Chapter 9

Synthesis of results and key messages

This chapter assembles the results from the work of the Flood and Coastal Defence project on the impacts of climate change on future flood risk, as presented in earlier chapters. It also brings out the key messages in the following areas:

- The main drivers of future flooding at catchment and intra-urban scales and their relative importance.
- The extent and nature of future flood risk – expressed in economic, social and environmental terms.
- Future coastal erosion, and the extent to which this will compound flood risks.
- The speed at which future risks might increase.

Finally, we present a summary of future risks for the four Foresight Futures scenarios for the UK.

9.1 Introduction and approach to synthesis

The work reported in Volume I addresses the causes, size and nature of future flood risks under the 'baseline assumption' that flood management policies – the current pattern of expenditure and technical approach – continue unchanged into the future. In so doing, the analysis identifies areas where changes in long-term policy might address future risks. Volume II identifies and analyses options for policy change.

The project has assessed future risks for four future scenarios – these combine differing degrees of climate change and socioeconomic change (see Chapter 1). In so doing, the analysis considered current policies against a range of possible futures.

As the baseline assumption is the starting point for our analysis, we start by setting out current levels of flood risk and expenditure on flood management (see Table 9.1).

Table 9.1 **Summary of present day flood-risks and flood management costs**

	People at risk million	Properties at risk	Value of property and agricultural land at risk £ billion	Expected Annual Damage £ million	Flood defence costs 2003-04 £ million
Fluvial and coastal flooding					
England and Wales	4.5	1,740,000	215	1,040	439
Scotland		180,000		32 (fluvial only)	14
Northern Ireland		45,000		16 (fluvial only)	11
Coastal erosion					
England and Wales				14	
Intra-urban flooding					
All UK		80,000		270	320
Total		**2,045,000**		**1,400**	**800**

(Totals have been rounded)

9.2 Drivers of future flood risk

9.2.1 What might be the main drivers of future risk of river and coastal flooding?

The drivers of flood risk at the catchment-level from river and coastal sources have been divided for the purposes of the baseline impacts analysis into six sets (see Table 9.2).

Table 9.2 **Drivers of future flood risk at the catchment scale**

Driver set	Driver	Classification
Inland climate change	Precipitation	Source
	Temperature	Source
Catchment runoff	Urbanisation	Pathway
	Rural Land Management	Pathway
	Agricultural Impacts	Receptor
Fluvial systems and processes	Environmental Regulation	Pathway
	River Morphology and Sediment Supply	Pathway
	River Vegetation and Conveyance	Pathway
Coastal climate change and processes	Waves	Source
	Surges	Source
	Relative Sea Level Rise	Source
	Coastal Morphology and Sediment Supply	Pathway
Human behaviour	Stakeholder Behaviour	Pathway
	Public Attitudes and Expectations	Pathway
Socioeconomics	Buildings and Contents	Receptor
	Urban Impacts	Receptor
	Infrastructure Impacts	Receptor
	Social Impacts	Receptor
	Science and Technology	Receptor

Some drivers, such as Precipitation and Urbanisation, act in a direct physical manner. The drivers shaded grey are of a more general nature and act indirectly through other drivers. These drivers have been assessed as of high importance but have not been quantified due the indirect nature of their action. The 12 most important drivers and their uncertainties are shown separately (see Table 9.3). The drivers are ranked there according to their economic impacts with the most important drivers at the top of the table.

Table 9.3 **The twelve most important drivers of flood risk at catchment scale, and their uncertainty in the 2080s**

	World Markets		National Enterprise		Local Stewardship		Global Sustainability	
	I	U	I	U	I	U	I	U
1	Social Impacts		Relative Sea Level Rise		Social Impacts		Environmental Regulation	
2	Relative Sea Level Rise		Infrastructure impacts		Relative Sea Level Rise		Relative Sea Level Rise	
3	Surges		Surges		Environmental Regulation		Vegetation and Conveyance	
4	Infrastructure Impacts		Buildings and Contents		Surges		Social Impacts	
5	Buildings and Contents		Coastal Morphology and Sediment Supply		Precipitation		Precipitation	
6	Coastal Morphology and Sediment Supply		Social Impacts		River Morphology and Sediment Supply		River Morphology and Sediment Supply	
7	Waves		Precipitation		Coastal Morphology and Sediment Supply		Buildings and Contents	
8	Precipitation		Urbanisation		Waves		Infrastructure Impacts	
9	Stakeholder Behaviour		Waves		Vegetation and Conveyance		Coastal Morphology and Sediment Supply	
10	Urbanisation		Urban impacts		Urban Impacts		Surges	
11	Urban impacts		Rural Land Management		Temperature		Urban Impacts	
12	Rural Land Management		Vegetation and Conveyance		Agricultural Impacts		Waves	

