of life, property, infrastructure and land.
- destruction of natural or man-made defences, which in turn may result in flooding of the hinterland.

Coastal protection requires the allocation of increasing public expenditure with the recognition that the impacts of natural hazards are set to increase both as a result of climate change and the continued pressure of development in marginal and vulnerable areas. The Global Vulnerability Assessment estimated that the coastal protection cost for European coastal states between 1990 and 2020 would exceed €120,000 million, with an additional indirect cost of over €41,000 million (EUrosion, 2004). Whilst the development issue can and must be addressed through planning policy awareness-raising, the response to climate change is more difficult to plan for. There are three main cost categories for local authorities that involve the greatest expense; these are monitoring, coast protection works, and research.

In 2001 public expenditure dedicated to coast defence in Europe reached an estimated €3,200 million (compared to £2,500 million in 1986). This comprised new investments made (53%), costs for maintaining existing protection schemes and monitoring the coastline (38%) and provision for purchasing coastal land at risk (9%). Between 1999-2002 300 properties had to be abandoned as a result of imminent coastal erosion risk and another 3,000 houses saw their market value decrease by at least 10% (EUrosion, 2004). However, the number and value of properties to which no loss occurred due to construction or continued maintenance of coastal defences is harder to quantify. Meanwhile the total value of economic assets located within 500 metres of the coast had
increased to an estimated €500-1,000 billion in 2000. Whilst it is unlikely that all of these assets would be at risk, the costs of shoreline management strategies clearly represent a tiny fraction of the damages that would be incurred should the coastline be left unprotected; shoreline management, therefore, becomes even more justifiable.

Coastal risk management involves mitigating and monitoring these risks. In England the main thrust of government coastal defence policy is to reduce risks through the provision of technically sound, economically justifiable and environmentally sustainable coastal defence schemes comprising flood prevention and coastal protection measures. Over the last 100 years some 865 kilometres of coast protection works have been constructed in England to prevent losses; this figure includes protection of low-lying areas prone to erosion. Implicit in all decisions to invest in risk reduction measures is the notion of 'acceptable' risk. The level of acceptable risk is, in part, controlled by legal responsibilities but it also varies with the perception of the individuals concerned and the resources available to manage the problem. Risk assessments address a number of key questions:

- What could happen - and on what timescale?
- Why might such events happen?
- What is the chance of it happening?
- What losses or damage could be caused?
- How can the problems be managed or reduced?

A risk-based framework focuses on the consequences of hazards and the implications of the management responses. For example, it should address not only the likelihood of a damaging event but also the chance of failure of the management measures, for example a coastal defence failure or a breakdown of an early warning system, and the resultant losses (eg. loss of life, injury, economic and environmental losses). The approach also supports the notion that management measures may reduce risks but generally they cannot eliminate them altogether.

On the coast the nature and extent of erosion and cliff recession and the existence of hazards can only be understood after investigations which lead to the development of some form of conceptual model for the processes taking place and an understanding of the coastal cliff behaviour. Their behaviour can be defined in terms of two key parameters:

- the retrogressive potential ie. the size, style and range of coastal recession events that may take place.
- the recurrence interval, ie. the timing and sequence of recession events.

Based on these parameters behavioural models can be developed and can provide a sound understanding of coastal processes and historical coastal evolution - often defined as scenarios which predict recession rates. The development of this 'probablistic' framework often involves a study of a number of key areas including:

- historical records
- the nature of recent changes in coastline form (eg. from historical maps, aerial photographs or monitoring)
- geological and geomorphological mapping
- assessing the relationship between climate and coastal change
Where development exists around the coastline most countries worldwide recognise that a balance must be struck between the need for coastal defences and the financial resources available taking account of the many national competing demands. For this reason, the economic effectiveness of management responses along the coastline is a key factor in terms of decision-making. The most usual approach to resolving these problems is through cost benefit analysis. This analysis takes account of environmental factors as well as property values and plays an important role in formulating the preferred policy options around the coast and in gaining funding towards the cost of new coastal defences (Thompson, 1998).

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

- acceptance of the risk; eg. by spreading or sharing the costs through insurance or compensation;
- avoiding vulnerable areas, eg. through measures to control new development in areas at risk from coastal erosion, instability and flooding;
- reducing the occurrence of potentially damaging events, eg. through active land management to reduce the magnitude or frequency of erosion, landsliding and flooding;
- protecting against potentially damaging events, eg. powers to prevent coastal flooding and erosion or to stabilise cliffs and slopes or through building improvements.

