Chapter 7

Environmental impacts of future flood risk

Many drivers of flood risk are affected by the environment. For example: agricultural land management affects catchment runoff; river vegetation affects conveyance; relative sea level affects the frequency with which land adjacent to coasts and estuaries is flooded.

In this chapter we consider the other side of the coin – the environmental impacts of flooding and the environment as a receptor. In particular we:

- Analyse the environmental impacts of flooding and flood management in fluvial and coastal zones.
- Consider the environmental implications of current trends of change in flood-management policies.
- Examine how the environmental impacts of flooding will be affected by the four Foresight Futures.
- Provide an environmental economic assessment of the impacts of flooding.

7.1 Introduction

Coastal and fluvial flooding affects the physical characteristics of the environment, the coastal, riverine and floodplain ecosystems, and the species those ecosystems support. Moreover, regular flooding is essential for the health and survival of many of these ecosystems. The size of natural alluvial river channels, for example, generally depends on the magnitude of the flood that occurs once every one to two years. Biodiversity within river channels depends on the frequency of flooding and associated movement of sediment. Floodplain wetlands are often maintained by inundation, and coastal saltmarshes require regular tidal flooding.

Infrequent large floods can disturb landforms and ecosystems, which may take several years to recover. While these floods can be seen as ‘natural’ parts of the environmental system, a *changing* frequency of flooding can disturb the equilibrium of a landform or ecosystem. The result may be seen as adverse environmental consequences: the area of saltmarsh may decline, or a river channel may be destabilised.

Whether a changed frequency of flooding does have an impact depends not only on the extent of the change but also on how close the system is to a threshold of change. A very large flood may have little effect in one location, and a relatively smaller flood a larger effect in another. However, the assessment of adverse environmental impact depends on the timescale over which we view the change. Longer timescales may see morphological change as part of a process of natural adjustment, driven by large-scale influences on flooding, such as climate change.

For centuries, people have set out to reduce the effects of flooding, through the construction of embankments to separate a river or coastline from its floodplain, or through the realignment or reconstruction of river channels. These measures to control flooding also affect physical landforms and ecosystems (see for example Viles and Spencer 1995; Nordstrom 2000; Sear *et al*. 2000).

In the 21st century, the changes in drivers we identified (see Chapter 2) will result in continued changes to the magnitude and frequency of flooding, with a range of environmental implications.

Some factors, such as climate change, may also directly influence floodplain ecosystems, including the species they contain (e.g., Harrison *et al*. 2001; Berry *et al*. 2001).

7.2 Environmental impacts of flood management

Although flooding in most fluvial, estuarial and coastal systems in the UK has been managed, it is only with the recent advent of Catchment Flood Management Plans and Shoreline Management Plans that there has been significant interest in the ecological implications of fluvial and coastal flood management. Data are therefore limited, with none in the consolidated form required to allow the full range of potential ecological effects of the wide range of flood-management practices to be established.

In the most general terms, measures to reduce the flood risk to a community can seek to reduce the physical hazard, reduce the exposure to the hazard, or reduce the vulnerability to loss and increase ability to recover (Table 7.1).

Table 7.1 **Examples of measures to reduce the flood risk**

Measures to reduce the flood risk	Example measures
• Reduce the physical hazard	• Flood embankments/sea defences • River channelisation • Washland storage • Reservoir impoundment • Catchment management
• Reduce exposure to the hazard	• Land use planning • Property-scale flood proofing
• Reduce vulnerability to the hazard	• Warning and preparedness • Insurance

‘Flood defence’ is traditionally concerned with reducing the physical hazard, although current flood-risk management practice seeks to consider and include all three groups of measures in

Table 7.1. In themselves, measures to reduce exposure and vulnerability usually have no negative environmental impact. In some cases, as in the case of land-use planning, they in fact may bring considerable environmental benefits when implemented in the place of measures to reduce the physical hazard. In this section we concentrate on the environmental impact of measures to reduce the physical hazard.

7.2.1 Fluvial systems

Flood management has traditionally included modification of the morphology of channels and floodplains to increase conveyance, to reduce flood levels or to contain higher flood elevations. Many approaches have been used, including channel maintenance to reduce sediment accumulation or vegetation growth, channel realignment, the construction of artificial channels, and the construction of embankments to separate the river from its floodplain.

The effects of flood management on the ecosystems of rivers, their surroundings and downstream are well documented (e.g. Brookes 1984; Sear *et al*. 2002b). In the most general terms, increasing water conveyance or reducing the storage capacity at a site increases flood peaks downstream. Habitat diversity at the site tends to decline and elimination of the natural connection between channel and floodplain has substantial impacts on riparian and floodplain wildlife. Downstream, changes in water flow and sediment also impact on ecosystem structure and function, while secondary ecological impacts are associated with changes in land use and water quality.