I = Impact in terms of economic damage **U = Uncertainty**

Legend	Degree of impact or uncertainty	Colour code
	High	
	Medium	
	Low	

We begin with an appreciation of the key messages emerging from the ranking, firstly at an overview level:

- Although there is great variation in the power of the drivers and their ranking across the scenarios, there is a clear message that many powerful drivers are forcing an increase in future flood risk.
- A combination of high economic growth, particular issues of governance and climate change combine to create a greater challenge for management of future flood risk under the two consumer-oriented scenarios, World Markets and National Enterprise.
- Many of the drivers that could be the most important are also the most uncertain, posing difficult challenges for flood management now and in the future.

At the level of driver sets:

- Under the baseline flood management assumption, the future with regard to the driver Social Impacts is bleak, especially under the less socially resilient futures, World Markets and Local Stewardship.
- Drivers connected with the impacts of climate change on coastal flood risk – Relative Sea Level Rise, Coastal Morphology and Sediment Supply, Surges and Waves – result in high increases in flood risk under most scenarios. Impacts are much worse under the high-emissions scenarios, World Markets and National Enterprise. These are also drivers of increasing coastal erosion risk. If current expenditure on coastal defences is continued, there is the potential for a 20-fold increase in local risk in the coastal floodplain. This scales to nearly an order of magnitude increase in national risk in the 2080s.
- Precipitation generates lower but still substantial increases in flood risk under all scenarios, with the greatest impacts under the higher emissions scenarios. The increased risk of inland flooding in the 2080s could result in a reduction of the annual probability of flooding of a defended area from 1 in 100 years to 1 in 17 years under the World Markets scenario. This corresponds to a trebling of national flood risk.

- Socioeconomic drivers, including Buildings and Contents, Infrastructure, Urban Impacts and Urbanisation rank highly. Under World Markets and National Enterprise, urban sprawl leads to increased runoff which increases the probability of flooding downstream. At the same time, new developments and weak planning controls on the types, densities and numbers of new buildings increase losses in floodplains. The converse is true under Global Sustainability and Local Stewardship. There is a clear message here regarding the importance of urban development to future flood risk.
- Environmental Regulation, River Morphology and Sediment Supply and Vegetation and Conveyance cluster around the middle of the ranking table under World Markets and National Enterprise. However, they rank higher under the two more environmentally-oriented scenarios, Global Sustainability and Local Stewardship, owing to regulatory frameworks that restrict the use of rivers for flood-defence purposes and promote restoration of their natural attributes.
- National risk scores for Agricultural Impacts are low. This reflects the small proportion of GDP generated by agriculture in the UK. This is not to say that local impacts are insignificant. For example, under National Enterprise the push for national food self-sufficiency increases risk in the farming sector through increased exposure of crops and livestock to damage by flooding.

Both Science and Technology and Public Attitudes and Expectations have been recognised as important drivers but have not been quantified as they act through other drivers:

- Science and Technology, acts through other drivers, increasing the value and potentially the vulnerability of receptors like Buildings and Contents and Infrastructure Impacts.
- Public Attitudes and Expectations could act to promote large reductions in flood risk. It is in a sense a virtual driver, reflecting public opinion and high levels of outrage which may follow major flooding, and bringing about changes in the exposure to and consequences of floods. Although flood management is held constant under the baseline assumption, and this driver is by definition unable to act, it is important at the interface between policy-makers and the public. The driver is considered more fully in Volume II of this report.

9.2.2 What might be the main drivers of future risk of intra-urban flooding?

The drivers in the high-level analysis summarised above are taken as affecting flood risk at the scale of catchments and their estuarial and coastal equivalents. The source terms in the Source-Pathway-Receptor (SPR) model are typically catchment-wide, long-duration precipitation events, and equivalent marine events.

