UK 2012 Climate Change Risk Assessment

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Climate Change Risk Assessment for the Floods and Coastal Erosion Sector

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Statement of use

This report presents the research completed as part of the UK Climate Change Risk Assessment (CCRA) for a selected group of risks in the Floods and Coastal Erosion sector. Whilst some broader context is provided, it is not intended to be a definitive or comprehensive analysis of the sector.

Before reading this report it is important to understand the process of evidence gathering for the CCRA.

The CCRA methodology is novel in that it has compared over 100 risks (prioritised from an initial list of over 700) from a number of disparate sectors based on the magnitude of the consequences and confidence in the evidence base. A key strength of the analysis is the use of a consistent method and set of climate projections to look at current and future threats and opportunities.

The CCRA methodology has been developed through a number of stages involving expert peer review. The approach developed is a tractable, repeatable methodology that is not dependent on changes in long term plans between the 5 year cycles of the CCRA.

The results, **with the exception of population growth where this is relevant, do not include societal change in assessing future risks, either from non-climate related change, for example economic growth, or developments in new technologies; or future responses to climate risks such as future Government policies or private adaptation investment plans**.

Excluding these factors from the analysis provides a more robust 'baseline' against which the effects of different plans and policies can be more easily assessed. However, when utilising the outputs of the CCRA, it is essential to consider that Government and key organisations are already taking action in many areas to minimise climate change risks and these interventions need to be considered when assessing where further action may be best directed or needed.

Initially, eleven 'sectors' were chosen from which to **gather** evidence: Agriculture; Biodiversity & Ecosystem Services; Built Environment; Business, Industry & Services; Energy; Forestry; Floods & Coastal Erosion; Health; Marine & Fisheries; Transport; and Water.

A review was undertaken to identify the range of climate risks within each sector. The review was followed by a selection process that included sector workshops to identify **the most important** risks (threats or opportunities) within the sector. Approximately **10%** of the total number of risks across all sectors was selected for more detailed consideration and analysis.

The risk assessment used UKCP09 climate projections to assess future changes to sector risks. Impacts were normally analysed using single climate variables, for example temperature.

A final **Evidence Report** draws together information from the 11 sectors (as well as other evidence streams) to provide an overview of risk from climate change to the UK.

Neither this report nor the Evidence Report aims to provide an in depth, quantitative analysis of risk within any particular 'sector'. Where detailed analysis is presented using large national or regional datasets, the objective is solely to build a consistent picture of risk for the UK and allow for some comparison between disparate risks and regional/national differences.

This is a UK risk assessment with some national and regional comparisons. The results presented here should not be used by the reader for re-analysis or interpretation at a local or site-specific scale.

In addition, as most impacts were analysed using single climate variables, the analysis may be over-simplified in cases where the consequence of climate change is caused by more than one climate variable (for example, higher summer temperatures combined with reduced summer precipitation).

Sector Summary

Introduction

The Climate Change Risk Assessment (CCRA) provides an assessment of the risks to the UK that could be caused by climate change in the future. This report covers the risk assessment for the Floods and Coastal Erosion sector.

This risk assessment is designed to examine the potential changes in flood and coastal erosion risk as a result of climate change. The assessment has been made assuming that there are no changes in the existing flood and coastal erosion risk management measures. Thus the analysis includes the current flood defences and protection against coastal erosion, but does not include any future changes as a result of adaptation policies and measures.

This means that the projections given in this report do not take account of the risk reduction benefits of future or planned adaptation measures, or the increase in risk that would occur as existing flood defences and other assets deteriorate, or the change in risk that would occur as existing flood defences and other assets are repaired or replaced.

The impact that adaptation policies would have on the projections presented in this report will depend on the resources that are made available to maintain the existing flood risk management system and implement further adaptation measures. As such, this report presents the potential risks that may be reduced further by targeted investment in flood risk management. The subsequent Economics of Climate Resilience study and more detailed investment plans of the Environment Agency, other risk management authorities and relevant Devolved Government agencies will determine the cost effectiveness of different adaptation measures.

The assessment is based on the UKCP09 climate projections, which indicate that the main climate drivers of flood risk (sea level rise, winter precipitation and storm rainfall intensity) will increase, leading to an increase in the risk of flooding. In order to assess the magnitude of climate change impacts, changes in the most important impacts have been estimated for the following epochs:

- Future climate scenarios, in the 2020s, 2050s and 2080s
- Future climate scenarios and projections of socio economic change, in the 2020s, 2050s and 2080s.

The three epochs used in the analysis (2020s, 2050s and 2080s) are those used for the climate projections in UKCP09.

The analysis has been carried out for tidal and river flooding, but not surface water flooding. Whilst the number of properties at risk from surface water flooding is similar to the number at risk from tidal and river flooding, suitable information for analysis were not available at the time of writing this report.

Key findings

It is estimated that about six million people in the UK (about 10% of the population) are at risk of flooding from rivers or the sea. A similar number are at risk from surface water flooding. In addition, about 3,000 km of the coastline (17% of the total length) is eroding. Thus, floods and coastal erosion are already serious risks in the UK, and they are projected to increase as a result of climate change.

Global sea level has risen at a mean rate of 1.8 mm per year since 1955. From 1992 onwards a higher mean rate of 3 mm per year has been observed. The climate change projections indicate that the sea level is highly likely to continue to rise and that the rate of rise is projected to increase. This would lead to an increase in tidal flood risk on the coast and in estuaries.