River flow in many UK rivers has been modulated by the construction of dams. While any reservoir can alter flood flows and the discharge of sediment, few reservoirs in the UK exist solely to reduce downstream flood risk. Lower flood peaks reduce the channel size downstream of reservoirs: the effects depend not only on the extent of the reduction but also on changes in sediment load and the characteristics of the bed and banks. Vegetation can stabilise bed and banks but may also reduce water conveyance.

Over the past few years, flood-defence practice in the UK has shifted towards ‘softer’ management approaches. These include such techniques as the restoration of channels and floodplains and the provision of washland storage. A washland is an area of the floodplain that is allowed to flood or is deliberately flooded by a river or stream for flood-management purposes, with the potential to form a wetland habitat. The provision of temporary washland storage is increasingly being considered as a flood-management action (for example, on the Cherwell upstream of Banbury). Such schemes are essentially seeking to maintain and enhance 'natural' processes of flood water storage, and appear to have no major adverse environmental implications on site and often have considerable environmental benefits. However, by allowing storage areas to fill early in the development of a flood they may exacerbate flooding downstream (ICE 2001) – modelling of the Cherwell restoration scenario demonstrated a significant effect on flood timing and hence flood level downstream.

Channel and floodplain restoration schemes are, in contrast, primarily intended to improve aquatic environments rather than as flood-management measures. The schemes completed so far produce relatively little benefit in terms of flood protection. Two schemes – for the River Cole (Sear *et al*. 2000) and the River Cherwell – have demonstrated the restoration of floodplain connectivity through manipulation of the channel morphology and roughness. There is, however, considerable uncertainty associated with the longer-term morphological and ecological performance of restored rivers.

7.2.2 Coastal and estuarine systems

Management of flood and coastal defences has been important in the evolution of the British coast for at least the past 600 years. Some influences date back to Roman times (Steers 1964; French 1997; Doody 2001). Over that time, land reclamation and flood defence has greatly reduced the intertidal area around estuaries, creating new land uses at the expense of mudflats, saltmarshes and other intertidal habitats. This change in land use includes extensive low-lying areas claimed for grazing – usually termed coastal grazing marshes – and for arable farming. In the UK, coastal grazing marshes are virtually always constrained in their capacity for landward migration by a break of slope or changes in land use such as arable farmland or urban development. Hence they require active flood management to maintain the species assemblages that they support.

More recently, and especially since the 1950s, protection of the open coast against erosion has directly degraded many cliff, shingle and dune environments. It has also greatly reduced the input of both beach and fine sediment to the coastal system (Clayton 1989; Hanson and Nicholls 2001). This has certainly degraded beach environments in areas such as Norfolk. The implementation of shoreline management planning (Defra 2001) is, in part, a response to this problem of sediment starvation.

7.2.3 Shoreline management

The rising costs of shoreline management, more rigorous appraisal of flood management projects and continued degradation of coastal habitats have triggered an important shift in thinking towards softer, more strategic flood and coastal defence. Just as flood management in fluvial regions has moved towards less aggressive techniques, similar notions influence thinking on shoreline management. Instead of an assumption of protection and 'hold the line', managed realignment of flood defences is now being actively considered in many locations. There have already been some trial schemes, especially along the south and east coasts, where degradation of intertidal habitats has been most marked (see Defra 2001). Within estuaries, the reduction of tidal levels using managed realignment is seen as a potential complement to traditional flood defence (Townend and Pethick 2002). The implications of managed realignment for habitats within the coastal zone (Figure 7.1) has been explored by Nicholls and Wilson (2002).

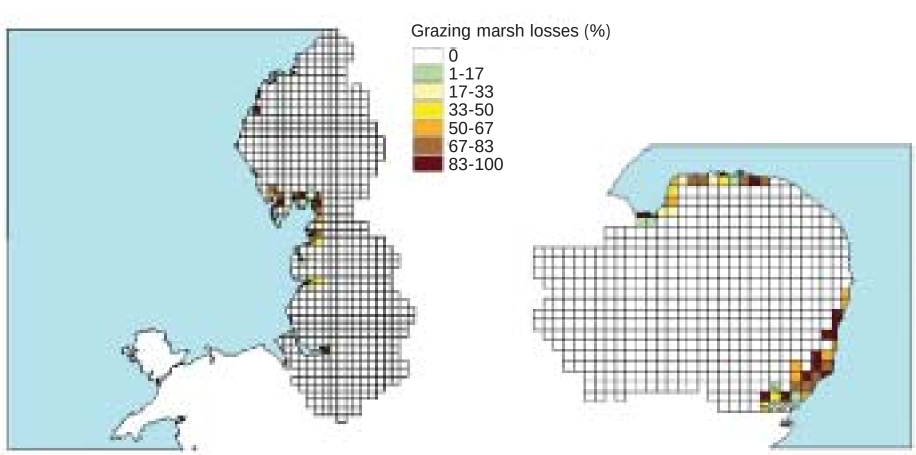
Concern over the loss of coastal grazing marshes (Figure 7.2) relates largely to the potential for these habitats to be of intrinsically greater value for biodiversity conservation than inland grazing marshes. For mobile species, such as the large populations of breeding and wintering waterfowl that these coastal grazing marshes support in the UK, the greater value of coastal sites could depend on their proximity to intertidal habitats. If this proves to be the case, then the replacement of coastal grazing marshes by grazing marshes further inland will not be effective in maintaining populations.
The challenge will then be to find suitable locations for the creation of grazing marshes in the coastal zone which are sustainable in the long term.