The drivers of flood risk acting within the urban area (see Table 9.4) relate to additional drivers and risks generated by the finer-scale flooding pathways and receptors present in the intra-urban zone. They essentially relate not to the invasion of the urban zone by external water coming over or through flood defences but to pluvial flooding from shorter duration rainfall events acting through internal pathways of flooding within the urban area.

Table 9.4 **Drivers of future flood risk at the intra-urban scale**

Driver set	Driver	Classification
Climate change	Precipitation	Source
Runoff	Urbanisation	Pathway
	Management of Peri-Urban Rural Land	Pathway
Urban conveyance systems and processes	Environmental Management and Regulation	Pathway
	Urban Watercourse Conveyance, Blockage and Sedimentation	Pathway
	Sewer Conveyance, Blockage and Sedimentation	Pathway
	Impact of External Flooding on Intra-Urban Drainage Systems	Pathway
	Intra-Urban Asset Deterioration	Pathway
Human behaviour	Stakeholder Behaviour	Pathway
	Public Attitudes and Expectations	Receptor
Socioeconomics	Building and Contents	Receptor
	Urban Impacts	Receptor
	Infrastructure Impacts	Receptor
	Social Impacts	Receptor
	Science and Technology	Receptor

As with the catchment-level analysis, the drivers of intra-urban flood risk have been ranked in order of importance, taking economic damage as the metric. The drivers shaded grey are of a more general nature and act indirectly through other drivers. These drivers have been assessed as being of high importance but have not been quantified due the indirect nature of their action. Table 9.5 lists the 12 most important drivers.

Table 9.5 **The 12 most important drivers of flood risk at intra-urban scale, and their uncertainty in the 2080s**

	World Markets		National Enterprise		Local Stewardship		Global Sustainability	
	I	U	I	U	I	U	I	U
1	Social Impacts		Infrastructure Impacts		Social Impacts		Environmental Management and Regulation	
2	Infrastructure Impacts		Stakeholder Behaviour		Environmental Management and Regulation		Social Impacts	
3	Buildings and Contents		Buildings and Contents		Stakeholder Behaviour		Precipitation	
4	Intra-Urban Asset Deterioration		Social Impacts		Precipitation		Stakeholder Behaviour	
5	Sewer Conveyance, Blockage and Sedimentation		Intra-Urban Asset Deterioration		Impact of External Flooding on Intra-Urban Drainage Systems		Buildings and Contents	
6	Stakeholder Behaviour		Precipitation		Urbanisation		Infrastructure Impacts	
7	Precipitation		Sewer Conveyance, Blockage and Sedimentation		Intra-Urban Asset Deterioration		Urbanisation	
8	Urbanisation		Urbanisation		Urban impacts		Intra-Urban Asset Deterioration	
9	Urban watercourse Conveyance, Blockage and Sedimentation		Urban Impacts		Urban Watercourse Conveyance, Blockage and Sedimentation		Urban Watercourse Conveyance, Blockage and Sedimentation	
10	Urban Impacts		Impact of External Flooding on Intra-Urban Drainage Systems		Sewer Conveyance, Blockage and Sedimentation		Sewer Conveyance, Blockage and Sedimentation	
11	Impact of External Flooding on Intra-Urban Drainage Systems		Urban watercourse Conveyance, Blockage and Sedimentation		Management of Peri-Urban Rural Land		Urban Impacts	
12	Management of Peri-Urban Rural Land		Management of Peri-Urban Rural Land		Buildings and Contents		Impact of External Flooding on Intra-Urban Drainage Systems	

I = Impact in terms of economic damage **U = Uncertainty**

Legend	Degree of impact or uncertainty	Colour code
	High	
	Medium	
	Low	
	Medium decrease	

The same overall messages apply as with the catchment-level drivers, and are not repeated. The key points are:

- As would be expected there is most red, indicating high-risk drivers, in the World Markets column, decreasing as one moves across to Global Sustainability. The number of high-impact drivers and their ranking is thus again very much a function of scenario.
- Social Impacts rank high owing, among other factors, to the health risks associated with the escape of sewage in intra-urban flood events.
- Precipitation ranks high under all scenarios.
- Drivers connected with the intra-urban drainage system are important. Of these Intra-Urban Asset Deterioration and Sewer Conveyance, Blockage and Sedimentation rank highly under World Markets and National Enterprise, and are not so prominent under the other two scenarios. This reflects the more uneven management of the assets under these scenarios.
- Urbanisation and Urban Impacts are important, reflecting the potential dangers in how urbanisation is managed and in urban creep and development which does not take flood risk fully into account.
- The impact on the intra-urban drainage systems of high water levels in the river and coastal waters adjacent to them and invasion by flood waters from these sources is a medium-ranked driver under all scenarios except Global Sustainability.