There has been significantly increased precipitation over northern Europe (an area which includes the UK) between 1900 and 2005, particularly noticeable since about 1979. There have been more frequent spells of very wet weather and an increase in total precipitation, at least during the last 40 years.

It is considered likely that winters will become significantly wetter and that extreme winter precipitation will increase across the UK in all regions, based on UKCP09 projections of future rainfall.

In summer, less overall rainfall is considered likely but future summers are projected to be characterised by intense heavy downpours interspersed with longer relatively drier periods. These winter and summer changes would lead to an increase in fluvial and surface water flooding.

Based on these projections, the analysis indicates that the risk from tidal and river flooding could increase. For example, the annual flood damages to properties is projected to increase by between 70% and 400% by the 2080s compared with the baseline as a result of climate change assuming no change in population or property numbers, and assuming no change in existing flood risk management measures.

The projected increases in flood risk for the 2050s and 2080s are consistent with projections produced in other projects. However there is a concern regarding the relatively large projected increase in the near-term (2020s) projections compared with the baseline. This reflects uncertainty in the dates of the baseline values, as discussed in Section 4.5.4.

Results presented for the 2020s in this report should therefore be treated with caution, and not be used for planning purposes.

Current vulnerability

The current level of vulnerability to flood risk is deemed to be high, for example:

- Approximately six million UK properties (or one in six of all properties) are currently exposed to some degree of flood risk, with about 560,000 properties in England and Wales at significant likelihood of tidal or river flooding (equating to an annual probability of 1.3% or 1 in 75 years on average).
- Present day Expected Annual Damage (EAD) to residential and non-residential properties from tidal or river flooding is of the order of £1.2 billion in England and Wales. The EAD is an estimate of the average annual damage to property and contents. The total damage could be much higher if other assets and indirect and intangible losses are included.

Many of the properties exposed to a degree of flood risk are in areas with flood defences. However the current system of flood defences will deteriorate over time and may require significant future investment to maintain, repair and replace if current levels of protection are to be maintained.

The flood events of summer 2007 demonstrated the major impacts that floods can have, not only on economies but also on peoples' lives. It also showed the importance of understanding the full extent of flood risks including indirect impacts so that preparation to face future events can be improved.

About three million properties are at risk of flooding from rivers or the sea and four million from surface water flooding. About one million of the properties at risk of flooding from rivers or the sea are also susceptible to surface water flooding, giving the overall total of six million properties referred to above. Flooding from groundwater also poses a threat in some areas, adding still further to the risk.

Whilst surface water flooding is recognised as a major source of flood risk, it has been difficult to explore the impact of climate change owing to a lack of suitable information on future flooding. Projected increases in rainfall intensity and volume are likely to increase the already considerable risks from surface water flooding.

The nature of flooding from the sea, rivers and surface water is different. Flooding from the sea and large rivers can be very extensive, with deep water and high flow velocities. In contrast, surface water flooding is generally shallow. However urban flood waters are often polluted by sewage leading to additional risks to health, higher repair costs and longer periods of disruption.

The analysis presented here highlights that a sizeable part of important infrastructure and public services is in flood risk areas. For example, over 50% of water and sewage pumping stations and treatment works are in the floodplain. Widespread floods can cause serious indirect impacts including disruption to power supplies, water supplies, communications and transport. Floods can also interfere with basic public services such as schools and hospitals. Recommendations for improving the management of flood risk for critical infrastructure were made in the Pitt Review (Pitt, 2008) and these are now being implemented.

About 3,000 km (17%) of the UK coastline are eroding. Unlike flooding, erosion causes a permanent loss of land. Whilst many areas of erosion are protected by coastal defences, erosion has already caused damage and loss of properties and agricultural land in some areas. Coastal erosion is a natural process, and would occur without climate change. However the rate of coastal erosion is likely to increase with climate change as the sea level rises. This could also lead to deeper water in nearshore areas which would in turn cause an increase in wave energy reaching the coast. Coastal erosion is likely to impact on buildings and infrastructure located along the coast.

Current policies across the UK are risk-based and, hence, are inherently adaptive and capable of responding to future change. Climate change is already included through Government policy and guidance that promotes a managed adaptive approach to flood risk. Over time it may be possible to reduce vulnerability by making space for water and other adaptation actions.

Impacts of climate change covered by the analysis

Impacts identified in the Floods and Coastal Erosion sector

Flooding and erosion are natural processes whereas risk is a uniquely human construct. Neither flooding nor erosion are “risks” in themselves but can result in a wide range of consequences.

A large number of potential consequences was identified, some of which were selected for detailed analysis through a process of scoring and consultation with sector specialists. These indicate the breadth and depth of the risks associated with flooding and coastal erosion, although they do not cover all the potential consequences as the project could only look at a limited selection.

The analysis provided projections of the following consequences of flooding:

- Number of people at risk
- Number of vulnerable people at risk based on the number of properties and people in the highest 20% of deprived areas
- Area of agricultural land at risk
- Number of residential properties at risk
- Number of non-residential properties at risk
- Annual flood damage to residential and non-residential properties
- Length of road and rail at risk
- Number of energy generation stations and major distribution substations at risk
- Number of hospitals and schools at risk
- Number of residential properties where the increase in flood likelihood could lead to an increase in insurance cost or difficulty obtaining flood insurance because of the high level of flood risk
- Area of Scheduled Ancient Monuments at risk.