Figure 7.1 **Saltmarsh (A) and coastal grazing marsh (B) in East Anglia**

The RegIS project examined changes in saltmarsh and coastal grazing marsh habitats in East Anglia and north west England to the 2050s (Nicholls and Wilson 2002). Analysis on the basis of two climate-change scenarios (low and high) and two socioeconomic storylines, Global Sustainability and National Enterprise, gives some idea of the potential impact of flood-management practices on coastal grazing marshes. Under Global Sustainability it was assumed that there was the potential for considerable managed realignment, whereas under National Enterprise it was assumed there was none. It was found that, while saltmarsh habitats can be expected to decline with rising sea level and the maintenance of the existing defence line, there is likely to be a net expansion in the area of saltmarsh and related intertidal habitats in both the Global Sustainability and National Enterprise scenarios as a result of planned realignment in the former and unplanned realignment in the latter. Unplanned coastal abandonment results from many flood compartments containing coastal grazing marsh seeing a dramatic increase in flood frequency. A significant decline in coastal grazing marsh is therefore likely under both futures.

Mudflats and sandflats in estuaries could also suffer from coastal squeeze (the process whereby an area of intertidal habitat is prevented from migrating landwards in the face of rising sea levels, owing to the presence of a hard boundary such as a sea defence). This would have concomitant impact on highly productive populations of invertebrates and birds (Austin *et al*. 2001). The UK's estuaries support millions of waterfowl during the winter months, principally because the mild winter climate allows invertebrates to flourish. Reductions in the area of intertidal mudflats may therefore significantly alter the capacity for estuaries to support these internationally important populations.

Figure 7.2 **The worst-case scenario for the loss of grazing marshes in the north west of England and East Anglia (Nicholls and Wilson 2002). Changes in flood management practices could lead to significant loss of grazing marsh under the Global Sustainability scenario**



Sand and shingle habitats are already declining (Pye and French 1993). We can expect erosion to accelerate in response to sea-level rise under all the futures, although the details are uncertain (see Chapter 6). These systems are intrinsically dynamic and often depend on continued supplies of new sediment. These are priority habitats in the UK's Biodiversity Action Plan and play important roles in both coastal protection and the conservation of biodiversity.

Shingle habitats support a distinctive flora and nesting birds of conservation concern, such as terns. Populations of Little Tern, for example, inhabit a diminishing number of nesting locations. Sea-level rise can therefore be both a threat and an opportunity for such species, if managed realignment can create new habitat. In addition, shoreline management and engineering works to manage and reduce erosion, especially beach nourishment, can also maintain sand and shingle habitats, with potential benefits for both coastal protection and biodiversity (e.g. Hanson *et al. 200*2). Efforts to link these processes through the appropriate design of such technologies can thus provide a dual benefit. However, we need to consider the wider consequences, especially at the sites from where sand and gravel have been extracted and on beaches that are downdrift.

7.3 Environmental impacts of changes in flooding

7.3.1 Fluvial systems

Extreme flood events are part of the 'natural' environment. They may nevertheless have large and long-lived environmental impacts (Whol 2000) that river managers or others believe to be adverse. Factors that influence the impact of large floods include the characteristics of the flood regime, channel gradient, bedload characteristics (the larger or heavier particles such as gravel and pebbles that are moved along the bottom of a channel by moving water), the strength of river bank and the shape of the channel (Hey 1997).

The floods of 2000/2001 allow us to assess the impacts of a series of large flood events on river channels in England and Wales (Sear *et al*. 2002a). In general, there was little morphological change in lowland river channels with their low gradients and cohesive banks. In contrast, morphological change was more widespread in upland channels. Deposition of fine sediment was a characteristic process in lowland river channels, a consequence of the high erosion of the land surface during these storms.

The summary description for drivers in the Catchment Runoff and Fluvial Processes driver sets (Appendix A) show that both the magnitudes and directions of *change* in flood magnitudes and sediment loads are very difficult to assess. Table 7.2 summarises how the various drivers might change river flows and sediment loads, and the effects of these changes on river channels that are sensitive to change. Most of the drivers lead to an increase in flood flows and sediment discharge. We would, therefore, expect sensitive river channels to become wider or deeper. In practice, many channels in Britain are heavily managed. Some will be less sensitive to changing river flows, but some may actually be made more sensitive. The floods of 2000/2001 affected engineered channels as much as natural channels (Sear *et al*. 2002a), although the types of change were often different.