9.3. Future flood risks – economic

The studies of drivers, which have provided valuable insights into the drivers discussed above, and the high-level flood-risk quantification for England and Wales are complementary. An analogy can be drawn with a forest of trees. Seen sideways, as in the drivers studies, the nature of each trunk is visible and the average height of each species estimated, but the spread and the shadows cast by the crowns cannot be appreciated. Seen from above, as in the risk quantification, the spatial extent and density of the whole forest is apparent although the individual contribution of each tree merges into the overall canopy.

The risk quantification took into account not only the driver sets of climate and physical processes but all the human and socioeconomic drivers. Thus we derived estimates consistent with the societal scenarios of future development, occupancy and asset levels. Once again, the driver studies applied the baseline assumption on flood management.

The results of risk quantification have been compared with actual damages from recent flood events. Comparison is difficult, but the indications are that the RASP results are of the right order, and that they are sufficiently robust for the purposes of this study.

The economic analysis was possible because of the existence of the RASP model for risk quantification and the availability of requisite data in England and Wales (see Chapter 4). These were not available for Scotland and Northern Ireland, for which we made more approximate estimates.

9.3.1 What might be the future economic damages?

The analysis of future economic damage superimposes the value of the assets on their distribution and the probability of flooding. Increases in economic damage under the two consumerist scenarios show similar patterns of high or medium increases over much of England and Wales.

The pattern of economic damages is similar under the Global Sustainability scenario, though with markedly lower increases. There is a general decrease in economic damages for the scenario Local Stewardship, reflecting both lower increases in probability and lower GDP growth and therefore asset values at risk (see Table 9.6).

Table 9.6 **Comparison of results – expected annual economic damage, residential and commercial properties (£ millions)**

Region	Present day	World Markets	National Enterprise	Local Stewardship	Global Sustainability
England	949	19,000	13,750	1,350	4,470
Wales region of EA	91	1,500	1,300	150	390
Total	1,040	20,500	15,050	1,500	4,860

The table shows large increases in potential economic damages under the two consumerist scenarios, with multipliers of 20 and 15 times, in contrast to the much more modest increases of 1.4 and 4.7 times under the two community-oriented scenarios. This has already been pointed out in the context of the drivers.

The picture for agricultural risk is more diverse, reflecting the nature of agriculture in the UK in the very different policy frameworks of the four scenarios. Under the globalised scenarios of World Markets and Global Sustainability, where much land of lower grade might go out of production and prices would be lower, agricultural damages decrease over much of England and Wales, with the exception of areas of very high-grade land. By contrast, under the localised scenarios of National Enterprise and Local Stewardship, damages increase because agriculture has greater value under these scenarios.

9.3.2 How might the situation differ in Scotland and Northern Ireland?

In the absence of any method comparable with RASP, damages for Scotland and Northern Ireland were assessed by more approximate means, and for the World Markets scenario only (see Table 9.7). It was only possible to arrive at estimates for inland flooding.

Table 9.7 **Expected annual economic damage, residential and commercial properties (£ millions) for Scotland and Northern Ireland, 2080s – catchment flooding only**

	Present day	World Markets
Scotland	32	68
Northern Ireland	16	32

9.3.3 What might be the size of intra-urban flood risks?

The Expected Annual Damages to property and contents from intra-urban flooding are shown in Table 9.8.

Table 9.8 **Expected annual economic damage, residential and commercial properties (£ millions) for all UK, 2080s – intra-urban flooding**

Present day	World Markets	National Enterprise	Local Stewardship	Global Sustainability
270	7,880	5,055	740	1,870

9.4 The effects of future risks on society

9.4.1 How many people might be at high risk of being flooded?

The number of people at high risk is a function of increases in the probability of flooding and of changes in the population distribution and density. The number becomes progressively lower moving from the World Markets scenario to the Global Sustainability scenario, with both climate change and societal drivers playing their parts. The potential increase in people at high risk from catchment and coastal flooding is a factor of between 2.2 and 1.4 (see Table 9.9).