In addition, the loss of agricultural land and Biodiversity Action Plan (BAP) habitats from coastal erosion was also assessed.

The consequences analysed in this sector were direct consequences of flooding and coastal erosion with the exception of the effects of increases in flooding on property insurance.

For each consequence, a 'risk metric' was selected. A risk metric provides a measure of the magnitude of the consequences in relation to the magnitude of the change in climate. It was not possible to undertake an analysis of climate change impacts in the following cases because of a lack of suitable information:

- Consequences of surface water flooding (including people, agricultural land, property, transport and other infrastructure)
- Number of water supply and sewage installations at risk.

Impacts identified in other sectors

Flooding and coastal erosion is a driver that has consequences in all the other sectors in the CCRA analysis. The flood related consequences that were analysed in other sectors are summarised below. The results from these analyses have been included in this report. Details of the analysis are contained in the relevant sector reports.

<u>Direct consequences</u>

- Deaths caused by flooding, analysed in the Health Sector
- Injuries caused by flooding, analysed in the Health Sector
- Flooding of natural and built tourist assets, analysed in the Business Sector
- Flood damage and interruption costs to business, analysed in the Business Sector
- Scour at bridges, analysed in the Transport Sector

- Disruption of Information and Communication Technology (ICT) systems, analysed in the Business Sector
- Spills from Combined Sewer Overflows (CSOs), analysed in the Water Sector
- Coastal evolution including the combined effects of coastal flooding, coastal squeeze and coastal erosion, analysed in the Biodiversity Sector.

Indirect consequences

- Mental health impacts of flooding, analysed in the Health Sector
- Supply chain disruption, analysed in the Business Sector
- Disruption and delay to road transport, analysed in the Transport Sector
- Flood impacts on mortgage revenues, analysed in the Business Sector
- Increase in insurance payout costs, analysed in the Business Sector.

Flooding and coastal erosion can cause wider indirect consequences including, for example, loss of services and disruption to peoples lives. Some of these consequences have been identified and assessed in the analysis. However, in other cases, there is currently a lack of information to support a UK analysis.

Results

The results of the analysis are summarised below. Where quantitative projections have been made, these include projected increases in population and property numbers (except where otherwise stated) and are presented as ranges from the lowest climate and socio-economic projections to the highest. The 2020s projections are not included in this summary for the reason given in the 'Key findings' section but are covered in the main report. All costs have been calculated at present day prices.

Not only are the numbers of people, property and other receptors at risk of flooding projected to increase, but also the frequency of flooding. For example the frequency of river flooding might increase by about two to four times by the 2080s. The results are given in terms of the number of receptors (people, property, etc) in most cases and information on the spatial scale that this will cover is only provided in a small number of cases, for example agricultural land at risk of flooding.

People

The number of people at risk of flooding (with an annual probability of 1.3% or greater) from rivers or the sea in England and Wales is projected to increase from the baseline of about 900,000 to:

- Between 1.3 million and 3.6 million by the 2050s
- Between 1.7 million and 5 million by the 2080s.

The number of properties in the highest 20% of deprived areas at risk of flooding (with an annual probability of 1.3% or greater) from rivers or the sea in England and Wales has been used to provide an indicator of the number of vulnerable people who might be at risk from flooding. This number of properties is projected to increase from the baseline of about 70,000 to:

- Between 120,000 and 400,000 by the 2050s

- Between 170,000 and 560,000 by the 2080s.

The number of flood related deaths (including overtopping of sea walls by waves during storms) is projected to rise from a present day total of about 18 per year to:

- Between 20 and 70 by the 2050s
- Between 30 and 120 by the 2080s.

The number of flood related injuries is projected to rise from a present day estimate of about 360 per year to:

- Between 400 and 1,350 by the 2050s
- Between 550 and 2,350 by the 2080s.

The number of people who might suffer mental stress as a result of flooding is projected to rise from a present day estimate of between 3000 and 5000 per year to:

- Between 8,000 and 17,000 by the 2050s
- Between 9,000 and 24,000 by the 2080s.

The present day number of people at risk from surface water flooding is estimated to be greater than the number at risk from river and tidal flooding. However it has not been possible to provide projections of the number of people at risk from surface water flooding for future climate change scenarios. UKCP09 projections indicate an increase in winter rainfall of between 12 and 30% together with a doubling of the frequency of heavy rainfall events. This indicates that surface water flooding is likely to get worse if adaptation measures are not implemented.

Property

The number of properties at risk of flooding (with an annual probability of 1.3% or greater) from rivers or the sea in England and Wales is projected to increase from the baseline of about 560,000 (370,000 residential and 190,000 non-residential) to:

- Between 800,000 and 2.1 million by the 2050s of which between 530,000 and 1.5 million are residential properties
- Between 1.0 million and 2.9 million by the 2080s of which between 700,000 and 2.1 million are residential properties.

The Expected Annual Damage (EAD) to properties from river and tidal flooding in England and Wales is projected to increase from the baseline of about £1.2 billion (£640 million residential and £560 million non-residential) to:

- Between £1.8 billion and £6.8 billion by the 2050s of which between £1.0 billion and £3.8 billion is for residential properties
- Between £2.1 billion and £12 billion by the 2080s of which between £1.2 billion and £6.5 billion is for residential properties.