The cost of reducing coastal erosion risks mainly relies upon national or regional budgets, rarely by the local community and almost never the owners of assets at risk or by the party contributing to the coastal erosion problem. This is emphasised by the fact that coastal erosion risk assessment has not been incorporated in the decision-making processes at the local level in some countries and information to the public on coastal risks remains poor. This highlights the importance of developing sustainable strategies for managing coastal natural hazards including erosion that will inform land-use development and planning by ensuring decisions are compatible with specific local coastal conditions and also future challenges.

![Figure 2.2: Financial consequences of coastal erosion and landsliding. McInnes 2006](adapted from Jones & Lee 1994)
The concept of risk as the interaction of the human environment with the physical environment is illustrated. Only when the two systems are in conflict do hazards such as coastal erosion, landsliding and flooding become a threat to the community. Of particular importance is the fact that as urban development increases, intensifies or spreads into vulnerable areas so the potential impact of hazards also increases.

Figure 2.3: Some of the physical impacts of climate change on a developed coastal zone (McInnes 2006.)
Landslide risk

Ground instability poses major risks to land use and development in Europe. Examples from Italy, France and Great Britain illustrate its significance. Over the last 40 years major landslide events have caused substantial loss of life and property, particularly in coastal zones, river valleys and mountainous regions. It should be stressed that problems have often arisen because of the lack of co-ordination between land use planning and decisions over coastal defence and other strategies. Many parts of the European Union suffer from an inheritance of unplanned communities and developments built on eroding clifftops and in other unsustainable locations - often, but not always, a result of nineteenth century development, or mass speculative development in the mid-twentieth century.

In Europe many catastrophic landslides are triggered by heavy storms and rainfall, coupled with soil erosion on mountain slopes. Areas with steep slopes, unstable materials and high soil moisture are at risk, and the problems posed by these factors are compounded by human activities such as deforestation and the construction of roads and buildings. Between 1980-2000 there were 535 fatalities as a result of landsliding and hundreds of millions of pounds of damage to property and infrastructure. The risk from landsliding in coastal locations is increasing in the face of climate change, not least because developments, through choice or necessity, are still being situated in vulnerable areas.

The European LIFE Environment study ‘Coastal Change, Climate and Instability’ (McInnes et al, 2000) noted that whilst major landslide events inevitably lead to significant loss of life and damage to property in developed areas, minor, longer term failures can also have costly implications through disturbance of structures and damage. This is particularly true for those coastal communities which do not have even the most basic monitoring systems and movements may go largely unnoticed, possibly leading to irreversible damage and substantial costs. This again accentuates the importance of integrating natural hazard management into land-use development and planning policies, particularly as there are few mitigation measures that can be implemented to combat more major ground movement events that occur with little or no warning.

Figure 2.5: The constraints to be taken into account in Landslide Risk Management. (Adapted from Leroi et al. 2005).
What are the Nature and Scale of Coastal Risks?

It is widely felt that instability problems are increasing in Europe. The reviews of recent landsliding and climatic changes show that in addition to a trend due to sea level rise there is a variability closely related to short-term climatic rhythms. The effective rainfall levels for southern Britain, for example, also show an increased availability of moisture and, therefore, soil moisture and ground water storage. The landslide record corresponds to this rhythm especially to the sequences of years wetter than the mean. It is, therefore, easy to speculate that the European coastline will become increasingly susceptible to landsliding. Changes in weather patterns will have an impact on inland mountainous areas as well as on the coast and it is believed that the question of instability, be it coastal or inland, remains a major and growing hazard, the implications of which are far from fully appreciated in many EU member states.

It is reasonable to assume that instability will continue to be a significant problem in Europe because, first, economic and technological development has resulted in a massive investment in infrastructure, buildings and industry, combined with increasingly complex patterns of commercial activity, all of which indicate a growing vulnerability to landslide hazard impacts. In addition, development pressures in many parts of the European Union have resulted in the opening up of previously under-developed regions thereby increasingly exposing human activities to natural hazards (Jones, 1999).

Recognition of the more widespread occurrence of slope instability within the European Union leads to the conclusion that the cost of slope failures are likely to escalate as a consequence of both climatic change and development pressures, unless active steps are taken towards mitigation. Much more positive measures of hazard management will be required in the future, increasingly focused on land-use planning based on carefully prepared hazard assessments (Jones, 1992).

In 'A review of landsliding in Great Britain' Jones and Lee (1994) concluded that landslide problems are not 'acts of God', unpredictable, entirely natural events that can at best only be resolved by avoidance or largescale engineering works. The role of human activity in initiating or reactivating many slope problems should not be underestimated. Urbanisation has resulted in the expansion of many towns and cities to such an extent in recent years that the most suitable building land has been fully occupied; so new suburban developments are often being proposed on potentially unstable slopes. Technological developments mean that instability-induced disruption to engineering projects has the potential of being both politically embarrassing and damaging to reputations as well as being extremely costly.