Table 9.9 **Number of people at high risk now and in the 2080s (thousands) – catchment and coastal flooding**

Region	Present day	World Markets	National Enterprise	Local Stewardship	Global Sustainability
England	1,410	3,270	3,320	2,060	2,210
Wales region of EA	150	190	230	200	190
Total	1,560	3,460	3,550	2,260	2,400

Table 9.10 shows an increase of between 5.4 and 4.5 in people at risk of intra-urban flooding. It should be borne in mind that the figures for intra-urban risk are more uncertain than those for catchment-level risk.

Table 9.10 **Number of people at risk now and in the 2080s for whole UK – intra-urban flooding**

	Present day	World Markets	National Enterprise	Local Stewardship	Global Sustainability
Properties at risk of flooding in 1 in 10-year event (thousands)	82	380	340	320	300
Numbers of people at risk (thousands)	197	912	816	768	720

Caution should be exercised in comparing Tables 9.9 and 9.10 as the criteria differ. The criterion for people at risk in Table 9.10 is an annual probability of flooding of 1 in 10, whereas that for catchment and coastal risk is 1 in 75.

9.4.2 What might be the impacts on the more socially vulnerable parts of the population?

The socially disadvantaged are characterised by poverty, ill health and an inability to take up benefits such as insurance. Flooding therefore affects them disproportionately.

A Social Flood Vulnerability Index has been implemented for the high-level quantitative analysis for England, where the necessary data exists. All scenarios except Local Stewardship show a similar pattern of small changes, with a tendency towards increased social vulnerability in urban areas and a decrease in rural areas. There is some divergence with the high ranking of the Social Impacts driver under World Markets and Local Stewardship in the qualitative studies of the drivers, indicating a need to improve predictive capacity in this area.

9.5 Impacts on the natural environment

To evaluate potential impacts on the environment, the project conducted an environmental study of climate and socioeconomic change under the four scenarios, given the baseline assumption for flood management. Since the baseline assumption is of no change in current flood management, it is in effect a picture of the parallel but independent evolution of the environment under the Foresight Futures scenarios. The key findings are:

- The environmental future differs greatly under the four scenarios.
- Coastal ecosystems have experienced a significant loss over the past 50 years, with flood and coastal defence being an important contributory factor, although this is increasingly recognised and policy is rapidly evolving in response to these issues.
- In the 21st Century, coastal change will continue. The changes will depend on a variety of drivers, including sea-level rise and climate change, as well as 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 coastal abandonment, planned and unplanned.
- The analysis of the economic value of wetland areas and ecosystems 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.

- The drivers of changing river flows are likely to increase both water and sediment discharge. Hence there will be a tendency towards a widening and/or deepening of river channels.
- In the past few years there has been a move towards 'softer' forms of river and floodplain corridor management. Although these, by design, have lesser 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.

9.6 Coastal erosion

Analysis shows that approximately 28% of the coastline of England and Wales is experiencing erosion, with the highest erosion rates along the east coast. However, a large proportion of the coastline is artificially held in position: a more realistic estimate is that *potential* erosion threatens 67% of the coastline.

It would be impossible to maintain all defences to their current standard under the baseline assumption for flood management (see Table 9.11). Approximately one-third of existing coastal defences could be lost. The cause, as in coastal flood risk, is the combined effect of waves, surges and sea-level rise, with coastal squeeze exacerbating the problem.

The assets most likely to be at risk under the baseline assumption would depend on the policy adopted for distribution of the available funds. For example, national assets, such as coastal power stations and high-value marine transport terminals, would probably remain a high priority, as would major towns. The coast in between the hard points formed by the defences of the key assets would perforce be left to retreat in a series of embayments with consequent impacts on agriculture and isolated properties in the affected areas.

Table 9.11 **Average erosion over next 100 years and Expected Annual Damage (EAD) due to coastal erosion for the 2080s for England and Wales**