Table 7.2 **Change in flood flows and sediment discharge under different drivers, and potential impacts on the form of natural river channels**

Driver	Change in flood flows	Change in sediment loads	Impact on natural river channel form
Climate Change	↑	↑	Channel widening, deepening and deposition
Rural Land Cover Field drainage (on impermeable soil)	↓	↓	Deposition and narrowing
Field Drainage (on permeable soil)	↑	↑	Channel widening, deepening and deposition
Afforestation (short-term)	↑	↑	Channel widening, deepening and deposition
Afforestation (long-term)	↓	↓	Deposition and narrowing
Intensive Grazing	↑	↑	Channel widening, deepening and deposition
Arable Farming	↑	↑	Channel widening, deepening and deposition
Urbanisation	↑	↓	Channel deepening and widening
Upstream River Channel Change	↑	↑	Channel widening, deepening and deposition
Impoundment	↓	↓	Deposition and narrowing

Extreme floods also may lead to contamination through the flooding of sewage treatment works and the subsequent dispersion of low-level household wastes, the flooding of sites storing hazardous materials, or the remobilisation of contaminated sediments on floodplains (such as mine wastes (Macklin 1996)).

7.3.2 Fluvial ecosystems

Extensive land drainage and river channelisation have resulted in the loss of vast areas of wetland in the UK (HMSO 1995). Consequently, many important habitats and species are now restricted to a small number of sites that are highly vulnerable to alteration in flooding regimes. Careful management of such sites is often required if the water requirements of specific animal and plant species are to be maintained (English Nature 1999).

Changes in the frequency, duration and lateral and vertical extent of flooding can have significant implications for wetland and aquatic habitats. Flooding may also influence communities and species directly by washing individuals out of their preferred habitat into sub-optimal downstream locations. For fish species, however, sediment movement is a major issue, with sedimentation of spawning habitats being implicated in the declines of populations of many species of freshwater fishes in Europe (Lelek 1980).

Along rivers, some habitats may be very stable and unchanging, as is often the case in low-energy lowland rivers, or highly unstable and dynamic, a state that is usually associated with higher-energy, upland streams.

In dynamic systems, where conditions change constantly, the ecosystem is likely to be relatively robust, adapting within a relatively short timescale. However, if the frequency and magnitude of flooding changes significantly, the geomorphology of the system, and hence the habitats, will also change. We can see an example of this in upland rivers across the UK, where changes in flood frequency and duration may have significantly affected the availability of good spawning areas for salmon. Salmon productivity has suffered badly in many rivers as a result of the scouring of gravel from spawning beds – and in some cases a subsequent lack of gravel recharge – and the smothering of spawning grounds with fine sediments. This has affected the recruitment of young fish into breeding populations.

Lowland rivers usually have relatively well modulated and managed flows with ecosystems that reflect the expected range of flows and inundation levels. Where rivers are subject to significant change in substrate or the velocity and level of the water, there can be profound effects on ecosystems (Vervuren *et al*. 2003). Increasingly, water-level management sets out to encourage the development and integrity of wetland communities, using flooding to recreate habitats and to promote the desired species to return. We can see examples of this practice on the Ouse Washes and Somerset Levels.

Changes in vegetation affect all the communities and species supported by an ecosystem, although we are only now beginning to investigate these complex interactions. For example, detailed studies of flooded grassland sites across England and Scotland have demonstrated the impact of flooding on soil invertebrates and the consequent impacts on breeding birds (Ausden *et al*. 2001). Increased flooding of grassland can benefit species of conservation concern in many floodplain areas (Ausden and Hirons 2002). However, the timing of flooding, the underlying soil type and the flooding history are all important in determining the impact on the soil's invertebrate community in an area.

We should note here that pollution and other factors affecting fluvial ecosystems may compound the impact of changes in the flooding regime. In many cases, it is difficult to isolate the implications of changes in flooding from the complex of interactions influencing the ecosystem.

7.3.3 Coastal and estuarine systems

Coastal and estuarine areas contain a diverse range of important intertidal habitats. These include vegetated shingle ridges, saltmarsh, saline lagoons, reed beds, mudflats, coastal grazing marsh, sand dunes, and various cliff environments (Lee 1998; English Nature *et al*. 2000). These habitats are sensitive to varying degrees to the drivers affecting flooding and erosion.

Many such habitats are related to coastal landforms that will naturally fluctuate morphologically in response to erosion and accretion. The long-term sedimentary balance is critical to maintaining sand dunes and beaches, shingle habitats, saltmarshes and mudflats. This is especially important as relative sea levels are already rising around most of the UK coast. Without a net input of sediment these landforms must retreat landward (see Chapter 6).