An estimate of the impact of flooding on heritage sites was made by estimating the area of Scheduled Ancient Monument (SAM) sites at risk of flooding (with an annual probability of 1.3% or greater) from rivers or the sea in England and Wales. The area is projected to increase from the baseline of about 7,000 ha to:

- Between 7,000 and 9,000 ha by the 2050s
- Between 7,500 and 10,000 ha by the 2080s.

The number of properties at risk from surface water flooding is estimated to be greater than the number at risk from river and tidal flooding. However, it has not been possible to provide projections of the number of properties at risk. As discussed above, under people at risk, increases in precipitation indicate that this problem is likely to get worse if adaptation measures are not implemented.

Agriculture

The area of agricultural land at risk of flooding with a 10% annual probability or greater to a depth of 0.5 m or greater from rivers or the sea in England and Wales is projected to increase from the baseline of about 200,000 ha to about 400,000 ha by the 2050s and over 500,000 ha by the 2080s. This represents an increase from about 2% to 5% of all agricultural land.

The corresponding figures for Grade 1, 2 and 3 agricultural land (primarily arable and horticulture) is a baseline of about 100,000ha, rising to about 240,000 ha by the 2050s and about 350,000 ha by the 2080s.

The area of very frequently flooded agricultural land (annual probability of 33% or once in three years on average) in England and Wales is projected to rise from a baseline of about 50,000 ha to about 120,000 ha by the 2050s and 200,000 ha by the 2080s.

Business

As the sea level rises the area of tourist beaches around the coast may reduce. It is projected that between 1,200 and 6,100 ha of beach area in the UK could be lost by the 2080s, which is between approximately 3% and 7% of total beach area.

It was not possible to provide quantified projections of the number of tourist assets at risk of flooding although flood frequency data indicates that tourist assets at risk of flooding on the coast could be inundated between three and five times more frequently by the 2080s if adaptation measures are not implemented.

Indicative estimates have been made of the cost of business disruption due to flooding based on information from insurance claims. The cost could rise from a present day annual average figure of £20 million to £50 million by the 2050s and £60 million by the 2080s. It is also estimated that the annual cost of lost staff days due to flooding might be of the order of £6 million, rising to about £9 million by the 2080s.

It was not possible to provide quantified projections of the effects of disruption to supply chains as a result of flooding, but research has shown that businesses that are affected by supply chain disruption suffer severe impacts including loss of share price and reduced sales performance.

Transport

The length of roads at risk of flooding (with an annual probability of 1.3% or greater) from rivers or the sea in England and Wales is projected to increase from the baseline of about 12,000 km (including 3,400 km of motorways and A roads) to:

- Between 13,000 km and 18,000 km by the 2050s (including 3,500 km to 5,000 km of motorways and A roads)
- Between 14,000 km and 19,000 km by the 2080s (including 3,900 km to 5,500 km of motorways and A roads).

The length of rail at risk of flooding (with an annual probability of 1.3% or greater) from rivers or the sea in England and Wales is projected to increase from the baseline of about 2,000 km to:

- Between 2,000 km and 2,900 km by the 2050s
- Between 2,300 km and 3,100 km by the 2080s.

The cost of delays and disruption to road transport is projected to be low (less than £10 million per year on average) to the 2050s but to become medium by the 2080s (between £10 million and £100 million per year) rising to above £100 million per year for the wettest climate scenarios.

In the last ten years there has been about one road or rail bridge failure per year due to scour. The number of failures is projected to increase although it was not possible to quantify the magnitude of the increase. This is because of a lack of national information on bridge foundations.

Critical infrastructure

It is estimated that about 700 water treatment works and pumping stations are at significant likelihood of flooding from rivers or the sea in England and Wales, about 40% of the total number of installations. Whilst the number of installations at risk of flooding is projected to increase, and the frequency of flooding is also projected to increase, it was not possible to quantify the magnitude of change.

The number of power stations at risk of flooding (with an annual probability of 1.3% or greater) from rivers or the sea in England and Wales is projected to increase from the baseline of about 20 (with a capacity of about 10GW or 15% of total generating capacity) to:

- Between 25 and 40 by the 2050s (with a capacity of between 15 and 22GW)
- Between 30 and 40 by the 2080s (with a capacity of between 19 and 25GW).

There are a total of about 20 nuclear sites in England, Wales and Scotland of which about seven would be at high risk of flooding and five at high risk of coastal erosion if adequate protection was not provided (regulations currently require flood protection to a 1 in 10,000 year standard). The reason for the high proportion of sites at risk of flooding or coastal erosion is that some of the sites are on the coast.

The number of major electricity substations at risk of flooding (with an annual probability of 1.3% or greater) from rivers or the sea in England and Wales is projected to increase from the baseline of 46 to:

- Between 50 and 75 by the 2050s
- Between 55 and 80 by the 2080s.

The number of hospitals at risk of flooding (with an annual probability of 1.3% or greater) from rivers or the sea in England and Wales is projected to increase from the baseline of about 50 (with about 3,500 hospital beds) to:

- Between 60 and 90 by the 2050s
- Between 60 and 100 by the 2080s.

The number of schools at risk of flooding (with an annual probability of 1.3% or greater) from rivers or the sea in England and Wales is projected to increase from the baseline of about 900 (with over 250,000 pupils) to:

- Between 1,000 and 1,700 by the 2050s

- Between 1,200 and 1,800 by the 2080s.

Flooding has the potential to disrupt Information and Communications Technologies (ICT) although it has not been possible to assess the potential impact.