It is also recognised that even minor, inconspicuous and relatively slow-moving failures can have costly repercussions through the disturbance of structures and infrastructure, including the dislocation of underground services. It is equally true that there are numerous examples of instability impacts due, at least in part, to human activity. Leaking water and drainage pipes can contribute to instability as can slope loading through inappropriate construction and indeed slope unloading through excavation. All these factors indicate the value for money that can be derived from the development of a sound approach to the sustainable management of instability problems in urban areas.

Figure 2.6: Cumulative distributions of natural events that have resulted in fatalities in Italy (adapted from Guzzetti & Salvati)
Responding to the Risks from Climate Change in Coastal Zones

Many problems could be reduced if there was a long term programme of active landslide management in place. Local communities need to come to terms with the situation and learn to 'live with landslides'. There is an increasing recognition of the need to minimise the risks and effects of instability on property and infrastructure and the general public. An improved understanding of instability issues, monitoring of instability sites, interpretation of results and the implementation of effective planning measures is also required.

Following the 1990s, United Nations' International Decade for Natural Disaster Reduction (IDNDR), a new challenge has been to communicate the understanding derived from valuable research to policy-makers and to local residents; the subsequent International Strategy for Disaster Reduction (ISDR) supports this task. Landslide risk management cannot be left to government departments and agencies alone. If a strategy is to be successful it must involve all sectors of the community as part of an holistic landslide management strategy.

Flooding risk

On the coast flood risk is determined by a combination of peak sea levels, wave activity and storm surges. Sea levels are driven by tides, which are controlled by movement of the moon and planets, and surges resulting from air pressure changes and wind speeds on the water surface. Tides, surges and wave action can be significantly modified 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 will increase sea level.

Coastal flooding can result from a combination of tide and surge levels that exceed the levels of sea walls but is more usually due to wave action in combination with high water levels. Close to the shore the maximum wave height is closely related to the water depth and the amount of wave run-up and overtopping is a function of the nature and configuration of the shoreline. Coastal defence infrastructure including sea walls, tidal barriers and related controls influence pathways and aim to control the impact that water flowing over defences or through breaches can have on the coastal floodplain. Sea walls often operate in combination with beach and foreshore management techniques such as beach recharge, groynes and breakwaters to control wave energy and improve the resilience of the coastal structures and limit wave overtopping.

Flooding can have severe impacts on people in terms of distress, injury or loss of life. Considerable demands are also placed on the emergency and public services during such events, particularly in developed areas (Environment Agency, 2005e). Both coastal and inland flooding can cause significant damage to property and developments as well as disrupting businesses and other services.
Flooding is a major concern facing coastal communities, particularly when considering predicted estimates of sea-level rise. EM-DAT, the international disaster database, suggests that floods comprised 43% of all disaster events between 1998 and 2002 (European Environment Agency, 2004). In the United Kingdom alone there are 2 million properties in coastal and fluvial locations at risk of flooding, with 80,000 urban properties threatened with heavy downpours that could overwhelm urban drains (Foresight, 2004). In the south-east of England alone flood risk areas make up 11% of the total land area posing a risk to 235,000 properties (Environment Agency, 2005). Without suitable action it is expected that flood risk will increase to unacceptable levels for a range of groups, not just people and property but also businesses, hospitals and emergency services. It is estimated that, if flood management policies and expenditure remain unchanged, annual losses in the United Kingdom will increase under every climate change scenario by the 2080s. However, the degree of increase will depend largely upon a number of factors including the amount of climate change and the extent to which assets continue to be situated in vulnerable locations. This is applicable to all EU coastal communities and the integration of flood risk into the planning and development process is one way of helping to reduce future costs for coastal communities in terms of economic, social and environmental losses.

Research has shown that flood warnings can reduce the damage to property by more than 25%, but only if properly communicated (Parker et al 1991, cited in Crichton, 2003). With the technology available today, the ability to provide early warning has allowed structures such as the Thames Barrier in London to be extremely effective at preventing millions of pounds worth of losses to people, property and businesses within the floodplain. It is estimated by the Environment Agency that the costs of a severe flood in the centre of London could possibly top the £30,000 million mark, before considering the cost to human life (Environment Agency, 2004). In comparison, the initial outlay involved with constructing the barrier and its associated defences reached approximately £535 million (valued at £1,300 million in 2001 prices), whilst the cost of operating and maintaining the barrier and the associated defences is approximately £6 million per year, plus £5 million (at 2001 prices) on walls and embankments (Environment Agency, 2004). The Environment Agency operates many smaller flood barriers across the UK that would also be used in conjunction with emergency response procedures.