Increased coastal protection has reduced the input of sediment in some regions, where there has consequently been widespread erosion and landward migration of coastal landforms and habitats, for example, in Norfolk and Essex. However, some areas, such as Morecambe Bay, are stable in the long term, with erosion and accretion roughly in balance. In a few areas of high sediment availability, accretion is occurring, around the Ribble estuary, for example. The flora and fauna of coastal habitats are adapted to these dynamic processes. We would expect a healthy coastal ecosystem to include some landform dynamics. However, if these changes significantly reduce the area of habitats, they can have important long-term environmental consequences. For example, loss of shingle habitats could threaten the small number of remaining breeding sites for Little Terns, *Sterna albifrons*.

Erosion is required to sustain cliffs and their associated habitats. We can see this in areas where accretion in intertidal areas has removed wave action, preventing further cliff erosion. For example, this has happened in front of Hadleigh Castle, in Essex, where the former active cliff cut in the London Clay has now degraded to a steep vegetated slope.

Saltmarshes and mudflats need regular tidal inundation to sustain the species within them. The dynamic conditions created by frequent tidal inundation result in hugely productive mudflat habitats, which can support high densities of invertebrates and migratory birds. Saltmarshes are inundated less frequently than mudflats but are also highly productive habitats. The frequency with which such land is submerged depends on its relative elevation within the tidal range. Mature saltmarsh is flooded only by high spring tides, and during surges (Pye and Allen 2000). Many species are dependent on particular saltmarsh types and inundation frequencies (Packham and Willis 1997).

Coastal grazing marsh and reed beds form the limited remains of the once extensive and diverse transition habitats between marine and freshwater ecosystems, although their current location is often artificial, comprising reclaimed areas of mudflat, saltmarsh and other intertidal areas. Marine flooding of these freshwater and brackish habitats can have significant environmental consequences, generally causing a change to more salt-tolerant habitats. Where the coastal grazing marsh derives from land reclamation, there is usually limited space for onshore migration so they are especially vulnerable to such changes. In many areas around the British coast where it was uneconomical to repair defences, there has been unplanned realignment and a transition back to marine intertidal habitats (French 1997; 2001). This has further reduced the area of coastal freshwater habitats and is likely to continue to do so.

7.4 Implications of current trends of change in flood management for the environment

A number of factors are changing the thrust of flood management in the UK, and their environmental implications cannot be ignored, even given the baseline assumption here on flood management. We have already described the move towards less aggressive flood defence and coastal protection. Flood-management agencies in the UK, and elsewhere, are moving away from a perspective of ‘flood defence’ towards ‘flood-risk management’. Another related factor is the change in the pattern of environmental regulation. These changes are at both the national and European level.

Directives and designations promulgated by the European Union have become increasingly important. Implementation of the Water Framework Directive has the objective of improving water quality and requires all coastal and inland waters to reach ‘good status’ by 2015. The EU’s Habitats and Species Directive requires member states to designate Special Areas of Conservation (SACs) for particular habitats and species. The Conservation of Birds Directive designates Special Protection Areas (SPAs). Significant parts of the British coast are so designated (English Nature *et al*. 2000), and consequently the British Government is required to take steps to maintain these areas in favourable condition.

A number of national policy and regulatory drivers also influence flood management in the UK. The main drivers include the Strategy for Flood and Coastal Defence in England and Wales (MAFF, 1993) and initiatives to plan more sustainable flood and coastal management. This is recognised through fluvial Catchment Flood Management Plans (CFMPs) and estuarine and coastal Shoreline Management Plans (SMPs). A wide range of other planning processes also interact, most notably the Local Planning Authorities development planning processes (e.g. Planning Policy Guidance 23 and 25).

The main environmental focus of flood-management policies is enshrined in these objectives:

- The Strategy for Flood and Coastal Defence in England and Wales, published in 1993 and currently under revision, states that there should be ‘provision of adequate, technically, environmentally and economically sound and sustainable flood and coastal defence measures'.

- High Level Targets for flood and coastal defence, agreed in 1999, set out to: 'avoid damage to environmental interest; to ensure no net loss to habitats and species covered by Biodiversity Action Plans (BAPs); to seek opportunities for environmental enhancement.'

The recent guidelines for the Flood Management Plans have more focused objectives, including:

- Shoreline Management Plans 'should comply with international and national nature conservation legislation and biodiversity obligations'.
- Catchment Flood Management Plans 'should have no significant detrimental effect on the environment, and where possible, opportunities will be sought for environmental enhancement'. However, 'This will not always be possible, but should be a key goal at CFMP level'.

To date, preferential consideration and protection has gone to areas designated for international and national nature conservation. The main repercussion of these policy drivers, and particularly the regulations of the Water Framework Directive, is that in future we may need to consider ecosystems in a wider context and at a greater spatial scale, including areas not designated for nature conservation. As an integral part of the policy-assessment process, this may require the development of high-resolution integrated models, involving catchment and coastal zone hydrology, hydrodynamics and geomorphology, to test the policy options against the ecosystem criteria.