Insurance and mortgages

As flood risk increases, the number of properties where insurance premiums are likely to increase or there may be difficulty obtaining insurance is likely to increase. The number of properties at risk of flooding (with an annual probability of 1.3% or greater) provides an indicator of the potential magnitude of this problem.

The number of residential properties at risk of flooding (with an annual probability of 1.3% or greater) from rivers or the sea in England and Wales is projected to increase from the baseline of about 370,000 to:

- Between 500,000 and 1.5 million by the 2050s
- Between 700,000 and 2.1 million by the 2080s.

The estimated value of mortgages on residential properties where insurance and therefore mortgages could be difficult to obtain in the future is projected to be of the order of £1-8 billion in the 2050s to £2-9 billion by the 2080s.

Insurance payout costs for flooding average between £200 million and £300 million per year. This is projected to increase to between £500 million and £1 billion by the 2080s. However the 2007 flood resulted in payouts totalling about £3 billion, demonstrating the severe effect that a major flood can have on the insurance industry.

Whilst average insurance payouts can be managed through pricing, there is a risk that very large future payouts could occur as the result of a very serious and widespread flood event.

Coastal erosion and evolution

The area of agricultural land in England and Wales that could be lost as a result of coastal erosion is projected to be:

- Between 3,500 and 6,000 ha by the 2050s
- Between 6,500 and 10,000 ha by the 2080s.

The area of BAP habitats in England that could be lost as a result of coastal erosion is projected to be:

- Between 140 and 280 ha by the 2050s
- Between 280 and 540 ha by the 2080s.

These figures only include certain priority habitats in England and therefore will underestimate the overall habitat area. In addition, the coastal erosion projections are tentative. It should be possible to improve these projections for the next CCRA using new analysis that has already been completed but not formally published.

It is estimated that about 3,000 km of the UK coast is eroding, or 17% of the overall total. It is also estimated that about 4,000 ha of land could be lost from coastal designated sites in England and Wales in the next 50 years although some habitat creation is expected to take place (from managed realignment schemes).

About 32,000 ha of habitat within designated sites are considered to be vulnerable to coastal flooding. As flooding increases, damage and loss of habitats may increase. It is estimated that about 4,600 ha of coastal floodplain habitat is already at risk of irreversible damage due to flooding, and this could increase to 5,160 to 5,630 ha by 2100..

The High++ sea level rise scenario

The projections in this risk assessment are based on the UKCP09 climate projections. However UKCP09 also includes a ‘High++’ scenario with an increased rate of sea level rise, which is a plausible low likelihood high impact scenario. A simple estimate suggested that the number of properties at significant likelihood of tidal flooding in England and Wales for a High++ scenario could be more than twice the projected number in the 2080s for the UKCP09 scenarios used in this analysis.

Uncertainty in future risks

The estimates of future risks are sensitive to climate and socio economic projections, both of which are very uncertain. The analysis on the number of properties at significant likelihood of flooding indicates that about 60% of the overall increase in risk (expressed as EAD) is due to the climate change scenarios and 40% due to the socio-economic scenarios in the 2080s.

Future risk is clearly very dependent on future climate. Whilst UKCP09 provides estimates based on current modelling capability, there remain uncertainties in future climate change which are not captured by current models. These unknowns might result in changes to climate projections that cannot be foreseen at present.

There is uncertainty in the baseline date used for the analysis arising from the fact that some of the modelling information has been updated where new information has become available. The effect of this is to cause uncertainty in the baseline date and therefore the magnitude of future change compared with present day.

Other Drivers

The CCRA projections provide an estimate of risks based on climate drivers and high level assumptions. The following issues, which have not been taken into consideration in the detailed analysis, will also affect future flood risk and management of the risk:

- **Spatial planning process (development)** – where and how new homes and businesses are built is just as critical as the number of additional properties.
- **Spatial planning process (emergency services)** – spatial planning can either act to improve resilience during times of emergency, when risks become acute, or decrease it. This has knock-on effects on the ability of the emergency services to respond.
- **Food production** – it may or may not be possible to transfer agriculture production to new areas away from those that have been made unusable for current purpose by frequent flooding. Some economic estimates of flood risk assume that this is possible.
- **New types of development** – technology in the home and business is set to increase. The nature of these developments can have a significant impact on flood damage. For example, if high technology hubs were to be developed in floodplains, the vulnerability of such developments would be high.

- **Public outrage to flooding** – public acceptance of flooding could increase or decrease. This in turn can influence political pressure for change.

Emerging Challenges

The majority of the findings reinforce what is already well-known. In particular, there is already significant flood risk in the UK and this is likely to increase based on the UKCP09 climate change projections. Some of the key challenges are summarised below.

- **Adaptation of existing flood defences** – The defence systems that protect the floodplains and coastline are well developed across most of the UK and have been built to allow for climate change since the 1990s and before. The lifespan of a defence is typically of the order of 50 to 100 years although many defences are already 20 or more years old.

  There is therefore likely to be a need to continue to adapt the existing flood risk management systems for future change. The total length of flood defences is over 40,000 km in England and Wales alone and adaptation to reduce flood risk is likely to remain a significant policy challenge for Government.

- **Joined up decision making** – The socio-economic projections cause a large proportion of the change in risk in the analysis. There are already policies and guidance in place to manage flood risk through spatial planning and other measures. These provide a framework to control the potential increase in flood risk from socio-economic change in the future.