Plate 2.3: Selsey near Chichester, West Sussex, UK. The major flood risks to the area are centred on the caravan sites, the single road link to the north and residential development to the east. The land to the west and to the north is protected by a 4km long narrow shingle ridge whilst to the east over 1,000 residential properties and businesses are protected by a 1.2km groyne-stabilised beach and a concrete seawall built in the 1950s.
Quantifying and mitigating risks

The costs of natural hazards in coastal zones fall broadly into three categories: economic, social and environmental.

The economic costs can be divided into two main categories:

- the costs of emergency provision and remediation in the occurrence of a hazardous event (most applicable to landsliding and flooding)
- the costs of mitigating the effects of natural hazards

Economic costs are the greatest in financial terms and are perhaps the most important from the perspective of local authorities and other organisations responsible for managing coastal defences. There are also other ‘indirect costs’ such as insurance costs, depreciation of property or land values and legal actions.

The cost of an emergency response may include emergency coast protection works, evacuation, provision of temporary accommodation, mobilisation of emergency and relief services, cost of investigations, transport delays and other interruptions. Mitigation is also very costly and involves research into coastal evolution and risks and preparation of high level plans and strategies to support the formulation of planning policies, the cost of coast protection schemes including design and construction, as well as the cost of coastal monitoring.

The social costs of natural hazards are largely intangible. Fatalities can be measured in real terms whilst health-related factors such as stress and depression, which may be related to risk, cannot be measured in the same way. The other factors that may impact upon the individual or society are largely related to inconvenience and are more difficult to measure.

Plate 2.4: Landslide stabilisation measures including ground anchors assist in reducing risks on the seaward slopes below the historic town of Sirolo, Marche Region, Italy.
Environmental costs are difficult to quantify because natural hazards promote natural coastal change. There are a wealth of ecologically important sites in coastal zones (e.g. SPAs, SACs or RAMSAR sites) and legislation may require the protection of these sites from erosion or flooding in order that they are maintained in a favourable condition. Environmental mitigation and, where possible, enhancement can result in significant additional costs for construction projects.

Costs arising from natural hazards can prove to be a significant burden for local tax payers, particularly in terms of funding the emergency response. Climate change will increase the frequency and intensity of natural hazards, which will further increase the financial burden to be faced by regional and local authorities together with government spending departments. Emergency response plays a key role in minimising the potential costs of a hazardous event. Early warning and preparedness are primarily a means of reducing the social costs of hazardous events, particularly those of the type considered in this report, enabling evacuation procedures to be effectively implemented and at-risk communities to seek refuge. To this end, early warning systems consist of three elements:

- forecasting and prediction of impending events;
- processing and dissemination of warnings to political authorities and the population;
- undertaking appropriate reaction to warnings.

These measures enable the cost in human suffering and loss of life to be minimised but the economic losses of an inevitable event are more difficult to control, particularly in the case of property loss due to landsliding.

In most European countries the government bears the brunt of the costs associated with both emergency response and remediation. The emergency services, armed forces, local authority emergency planning departments and national flood warning services could all be mobilised, along with other emergency response teams.

Householders pay a more personal cost as a consequence of a hazardous event; possibly involving fatalities or injury as well as stress. Flooding and landsliding can be traumatic events for those affected, particularly when there is little warning. Rising insurance excesses represent an additional cost to householders and in some locations insurance is no longer available. The economic value of working time can also be calculated; the loss of productive (working) and leisure time is often a very significant factor for householders in a severe natural hazard event (UKCIP, 2004). This may be compounded by the disruption to the transport network and infrastructure that almost always accompanies hazardous events, particularly flooding. Insurance companies are also dealing with the costs of natural hazards; worldwide insurance losses for natural catastrophes reached almost US$ 100 billion for the 1990s (Munich Re, 2000, cited in Crichton, 2003), whilst subsidence hazards cost insurers nearly £1 million per day on average (ABI, cited in Crichton, 2003).

One of the most important ways of reducing risk is to continue to develop a "culture of prevention". Hazard mitigation measures are built to a large extent on warning technologies such as telemetry that can monitor the accumulation of soil moisture in a watershed that could serve as a warning of sudden flooding downstream, or satellite sensors that might read telltale signs of collapsing hillsides before any incident occurs (ISDR, 2002). Whilst this cannot prevent a catastrophe occurring it has the potential to limit significantly the impact on vulnerable communities. Monitoring is an important means of providing a basis for early warning and preparedness. This aims to reduce the costs associated with emergency response procedures by encouraging preparation for an impending event either by protecting people and assets at risk from a particular hazard, or by evacuating those that cannot be protected. The gauging of floodwaters, particularly during and after heavy rainfall, can allow accurate predictions of how water levels may change based on the monitoring of previous events. As a consequence, the areas at risk from potential flooding can be predicted and suitable action taken to minimise the damage experienced. Bridge sensors can be used as an effective way of triggering warning alarms when the water levels beneath reach critical height. This allows floodgates to be closed where possible and minimises the impacts of a flooding event.