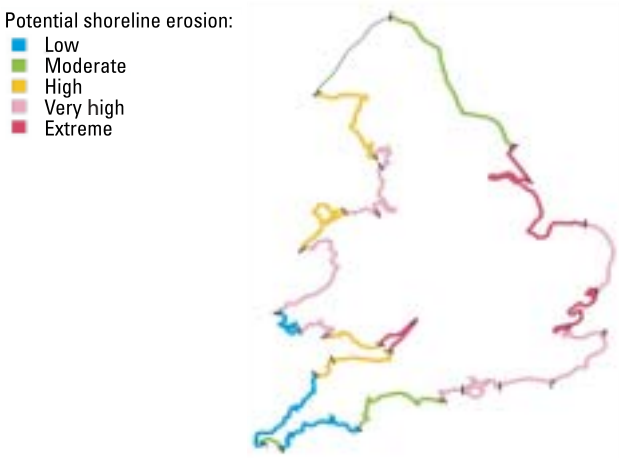
	At present day rate	World Markets	National Enterprise	Local Stewardship	Global Sustainability
Average erosion next 100 years (metres)	20m–67m	141m–175m	113m–150m	99m–138m	82m–123m
EAD £ million	14	126	87	51	46

The economic impact of coastal erosion is less than the economic impact of coastal flooding. It could, however, increase by between three and nine times today's levels by the 2080s. Although the value of built assets at risk from coastal erosion is substantially lower than those at risk from flooding, the rate of coastal change greatly influences the latter. Thus defence of floodplain areas is inextricably linked to adjacent coastal landforms and changes to these.

Coastal erosion has high societal and human connotations. The study of Wales highlighted the importance of the coast as a valuable asset to the tourist industry.

The possible distribution of coastal erosion varies around the UK – see Table 9.12 which illustrates the World Markets case. The geographical coincidence between the two risks demonstrates their origins in common drivers, showing that their effects are likely to combine in parts of the coast.

Figure 9.12 **Regional differences in potential shoreline erosion and a sample plot of increases in flooding risk in the 2080s from Chapter 4**



9.7 How quickly might flood risks increase?

This is a complex and difficult question: the answer is highly uncertain. The project carried out quantitative analysis for one scenario, World Markets. Under this scenario, the general picture for the 2050s is similar to that for the 2080s, with a high proportion of the increased risk being generated by the 2050s. This reflects the convex growth trajectory of climate change in the World Markets scenario with its high emissions of greenhouse gases. The rate of change of flood risk is likely to differ under other scenarios.

Other drivers may not follow this pattern. However, the Foresight Futures of socioeconomic change give us no more clues to their time evolution than a set of figures for compound growth in GDP. The future of the human and environmental drivers will depend on changes in the climate of political and public opinion. These drivers are therefore just as uncertain as the future of global emissions and climate change.

The uncertainty, not only in the future values of the drivers but also in their time evolution, emphasises the difficulties in managing the risks posed by floods.

9.8 The influence of climate change on flood risk

In most of our analysis we have preserved the associations between the socioeconomic scenarios and the UKCIP climate-change scenarios. The associations have enabled us to explore future flood risks without having to explore a large number of permutations.

There is, however, no reason why high growth and World Markets should be inextricably linked to high emissions. In order to explore how much emission control might reduce risk and make the task of flood management easier we have carried out a risk quantification analysis for catchment and coastal flooding in England and Wales for the 2080s, combining World Markets with the UKCIP02 Low emissions climate change scenario. The results are shown in Table 9.14 where they are compared with the values for World Markets/ High emissions.

Table 9.13 **Summary of Expected Annual Damage (£ million) – present day and 2080s**

Risk	Location	Present day	World Markets	National Enterprise	Local Stewardship	Global Sustainability
Fluvial and coastal erosion and flooding						
Fluvial and coastal flooding	England and Wales	1,040	20,500	15,050	1,500	4,860
Coastal erosion	England and Wales	14	126	87	51	46
Fluvial flooding only	Scotland	32	68	Not available		
Fluvial flooding only	Northern Ireland	16	32	Not available		
Intra-urban flooding						
	All UK	270	7,880	5,055	740	1,870
Total risks £ millions (rounded to the nearest £100 million)	All UK	1,400	28,600	20,200	2,300	6,800
Growth in GDP relative to present day		1.0	14.1	4.6	2.6	8.1
GDP (£ billions)		1,070	15,100	4,910	2,780	8,630
EAD as a percentage of GDP		0.13%	0.19%	0.41%	0.08%	0.08%

Table 9.14 **Comparison of future EAD in the 2080s: World Markets/High and Low emissions**

Risk	Location	Present day	World Markets/ High Emissions	World Markets/ Low Emissions
Fluvial and coastal flooding	England and Wales	1,040	20,500	15,100

It can be seen that under World Markets we might reduce flood risk by up to 25% if we were able to achieve a substantial reduction in emissions.