- **The drivers of risk** – 'Expected annual damage' provides a useful and widely used tool for exploring economic efficiency. However, it does not reflect the potential changing nature of the risks associated with climate and socio-economic changes and the changing public reaction to these risks. For example, significant events could become more widespread and more frequent, resulting in economic and social disruption that is not fully identified and/or measured using present methods.

Adaptive capacity/awareness in sector

Adaptive capacity provides a measure of the ability of the sector to adapt to climate change. It is considered in terms of 'structural adaptive capacity', which is the extent to which a system is free of structural barriers to change, and 'organisational adaptive capacity', which is the extent to which organisations can devise and implement adaptation strategies.

Adaptation measures are a common feature of new work undertaken in the Floods and Coastal Erosion sector. However, the main difficulty is that most of the flood risk (in terms of assets and people at risk) is already present on the floodplains. Adaptation of existing properties and infrastructure to reduce risk could be expensive and may have limited effectiveness in some cases. In addition, the costs of adapting existing flood defences and other flood risk management assets could also be high.

Adaptive capacity in the sectors is the subject of an investigation by Defra to be reported later in 2012.

About the analysis

Data limitations

There are a number of important limitations in the available data for the analysis including the following:

1. Most of the analysis is based on information for England and Wales, which is supported by quantified models. Suitable information for analysis was not available for Scotland and Northern Ireland, which together represent about 6% of the flood risk to the UK as a whole.

2. The analysis is generally based on tidal and river flooding. There is much less information available for surface water flooding which meant that it could not be covered by the analysis. In particular, no information was available on future projections of the consequences of surface water flooding.

Data Quality and Modelling Issues

The process followed in the analysis was to look at the current vulnerability of the UK to flood risk, and then project the consequences of climate change for a range of climate change scenarios in the 2020s (2010-39), 2050s (2040-69) and 2080s(2070-99). Government projections of population and property numbers were then applied to relevant consequences (for example, number of people at risk) to obtain future projections that take account of both potential climate change and socio-economic change.

The analysis used two approaches: the use of results from national flood modelling for England and Wales (undertaken by the Environment Agency) and the use of flood frequency information for assessing changes in the frequency of flooding for receptors that are not covered by the modelling (derived from UKCP09 for sea level rise and Kay *et al.*, 2010 for river flood flows).

The national flood modelling is the national approach that has been used to develop investment strategies for England and Wales. It covers England and Wales but not Scotland and Northern Ireland. These countries were therefore excluded from much of the analysis. Other sources of information (for example Shoreline and Catchment Management Plans) were not used because they are regional and not national.

The availability of data is a major constraint on the scope of the analysis that could be carried out. Key areas where suitable information was not available include future projections for surface water flooding, up-to-date coastal erosion estimates and the locations of some critical infrastructure (notably water treatment and sewage works).

Limitations of the analysis

The study is concerned with assessing the underlying change in flood risk due to climate change, so that comparisons can be made with other types of climate change risk. The baseline for the analysis includes the assumption that the existing defence system (in England and Wales) will be maintained at its current extent and, over the long term, maintained to its current condition.

This risk assessment therefore examines the potential changes in risk without any changes to existing flood risk management measures. This means that the projections given in this report do not include the risk reduction benefits of future adaptation measures or the increase in risk that would occur as existing flood risk management measures deteriorate.

The projections are therefore unlikely to be realised in practice because of the effects of adaptation policies, future measures to reduce flood risk and the effects of asset deterioration. The projections should therefore be interpreted as the increase in flood risk that would occur if no flood risk management measures were to be implemented other than operating and maintaining the existing defence system.

The reason that this approach was adopted was that it could not be stated with certainty what the effects of future flood risk management measures would be. This depends on a range of factors including availability of resources and potential future changes to policy. In addition, it was considered unreasonable to include defence deterioration in the analysis as this would lead to much higher projections of future risk that are unlikely to be realised in practice because of ongoing maintenance and repairs.

Great care is therefore needed in interpreting these results since they do not reflect current or future flood and coastal erosion risk management policies. The results are not *predictions* of what will happen and this should be borne in mind throughout the report.

However the risk assessment does provide a baseline against which to assess potential adaptation options.

Confidence in the results

Recent years have seen a marked improvement in the data and models for this type of study. In England and Wales in particular, the modelling approaches are beginning to mature and credible national estimates have been obtained. In Scotland and Northern Ireland the data is being assembled that would enable similar models to be developed.

The analysis is considered to provide robust projections of future change as the national models used in the analysis have been developed, tested and improved over a number of years. However, as with all modelling of this type, there are large uncertainties that mean these results should be treated as projections of plausible changes in risk to allow comparison of the relative size of risk from flooding to other climate driven risks considered in the CCRA. The results should not be considered as predictions of future change.

There are also large gaps in the analysis. Work is in progress to fill gaps in knowledge, particularly future risks from surface water flooding, and river and tidal flooding in Scotland and Northern Ireland.

There are a number of key assumptions in the analysis. In particular, this analysis is based on the assumption that the existing flood defences will be maintained in their present condition over the long term, but without improvement or raising the height of defences. This assumption is used in order to assess the underlying change in flood risk due to climate change only, which is not affected by changes in the extent and level of protection that may be provided by the flood defence system in the future or the effects of defence deterioration.

The analysis is considered to provide a good indication of the potential increase in risk, in order to aid a relative assessment across all sectors. However the calculated projections do not take account of future measures to reduce flood and coastal erosion risks or the effects of deterioration, and therefore should not be used for purposes other than the CCRA.