In a similar way, the monitoring of ground movements and rates of coastal erosion can allow predictions on future movement in terms of timing and extent. Satellite monitoring of land movements can detect
Plate 2.5: Fairlight village, East Sussex, UK is located on the top of high, weak sandstone cliffs. Part of the village (at the right hand end of the photograph) benefits from coast protection already and further works are proposed to protect the remainder of the developed frontage.

Plate 2.6: Part of the low-lying coastal zone near the town of Sete within the Languedoc-Roussillon Region of France. The barrier beach (lido system) protects assets, and lagoons of environmental importance from coastal erosion. Coastal protection works also reduce risks to the highway from marine erosion.
minimal changes in the land mass and can help predict the location of possible landsliding events. Monitoring also forms the basis of decisions in relation to coastal protection policy, particularly where the analysis of long-term data trends allows a good understanding of spatial coastal change. This can also assist our insight into the long-term effects of climate change and consequently the level of protection that may be appropriate in the future. It should be noted here that, although monitoring goes a long way to assist managing the costs of natural hazards, it has its own costs associated with it. However, these are small compared to the expenditure that would be necessary to cope with the damage and losses associated with unexpected landsliding or flooding events, and the damage caused by inappropriate and unsustainable defences constructed after poorly informed decision-making.

Research is the third component of effective management of coastal natural hazards. Coastal protection measures have traditionally protected against the current level of risk with some member states making an allowance in their design for sea level rise. However, it has become increasingly apparent that in the light of climate change prediction the level of hazard is likely to vary significantly. It is necessary to define the anticipated level of risk and to plan accordingly. Research into future scenarios and conditions will assist adaptation to those new conditions thus minimising the impacts of hazardous events and the associated costs.

**The insurance industry role**

The insurance industry is actively assessing the growing trends and impacts of natural hazards and recognising the effects of climate change. Observed throughout the world in recent decades and clearly reflected in the claims burdens of the insurance industry, the increase in natural catastrophe losses is one of the first and strongest pieces of evidence that the impact of global environmental changes generated by human activity is growing. Changes in exposure and vulnerability do not sufficiently account for the increase in natural catastrophe losses in its entirety. On the contrary, there is mounting evidence that the frequency and intensity of weather-related natural catastrophes are increasingly being influenced by global environmental changes, and above all by climate change (Munich Re, 2003).

Insurance against the occurrence of natural hazards assumes acceptance of the risks associated with them and aims to spread the cost between those affected by them. Natural hazards are an ever-burgeoning sector of the insurance market. Recent decades have seen a large increase in losses associated with natural hazards not only due to the fourfold increase in the global population, many concentrated in coastal zones, but also because the number of great natural catastrophes has increased threefold. There are fears that loss potentials could develop in certain areas that will be ‘capable of stretching the capacity of the insurance industry to its limits’, (Munich Re, 2003). As a result, the insurance industry has attempted to play an increasing role in managing the impacts of natural hazards through measures such as exclusions and encouraging clients not to rely solely on mitigation loss measures but also to act in an environmentally friendly manner.

In the immediate aftermath of a natural disaster, one of the most apparent ways to measure the magnitude of the event is to assess the costs in terms of loss of human life. This is particularly the case within the media, as it is the cost that can be most widely related to. It has been estimated that in 2002 there were 459 fatalities in Europe as a result of natural catastrophes, the majority of which were caused by flooding (Munich Re, 2003). Due to the nature of natural catastrophes the number of fatalities experienced in any one year is often unrepresentative of the average losses over a number of years. As a result, a figure for the average losses gives a more accurate picture of the vulnerability. Poorer countries or regions are often more vulnerable as they are less well equipped to protect and prepare themselves. These locations are also more likely to have developments located in areas at risk, leading to greater human costs in the event of a natural catastrophe.

Living within a hazard prone area and the knowledge that one is potentially at risk can contribute to a high level of stress. The Global Vulnerability Assessment carried out for the UN-IPCC estimated that as a result of sea level rise the annual number of victims of actual coastal erosion or flooding would reach 158,000 by 2020 (EUrosion, 2004). When considering the additional number impacted by landsliding and other hydrogeological problems this figure increases dramatically.
Research carried out following serious flooding in Lewes, Sussex, on the south coast of England outlines some of the potential health issues for those at risk. Lewes experienced severe flooding in the year 2000 and it was found that people whose homes were flooded were four times as likely to suffer from psychological distress than those who weren't flooded, and that flooding was also associated with increased risk of earache, sickness and vomiting (Health Protection Agency, 2004). It was also noted that severe flooding may become more commonplace as a result of climate change and, therefore, it is important to understand the long-term health implications so that it is possible to inform policy for flood prevention and support individuals and communities affected by flooding (Health Protection Agency, 2004).