The implications of this are considered further in Volume II.

9.9 Summary of risks and conclusions

The key risks are summarised in Table 9.13. In this table increases in risk represented by expected annual damages (EAD) have been juxtaposed with growth in GDP under the four scenarios. This enables the risks to be viewed both in the context of impacts on people and assets affected and in the context of national wealth.

A number of key messages emerge from this study and the analysis of drivers:

- While there is great variation across socioeconomic scenarios of the future, the clear message is that under all climate and socioeconomic scenarios we can expect to see substantial increases in flood risk in terms both of people at risk and economic impacts.
- Risk as a percentage of GDP increases marginally under World Markets. It declines under the high-growth/low emissions Global Sustainability and under Local Stewardship. The big rise under National Enterprise conveys the dangers of ending up in a low-growth – High emissions combination.
- The environment is not by definition influenced by flood-management activities under the baseline assumption of constant expenditure, except at the coast, but social impacts, in the shape of disproportionate effects on the disadvantaged, may be severe under World Markets and Local Stewardship.

- A combination of high climate change and adverse issues of governance combine to create a much more challenging problem for flood-risk management under the two consumer-oriented scenarios, World Markets and National Enterprise. EAD rises under both scenarios as a proportion of GDP, whereas it declines under the other two scenarios. We can make things easy or difficult for ourselves in flood-management terms by seeking emissions reduction. The management of future urban development is equally important.
- Whereas the climatic drivers are most prominent under the two consumerist scenarios, environmental and societal influences affect flood pathways through increased regulation under the two community-oriented scenarios. The key message here is that care must be taken to factor flood management into future environmental regulation, and that environmentalists and engineers must work together to find better ways of achieving their objectives.
- Many of the drivers which are potentially the most important are also the most uncertain, posing difficult challenges for flood management now and in the future, and underlining the need for well-targeted research.
- Although by definition constrained under the baseline assumption for flood management, Stakeholder Behaviour and public perception, are likely to be key influences in future flood management (this issue is taken up in Volume 2).
- Science and technology, an indirect driver of risk through increasingly complex and potentially vulnerable infrastructure, buildings and contents, is shown in the rankings as 'Known to be important but not quantified'. This is in a sense a warning that all our predictions might be overthrown by quantum changes in the technology on which we depend and its vulnerability to flooding. On the other hand, science and technology hold considerable potential for better management of flood risk in the future, a topic that is addressed in Volume II of this study.
- Under World Markets we might reduce flood risk by up to 25% if we were able to achieve the maximum reduction in emissions. This reinforces the message regarding the dangers inherent in National Enterprise, where we have a combination of high climate change creating a large increase in risk, which is not matched by economic growth needed to put government and

the private sector in a good position to respond. The point is further reinforced if we look at Global Sustainability, where we have good economic growth coupled with Low emissions, leading to significant risk reduction.

- The Foresight study described in the two volumes of this report is unprecedented in many respects. It has brought together experts from diverse disciplines to study the risks of flooding and coastal erosion for all of the United Kingdom over very long time-scales. It has engaged with stakeholders from across government, industry and more broadly. This formidably ambitious undertaking has been completed over a very short timescale. The Foresight Flood and Coastal Defence project therefore stands as a milestone example of what is achievable in the integrated assessment of risks associated with climate and socio-economic change. It should also act as a stimulus to subsequent studies that have the time and resources to dissect specific issues in more depth and with better quantitative tools than was feasible within the context of this study. It has highlighted a field of cross-disciplinary research that merits the attention of government, researchers and wider stakeholder groups.

- Many complementary research initiatives are already underway, supported by Defra, the Environment Agency, the Research Councils and the European Commission, amongst others. These ongoing and future studies will serve to fill out and progressively update the insights provided by this study and inform the ongoing decision-making processes within government and morewidely that rely on accurate and farsighted insights into present and future risks. Some major gaps in existing knowledge that must be filled if we are to better understand and manage the risks of flooding and coastal erosion in future have been highlighted in this study. We have also restated the need to address skill shortages if risks are to be managed more effectively in future, a problem that has already been recognised in parts of Government and industry.

- This report has concluded by raising a series of strategic choices for Government and other stakeholders in the process of managing flooding and coasts. The choices are not easy, but this project has demonstrated how inter-disciplinary science and technology can be brought to bear on a difficult problem in order to help Government develop sustainable solutions.