The indirect consequences of flooding including business disruption and health impacts have been addressed to some degree in the CCRA analysis, but this is an area where research could benefit future cycles of the CCRA. It is encouraging to see that relevant data is being collected and analyses carried out following recent flood events, for example July 2007 (Environment Agency 2010).

Acknowledgments

A list of contributors to the development of this report is provided in Appendix I. We wish to acknowledge the author of the costs assessment Chapter 7, Alistair Hunt of Metroeconomica.

Glossary

Adaptation (IPCC AR4, 2007)

- **Autonomous adaptation** – Adaptation that does not constitute a conscious[1] response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. Also referred to as spontaneous adaptation.

- **Planned adaptation** – Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.

Adaptive Capacity -The ability of a system to design or implement effective adaptation strategies, to adjust to information about potential climate change (including climate variability and extremes), to moderate potential damage, to take advantage of opportunities, or to cope with the consequences (modified from the IPCC to support project focus on management of future risks). As such this does not include the adaptive capacity of biophysical systems.

Adaptation costs and benefits

- The costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs.

- The avoided damage costs or the accrued benefits following the adoption and implementation of adaptation measures.

Consequence - The end result or effect on society, the economy or environment caused by some event or action (e.g. economic losses, loss of life). Consequences may be beneficial or detrimental. This may be expressed descriptively and/or semi-quantitatively (high, medium, low) or quantitatively (monetary value, number of people affected etc).

Impact - An effect of climate change on the socio-bio-physical system (e.g. flooding, rails buckling).

Pluvial flooding – Surface water flooding.

Response function - Defines how climate impacts or consequences vary with key climate variables; can be based on observations, sensitivity analysis, impacts modelling and/or expert elicitation.

Risk - Defined as the probability multiplied by consequence. Ideally the probability and consequence would be quantified but a similar qualitative matrix can be used.

Sensitivity - The degree to which a system is affected, either adversely or beneficially, by climate variability or change.

Uncertainty - A characteristic of a system or decision where the probabilities that certain states or outcomes have occurred or may occur is not precisely known.

Vulnerability - Climate vulnerability defines the extent to which a system is susceptible to, or unable to cope with, adverse effects of climate change including climate

[1] The inclusion of the word 'conscious' in this IPCC definition is a problem for the CCRA and we treat this as anticipated adaptation that is not part of a planned adaptation programme. It may include behavioural changes by people who are fully aware of climate change issues.

variability and extremes. It depends not only on a system's sensitivity but also on its adaptive capacity.

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1 Introduction

1.1 Background

It is widely accepted that the world's climate is being affected by the increasing anthropogenic emissions of greenhouse gases into the atmosphere. Even if efforts to mitigate these emissions are successful, the Earth is already committed to significant climatic change (IPCC, 2007).

Over the past century, the Earth has warmed by approximately 0.7°C[2]. Since the mid-1970s, global average temperature increased at an average of around 0.17°C per decade[3]. UK average temperature increased by 1°C since the mid-1970s (Jenkins *et al.*, 2009), however recent years have been below the long-term trend highlighting the significant year-to-year variability. Due to the time lag between emissions and temperature rise, past emissions are expected to contribute an estimated further 0.2°C increase per decade in global temperatures for the next 2-3 decades (IPCC, 2007), irrespective of mitigation efforts during that time period.

The sorts of impacts expected later in the Century are already being felt in some cases, for example:

- Global sea levels rose by 3.3 mm per year (± 0.4 mm) between 1993 and 2007; approximately 30% was due to ocean thermal expansion due to ocean warming and 55% due to melting of land ice. The rise in sea level is slightly faster since the early 1990s than previous decades (Cazenave and Llovel, 2010).
- Acidification of the oceans caused by increasing atmospheric carbon dioxide (CO_2) concentrations is likely to have a negative impact on the many marine organisms and there are already signs that this is occurring, e.g. reported loss of shell weight of Antarctic plankton, and a decrease in growth of Great Barrier coral reefs (ISCCC, 2009).
- Sea ice is already reducing in extent and coverage. Annual average Arctic sea ice extent has decreased by 3.7% per decade since 1978 (Comiso *et al.*, 2008).
- There is evidence that human activity has doubled the risk of a very hot summer occurring in Europe, akin to the 2003 heatwave (Stott *et al.*, 2004).

The main greenhouse gas responsible for recent climate change is carbon dioxide (CO_2) and CO_2 emissions from burning fossil fuels have increased by 41% between 1990 and 2008. The rate of increase in emissions has increased between 2000 and 2007 (3.4% per year) compared to the 1990s (1.0% per year) (Le Quéré *et al.*, 2009). At the end of 2009 the global atmospheric concentration of CO_2 was 387.2 ppm (Friedlingstein *et al.*, 2010); this high level has not been experienced on earth for at least 650,000 years (IPCC 2007).

The UK government is committed to action to both mitigate and adapt to climate change[4] and the Climate Change Act 2008[5] makes the UK the first country in the world

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[2] Global temperature trends 1911-2010 were: HadCRUT3 0.8˚C/century, NCDC 0.7˚C/century, GISS 0.7˚C/century. Similar values are obtained if we difference the decadal averages 2000-2009 and 1910-1919, or 2000-2009 and 1920-1929.
[3] Global temperature trends 1975-2010 were: HadCRUT3 0.16˚C/decade, NCDC 0.17˚C/decade, GISS 0.18˚C/decade.
[4] http://www.defra.gov.uk/environment/climate/government/

to have a legally binding long-term framework to cut carbon emissions, as well as setting a framework for building the nation's adaptive capacity.