The insurance industry is becoming increasingly involved in the area of hazard mitigation by identifying zones in which the risk is considered to be too great to warrant insurance. Developers are also becoming increasingly restricted by the planning system over where they can construct property. In this way, people are guided towards lower-risk areas which would include reduced losses should a hazardous event occur. However, the implication of this is that people may be unable to live in the areas that they may desire and are victims of forced choice.

The financial implications of climate change and coastal risks

The effects of predicted changes in climate are causing considerable concern to those responsible for coastal risk management. Without more effective and integrated coastal planning, the consequences for the coastal zone could be severe. Increases in the intensity of precipitation, a rise in sea level and increased storminess will elevate the risk of coastal flooding. This will have particular consequences for sensitive areas that are already close to or below mean sea level such as the Dutch and German North Sea coastlines (IPCC, 2001).

Southern Europe also seems to be more vulnerable to these perturbations, but it is noted that northern Europe already has a high exposure to coastal flooding (Acacia, 2000). A rise in sea level will compound the risks already faced by coastal communities as it will likely lead to a promotion of coastal erosion and lead to the inundation and displacement of wetlands and lowlands, the erosion of shorelines, the exacerbation of coastal storm flooding and the deterioration of water quality (IPCC, 2001). Indeed, the EUrosoin project (2004) stated that ‘the prospect of further sea level rise due to climate change and the heritage of mismanagement in the past imply that coastal erosion will be a growing concern in the future’.

The potential impacts of a one metre sea level rise in selected European countries suggest that 13 million people in five European countries could be flooded, with the highest potential impact in the Netherlands. Significant areas of Europe’s coastal zones are low-lying and vulnerable to high-tide and storm-surge flooding, which will be exacerbated by climate change effects such as sea-level rise and increases in storm intensity or frequency. It is estimated that 9% of all European coastal zones (if defined as a 10 kilometre strip) lie below a 5 metre elevation and are potentially vulnerable to sea level rise, with 85% of the coast of the Netherlands and Belgium under 5 metre elevation, 50% in Germany and Romania, 30% in Poland and 22% under 5 metre elevation in Denmark, where 100% of the population lives within 50 kilometres of the coast. In the United Kingdom 75% of the population live within 50 kilometres of the coast, whereas the average for the EU is one-third of the population (EEA, 2005).

The potential consequences of extreme climate events such as rainfall and storms is also of concern. More intense rainfall has already been recorded, and predictions for the future under the warmer climate scenarios include Northern Europe becoming generally wetter with more days of high rainfall and periods of summer drought, and southern Europe becoming generally drier with prolonged droughts and a higher proportion of rainfall falling on very wet days. The increasing winter rainfall expected over most of Europe will lead to greater flood risk including consequences for flash flooding, urban drainage, water management, erosion, slope stability and ground water recharge.

The number of severe winter storms over Western Europe is expected to increase. Europe’s vulnerability to storms is demonstrated by the impact of storm Lothar in France on 26 December 1999, which killed 87 people and destroyed 5,000 square kilometres of forest. In Western Europe (e.g. UK, France and Germany) windstorms are expected to increase property damage losses by 15% in 2070-2099 (compared to the 1961-1990 baseline) with adaptation, or by 20% or more without adaptation. In
1999, for example, a series of three storms produced €16 billion in economic losses at 2004 prices (MICE Project, 2005).

Recent research on climate change science is focussing increasingly on rapid climate change. Whilst gradual climate change over the next century is expected, there are some processes which may have a trigger point which, once exceeded, will make changes inevitable, sometimes abrupt and frequently irreversible. Although it is difficult to quantify the risk of these events and the probability of occurrence is low in the current climate, they could be very high-impact, so estimating their European and regional consequences can provide plausible worst case climate scenarios for impacts studies and adaptation planning.

 Ranked by economic losses, Europe suffered the 4th largest natural catastrophe of 2005, the winter storm Erwin/Gudrun, with 18 fatalities, US$ 5,800 million economic losses and US$ 2,500 million insured losses (Munich Re, 2006). In June 2005 Europe also sustained severe damage from climate change, and is warming 40% faster than the world as a whole. Storms in 1999 and floods in 2002 each cost €13 billion, whilst a heat wave in 2003 cost €10 billion. The European Commission has estimated the future cost of potential cumulative global damage, if no effective action is taken, at €74 trillion at present day values.

The IPCC has compiled a selection of national figures to emphasize the scale of the human and ecological assets that could be affected by sea-level rise, which are shown in the following table (IPCC, 2001): Impacts of sea level rise in selected European countries, assuming no adaptation, and with adaptation costs.