Here we examine the relationship between flood-management policies and the environment, focusing on two questions:

- What is the likelihood of active consideration of the environment in flood-risk management under the four future socioeconomic worlds?

- What is the likelihood of environmentally-oriented measures being implemented in each world, and what would be the barriers to their implementation?

7.5 Foresight Futures and the environment

The emphasis in this section is on the environmental impacts of flood management policies that are implicit in the four Foresight Futures.

World Markets: a market-oriented approach

Under this future world:

- There would be little incentive to implement environmentally-oriented flood-management measures. Indeed there would be little demand for reduced development in flood-prone areas.
- There might be inadvertent benefits to the environment, such as the abandonment of all Grade 4 and 5 agricultural land, possibly allowing more space for natural or semi-natural ecosystems in areas where land pressures are lower, such as uplands.
- Some coastal grazing marsh areas would be abandoned due to increasing flood risk and insufficient resources for defence upgrade, but again environmental benefits (e.g. saltmarsh gains) are inadvertent and there is a net loss of freshwater coastal habitats.

National Enterprise: a market-oriented approach

Under this future world:

- Actions would focus on meeting immediate local needs for defence against flooding. The emphasis would be on measures for 'traditional' flood defence, with little consideration for the environment.

- Some coastal grazing marsh areas would be abandoned due to increasing flood risk and insufficient resources for defence upgrade.

Local Stewardship: a community-oriented approach

Under this future world there would again be a presumption in favour of environmental protection, with a preference for implementing flood-management measures that have minimal environmental impact.

- Measures to reduce exposure and vulnerability to flood would be favoured over measures to reduce the physical hazard; and again where these are necessary there would be a preference towards ‘soft’ engineering approaches.
- Flood management would be seen as a component of broader environmental management. The downstream implications of actions would not necessarily be considered, and it may be difficult to manage large basins, such as the Thames, covered by several agencies.
- Where coastal defences could not be maintained within the available budget, there would be active managed realignment or planned abandonment. Habitat creation would compensate for losses of coastal grazing marshes and other freshwater habitat, taking a local perspective, which might be problematic, given the limited areas of suitable coastal sites.

Global Sustainability: a community-oriented approach

This future world would favour environmental protection, with a preference for flood-management measures that have minimal environmental impact.

- Land use planning, for example, would be preferred over physical measures to reduce the flood hazard. Such measures, where implemented, will work with the environment and will include, for example, managed realignment of the coast, and inland measures to maintain and enhance connections between rivers and floodplains, and to minimise the effect of activities in the catchment on flood runoff.

- Flood management would be seen as a component of broader environmental management, integrated with policies for land use and water supply, for example.
- The downstream implications of upstream actions would be explicitly considered.
- Where the available budget would be too low to maintain coastal defences, there would be active, managed realignment or planned abandonment. Habitat creation would compensate for losses of coastal grazing marshes and other freshwater habitat, but this would tend to be in more inland locations due to the lack of suitable coastal sites. Gains in neighbouring regions, or even neighbouring countries, might replace losses in areas such as East Anglia.

7.6 Environmental economics

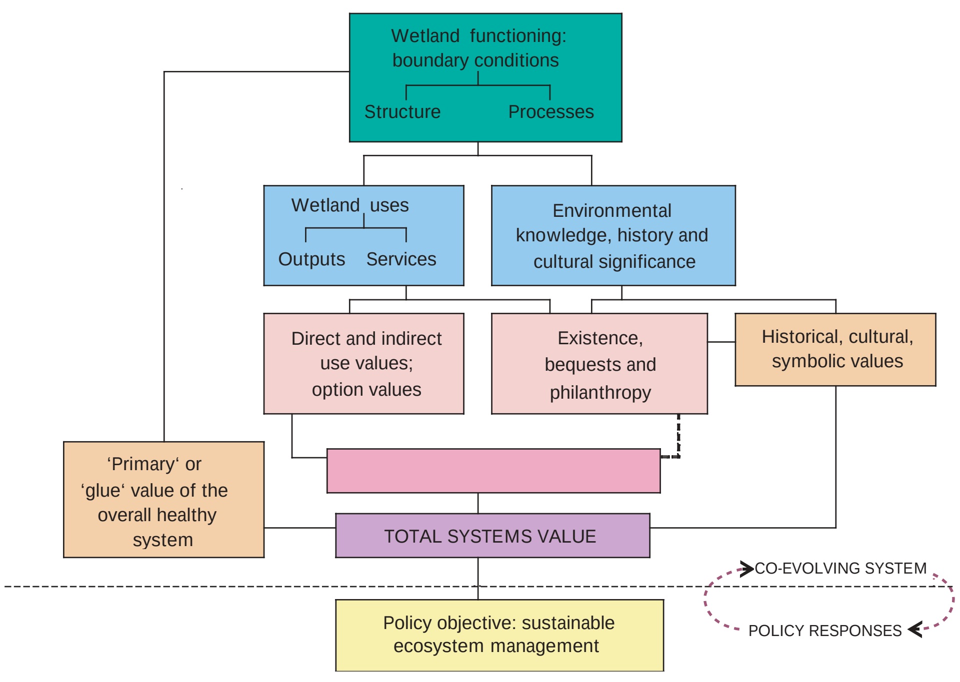
Any attempt at an economic analysis of environmental impacts has to contend with the problem that it is difficult to quantify environmental goods. For this reason, our earlier definition of flood risk – as a function of the probability and consequence of flooding, with the consequences of flooding being quantified in terms of the expected annual damage to people, agriculture and property – takes no account of the environmental dimension of flood risk.