<table>
<thead>
<tr>
<th>Country</th>
<th>Sea-Level Rise Scenario (m)</th>
<th># 10^3 Population Coasts</th>
<th>Coastal Floodplain Population</th>
<th>Population Flooded per Year</th>
<th>Capital Value Loss US$ 10^1% GNP</th>
<th>Land Loss Km^2 % GNP</th>
<th>Wetland Loss (km^2)</th>
<th>US$ 10^1% GNP</th>
<th>Adaptation Costs US$ 10^1% GNP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netherlands</td>
<td>1.0</td>
<td>10,000</td>
<td>67</td>
<td>3,600</td>
<td>24</td>
<td>186</td>
<td>69</td>
<td>2,165</td>
<td>6.7</td>
</tr>
<tr>
<td>Germany</td>
<td>1.0</td>
<td>3,120</td>
<td>4</td>
<td>257</td>
<td>0.3</td>
<td>410</td>
<td>30</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Poland</td>
<td>0.1</td>
<td>n.a.</td>
<td>n.a.</td>
<td>25</td>
<td>0.1</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Poland</td>
<td>0.3</td>
<td>n.a.</td>
<td>n.a.</td>
<td>58</td>
<td>0.1</td>
<td>4.7</td>
<td>5</td>
<td>845</td>
<td>0.25</td>
</tr>
<tr>
<td>Poland</td>
<td>1.0</td>
<td>235</td>
<td>0.6</td>
<td>196</td>
<td>0.5</td>
<td>22.0</td>
<td>24</td>
<td>1,700</td>
<td>0.5</td>
</tr>
<tr>
<td>Estonia</td>
<td>1.0</td>
<td>47</td>
<td>3</td>
<td>n.a.</td>
<td>n.a.</td>
<td>0.22</td>
<td>3</td>
<td>&gt;580</td>
<td>&gt;1.3</td>
</tr>
<tr>
<td>Turkey</td>
<td>1.0</td>
<td>2,450</td>
<td>3.7</td>
<td>560</td>
<td>0.8</td>
<td>12</td>
<td>6</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

Note: Impacts of sea-level rise in selected European countries, assuming no adaptation, plus adaptation costs (from Nicholls and de la Vega-Leinert, 2000). "Available national results emphasise the large human and ecological values that could be affected by sea-level rise. The table shows results of national assessments in The Netherlands (Baarse et al., 1994; Bijlsma et al., 1996), Poland (Zedler, 1997), and Germany (Steffen and Simmering, 1996; Ebenbeh et al., 1997) for existing development and all costs adjusted to 1990 US$. In the table, adaptation assumes protection except in areas with low population density. People at risk are the numbers of people flooded by storm surge in an average year. Adaptation/protection costs for Poland include capital and annual running costs; % GNP assumes that costs are all incurred in 1 year. Subnational and local studies from East Anglia, UK (Turner et al., 1995); South Coast, UK (Bali et al., 1991); Rochefort sur Mer, France (Auger, 1994); Estonia (Kont et al., 1997); and Ukraine (Lenhart et al., 1996), as well as regional reviews (Tooley and Jelgersma, 1992; Nicholls and Hoozemans, 1996) also support this conclusion. Many of Europe’s largest cities such as London, Hamburg, St. Petersburg, and Thessaloniki are built on estuaries and lagoons (Frasetto, 1991). Such locations are exposed already to storm surges, and climate change is an important factor to consider for long-term planning and development."

*Figure 2.7: Impacts of sea-level rise in selected European countries, assuming no adaptation, plus adaptation costs: Extract from IPCC Report “Climate Change 2001: Working Group II: Impacts, Adaptation & Vulnerability, Chapter 13, Table 13-5” (IPCC, 2001).*

The Netherlands faces the greatest potential losses of the selected countries, with a capital value loss of 69% of their GNP and a land loss of 6.7% of the total. This represents a huge loss, particularly when considering that the potential losses of the next most badly affected country of those selected, Germany, only reaches 30% of the total GNP, less than half in comparison. However, the importance of determining an accurate sea level rise scenario can be observed, with the land losses experienced varying from between 0.1 and 0.5% of the total. This variation in predictions makes it difficult for coastal managers to plan effectively for the future.
Insurance as a tool for risk management in the context of climate change

The last few decades have seen increasing concern over the extent and frequency of natural disasters, with great implications for Europe's insurance industry. This is primarily as a result of the continuing steady growth in population and the increasing concentration of people and economic values in urban areas (Berz, 1999). However, there is the additional contribution of climate change, which is expected to compound the existing problems by leading to increases in storm surges, thunderstorms and rainstorms, all of which have considerable implications for flooding, coastal erosion and instability in the future.

The insurance bill for extreme weather events and rising sea levels is set to increase tenfold by the year 2050, making some locations uninsurable. The increase is due mainly to ‘mounting economic values and insured liabilities in heavily exposed metropolitan areas’ (Berz, 1999); losses will bankrupt parts of the industry, which needs government action to halt climate change. Costs to the insurance industry can be minimised by adaptive measures if initiatives are taken soon. The insurance industry itself is expected to take an increasingly active role in controlling its costs (Acacia, 2000).

It is with this understanding that we must address appropriate adaptation strategies, which take into account the continuing existence of risk in the coastal zone. Many of the impacts of sea level rise could be avoided or managed effectively given proactive measures today (Acacia, 2000). However, this requires long term planning strategies to be developed for shoreline management. Indeed, Foresight (2004) states that ‘decisions taken today will have a profound impact on the size of flooding risks that future generations will need to manage. They will also strongly influence the options available for managing those risks’. Strategies across EU coastal communities will vary enormously depending on a number of factors. Clearly, an assessment of the economic value of the assets at risk will be carried out; this will be influenced by the level of finance available for protection work. (Klein et al, 1999, cited in IPCC, 2001) argue that successful adaptation requires an integrated approach, including recognising the need for ‘adaptation, planning, implementation and evaluation’. The European Environment Agency (2004) believes the need for adaptation to climate change should begin as soon as possible because:

- ‘anticipatory and precautionary adaptation is more effective and less costly than forced, last minute, emergency adaptation or retrofitting’; and that
- ‘climate change may be more rapid and more pronounced than current estimates suggest. There is a risk of under-adaptation and the potential for unexpected sudden events’.

Responsibilities for dealing with natural hazards and climate change impacts are often divided at a national level, with concerns of disaster management, prevention and relief often associated with Civil Defence or Ministries of Interior, whilst climate change policies and international co-operation are frequently managed by Ministries of Environment and Energy (Sperling and Szekely, 2005). Active co-operation and sharing of information are required for effective adaptation planning at its highest level. Similarly, synergies are essential in terms of links between regions and local authorities taking note of advice and guidance from central government.

A difficulty in assessing and evaluating cost implications of climate change is the lack of coherent data on the costs of individual hazards within the coastal zone. It is recognised that the exact figures for economic losses are always difficult to determine because data is available only for a proportion of all the events that occur over a given period of time. Frequently, the majority of costs are aggregated together under broad categories. A further deficiency has been the apparent absence of figures for more localised areas, the majority being for the global, European or national costs. In addition, comparisons are difficult to make between member state costs within Europe because there is a lack of a uniform method for data collection. Quoting losses on an EU-scale does not convey the disparities in losses for individual countries; the impact can vary significantly and can be particularly severe for those countries which have economies in transition. Also, estimates tend to vary between sources, particularly where certain publications use estimates and others provide the real cost.

The increasing magnitude of the costs associated with natural hazards in the coastal zone, particularly in terms of damage to assets, protection and maintenance of defences is a major concern. The costs associated with protecting these assets are small in comparison to the losses that would be incurred if
no action were to be taken, thus proving relatively cost-effective. However, despite uncertainty over future conditions, there is a recognition that climate change will increasingly lead to significant rises in the costs of natural hazards over the coming decades. It will be impossible to develop strategies that negate climate change because the future level of risk cannot be defined to that level of accuracy. It is, therefore, only possible to decrease the risk and vulnerability of natural hazards to an acceptable level.

It has been agreed widely that investment must increase to react to the predicted rise in costs associated with climate change within coastal zones. This will still be cost-effective, even if the value of assets at risk does not increase as expected. Hazard mapping is likely to provide the most effective way of providing a basis for managing natural hazards by helping to avoid unsuitable areas of the coastline. With uncertainty over climate change there have been calls to internalise the risks associated with natural hazards into the planning framework as a means of controlling the impacts and costs. In this way it would be possible to move towards creating a culture of prevention, advocating cost-effective preventative action rather than costly post-disaster remediation.

The Response LIFE-Environment Project provides a methodology for regional and local authorities, and other interest groups, to identify and assess the risks arising from climate change along their coastline, enabling them to prioritise the results and to assist the formulation of a cost-effective preventative response. The Response Project also provides a range of examples of innovation and best practice to demonstrate how, once identified, these risks can be managed.

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11. UKCIP, Meteoecomnica, 2004. 'Costing the impacts of climate change in the UK: Overview of guidelines'.


Plate 2.7: At Criel-Sur-Mer on the Channel coast of France rapid erosion of the vertical chalk clifflines has resulted in the loss of residential cliff top properties. For environmental and economic reasons coastal defence was not an option; recently a row of the most vulnerable properties (A) have been demolished under the provisions of the Barnier Law.