Changes in climate and flooding regime will, however, lead to different impacts on environments, habitats and ecosystems under the four Foresight Futures. There will be environmental gains in some types of system, while others might show losses. In this section we first consider the current preferences and the values that we place on the environments most likely to be affected, i.e. coastal wetlands: saltmarshes and other intertidal zones, coastal grazing marshes, and riparian wetlands. In a second step, we consider the specific implications of the future scenarios and how these values might evolve, taking into account the results of our earlier assessment on the evolution of drivers of changes in flood risk in the four futures.

7.6.1 Current preferences for environmental assets

Environmental economists deploy various methods to estimate current preferences for environmental assets. The basic theory is that the processes, composition and functions of ecosystems provide ‘goods’ and services. We can then assign monetary economic values to these ‘outputs’ (see Figure 7.3 (Turner *et al.* 2001; Ledoux and Turner 2002)).

Figure 7.3 **Functional and other dimensions of wetland values (adapted from Turner *et al.* 2001)**



The main problem with including environmental services in economic choices is that markets attach no economic value to many of the goods and services we derive from our landscapes, habitats and ecosystems. There is a gap between market valuation and the economic value of environmental resources. To fill these gaps, we must first identify, and then where possible monetise, these goods.

Environmental economists traditionally split total economic value into use and non-use values. The overall picture emerging from the literature is that the values involved in coastal and non-coastal wetlands could be high, with total values ranging from about £40 to £40,000 per hectare per year in 2000 prices (Table 7.3). Estimates indicate that we derive the highest values from coastal wetlands through fisheries, commercial or recreational, and coastal defences. For freshwater wetlands, the highest values come from flood control and pollution control, with wetlands as contaminant sinks.

Table 7.3 **Coastal and non-coastal wetland values**

Type of value	Coastal (Year 2000 GBP/ha/yr)	Freshwater (Year 2000 GBP/ha/yr)
Commercial Fishing	7.7-963 (oyster, Batie and Wilson 1978) 1.5 (blue crab, Lynne *et al.* 1981) 1.78-3.34 (blue crab, Fischer *et al*. 1986) 1.8-28.8 (Costanza and Farber 1987) 77.4-309.7 (Amacher *et al*. 1989) 20.6 (Costanza *et al*. 1989) 16 (saltwater fishing, Farber, 1996) 731.7 (fish, Stephenson 2001)	
Recreational Fishing	12.3 (Amacher *et al*. 1989) 1324.4 (saltmarsh- fish Bell 1997)	114.7 (van Vuuren and Roy 1993) 4.28 (Farber 1996)
Waterfowl hunting	7 (Farber 1996)	139.8 (Gupta and Foster 1975) 26.1-281.8 (van Vuuren and Roy 1993)
General recreation	3.09 (Costanza *et al*. 1989)	152.9 (Thibodeau and Ostro 1981)
	7.2 (Bergstrom *et al*. 1990) **	
Coastal defence/flood control	1.7-2.1 (Farber, 1987) 128.9 (Costanza *et al*. 1989) 7334 (King and Lester, 1995) 74-380.1 (Farber 1996)	2984.9 (Thibodeau and Ostro 1981)
Pollution control	1 (Farber 1996)	2337.8 (Thibodeau and Ostro 1981) 5051.2-11747.1 (Gren 1990) 385.7-1146.3 (Dehnhardt 2002)
Total value *	(not expressed per ha)	27870-42598 (Hanemann *et al*. 1990) 270.2-612.1 (Lant and Roberts1990) 1121.5-20404.1 (Kosz 1996) 129.6-2486.4 (Poor 1997) 38.4-106.10 (Mullarkey and Bishop 1999) 421 (Loomis *et al*. 2000)
	2746.2-8961.2 (Whitehead and Blomquist 1991) ** 220.1 (Stevens *et al*. 1995) ** 142.8-454 (Pate and Loomis 1997) **	

* not addition of single components but independent estimation of total economic value through contingent valuation.

** studies done for general wetlands (no distinction between coastal and non-coastal).

7.6.2 Future preferences for environmental assests

Economic valuations of the environment depend critically on the preferences that individuals place on environmental goods and services as both consumers and citizens (Sagoff 1988), and also on the level of provision of goods and services. These are both likely to change in the future and therefore have important consequences for any attempt to place an economic value on environmental factors in our futures scenarios.

Projecting environmental values into the future involves assumptions at four different levels:

- The preferences for environmental goods and services may vary between socioeconomic scenarios.
- Incomes and income distribution will influence the expression of these preferences via demands.
- Different levels of economic activity will have a direct impact on the level of environmental goods and services in each of the four Foresight Futures.
- Institutional structures will influence levels of provision and the extent to which demand and supply can interact to find equilibrium.

Individual preferences can vary among the Foresight Futures. For example, the World Markets scenario could be characterised by preferences focused on individual, capital-intensive, perhaps conspicuous, consumption. Demand for environmental services for recreation might be correspondingly lower than in other scenarios. This might imply that the marginal value of these services could also be lower, despite the reduced level of provision through high levels of economic growth and weaker environmental protection.

Average incomes and income distribution will be radically different between scenarios. This could be significant for environmental values. Since economic value is expressed through ‘willingness to pay’, which in turn is predicated on ability to pay, alterations in income distribution could substantially influence the total willingness to pay for particular environmental provisions.

The costs of supply of environmental goods and services will also be influenced by the level and type of economic activity, and the ways in which economy environment interactions are managed. These will vary across scenarios. This will create further differences in values for changes in provision: for example, the value of a hectare of coastal wetland depends partly on the amount of similar wetland existing in neighbouring areas and further afield.

While in theory there will exist for each scenario some balance between demand for and supply of environmental goods and services, we also need to consider the likely roles, and failures, of institutions. For example, the World Markets scenario could be characterised by greater conversion of public to private goods, in particular in terms of private landowners being able to exclude others from enjoyment of the landscape. On the other hand, in the Foresight Futures Global Sustainability and Local Stewardship we can imagine comprehensive ‘right to roam’ legislation. This could make the value gained from a given piece of land substantially higher under Global Sustainability and Local Stewardship than the World Markets scenario.

Such differences in value have nothing to do with preferences as such, but rather depend on the institutional structures within which individuals can express their preferences. Similarly, the individualist scenarios might be characterised by the wealthy taking measures to protect themselves and their property from the worst effects of environmental degradation, while leaving the poor to fend for themselves. The communal scenarios would be characterised by concerted communal action to defend communities more generally.

Finally, the way in which decisions are made will vary across scenarios. Decision-making in the scenarios that place a premium on community values, such as Global Sustainability and Local Stewardship, will occur more through democratic processes and social debate. In World Markets or National Enterprise, decision-making would be based more on individual preferences, using tools such as cost benefit analysis.

7.7 Key findings

- Flood impacts on channel morphology and physical habitat are driven by changes in both water and sediment load, and are moderated through the resistance of boundary materials to erosion. Hence channel and catchment management can have differential impacts on a channel's ability to adjust to changes in water and sediment regime.
- The magnitude of impact of an extreme flood event on river channel form depends on how close the river reach is to a threshold of geomorphic change: a very large flood may have little effect in one location, and a relatively smaller flood a larger effect in another.
- The drivers of changing river floods are generally likely to result in increases in both water and sediment discharges, and hence a tendency towards a widening and/or deepening of river channels.
- In the last few years there has been a move away from 'concrete' river training to 'softer' forms of river and floodplain corridor management. Although these, by design, have smaller adverse impacts on the environment, their effectiveness through the range of flood flows remains to be fully established, as do the ecological implications of different flooding regimes.
- Coastal ecosystems have experienced significant losses, with flood and coastal defence being an important contributory factor in the last 50 years. This issue is increasingly recognised and policy is rapidly evolving in response.
- In the 21st Century, coastal changes will continue, depending on a variety of drivers, including sea-level rise and climate change, as well as outcomes of coastal- and flood-management policy. On balance, coastal grazing marsh appears to be the most threatened coastal habitat under all four Foresight Futures, as intertidal losses are likely to be offset by planned and unplanned abandonment of coastal defences.
- It is essential to translate environmental impacts of flooding into effects on human welfare to inform policy-making.

- Current knowledge shows the importance of the economic values attributable to wetland areas and ecosystems most likely to be impacted by flooding. Our overview points to the highest values stemming from fisheries benefits and coastal-defence services for coastal wetlands, and flood-control and pollution-reduction services for non-coastal wetlands. However, more formal existing analyses attempting to link wetland values to ecosystem services and characteristics statistically have so far been inconclusive.
- There are severe difficulties associated with attempts to project present environmental preferences and values into future scenarios. Nevertheless, consistent assumptions on preferences, levels of income, income distribution and institutional structures can help build a picture of how values for ecosystems might vary across the four future scenarios. We have provided some examples illustrating how this might be done.