The Act sets a clear and credible long term framework for the UK to reduce its greenhouse gas (GHG) emissions including:

- A legal requirement to reduce emissions by at least 80% below 1990 levels by 2050 and by at least 34% by 2020.
- Compliance with a system of five-year carbon budgets, set up to 15 years in advance, to deliver the emissions reductions required to achieve the 2020 and 2050 targets.

In addition it requires the Government to create a framework for building the UK's ability to adapt to climate change and requires Government to:

- Carry out a UK wide Climate Change Risk Assessment (CCRA) every five years.
- Put in place a National Adaptation Programme for England and reserved matters to address the most pressing climate change risks as soon as possible after every CCRA.

The purpose of this first CCRA is to provide underpinning evidence, assessing the key risks and opportunities to the UK from climate change, to identify priorities for action and to implement climate adaptation policies for current and future policy development as part of the statutory National Adaptation Programme which will begin from 2012. The CCRA will also inform devolved Administrations' policy on climate change mitigation and adaptation.

Climate Change Act: First 5 year Cycle

The Scope of the CCRA covers an assessment of the risks and opportunities to those things which have social, environmental and economic value in the UK, from the current climate and future climate change, in order to help the UK Government and Devolved Administrations identify priorities for action and implement necessary adaptation measures. The Government requires the CCRA to identify, assess, and where possible estimate economic costs of the key climate change risks and opportunities at UK and national (England, Wales, Scotland, Northern Ireland) level. The outputs from the CCRA will also be of value to other public and private sector organisations that have a stake in the sectors covered by the assessment.

The CCRA will be accompanied (in 2012) with a study on the Economics of Climate Resilience[6] (ECR) that will identify options for addressing some of the priority risks identified by the CCRA, and will analyse their costs and benefits. This analysis will provide an overall indication of the scale of the challenge and potential benefits from acting; and, given the wide-ranging nature of possible interventions, will help to identify priority areas for action by Government on a consistent basis.

This will be followed by statutory adaptation programmes implemented by the UK Government and for Scotland, Wales and Northern Ireland through the DAs. These national adaptation programmes will set out:

- objectives in relation to adaptation
- proposals and policies for meeting those objectives
- timescales

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[5] http://www.legislation.gov.uk/ukpga/2008/27/contents
[6] http://www.defra.gov.uk/environment/climate/government/

- an explanation about how those proposals and policies contribute to sustainable development.

The CCRA analysis has been split into eleven sectors to mirror the general sectoral split of climate impacts research; agriculture, biodiversity, business, built environment, energy, flooding, forestry, health, marine, transport and water.

1.2 Scope of the Floods and Coastal Erosion Sector Report

This Floods and Coastal Erosion Sector Report is one of the 11 Sector reports commissioned as part of the CCRA, which provide the underpinning evidence used in the development of the UK CCRA to be delivered to Parliament, as required by the Climate Change Act, by January 2012. Sector Reports include the main risks and opportunities identified within each sector, drawing from the information in other sector reports where relevant.

A list of climate change impacts in the Floods and Coastal Erosion sector was developed in consultation with sector specialists (the ‘Tier 1’ list of impacts). There were too many impacts to be analysed within the time and resources available for the CCRA, and a selection of impacts for analysis was made (the ‘Tier 2’ list).

This report covers the Tier 1 and Tier 2 lists, and the analysis undertaken to provide projections of the consequences of climate change. The analysis includes projections for climate change only and with socio-economic change. The economic impacts have also been assessed. This report also includes the results of analysis of flood related impacts carried out in other sectors in order to provide an overview of flood related impacts assessed in the CCRA as a whole. The relationship between this and other sectors is summarised in Table 1.1.

Table 1.1 Relationship between the Floods and Coastal Erosion sector and other sectors

Sector	Consequences of flooding	Consequences of coastal erosion
Marine and Fisheries	Damage and disruption in coastal areas (including ports)	Retreat of coastline: damage and disruption; exposure of geological and archaeological features, etc.
Biodiversity	Coastal squeeze; flood damage; waterlogging; enhancement opportunities	Habitat loss and gain.
Water	Flooding of water supply, distribution and treatment infrastructure	
Agriculture	Flooding of agricultural land; saline intrusion	Loss of land
Forestry	Waterlogging	
Health	Risks to people (death; injury; mental health)	
Built Environment and Ecosystem Services	Flood damage to buildings and the urban environment	Loss of property
Transport	Flooding of transport links: damage and disruption	Loss of transport links

Sector	Consequences of flooding	Consequences of coastal erosion
Energy	Flooding of energy generation and transmission infrastructure	Loss of infrastructure and damage (for example, exposure of buried pipelines)
Business, Industry and Services	Flooding of business and tourist assets; business disruption	Loss of business and tourist assets

1.3 Overview of the Floods and Coastal Erosion Sector

1.3.1 Introduction to the Floods and Coastal Erosion Sector

Floods and coastal erosion are already serious risks to the UK, and they are projected to increase as a result of climate change. The Floods and Coastal Erosion Sector covers the potential increase in flood and coastal erosion risk caused by climate change. The main sources of increases in flooding are:

- Tidal flooding, which is likely to increase due to sea level rise. Increased storminess and wave action may also contribute to an increase in flooding.
- River flooding, which is likely to increase due to increases in river flows caused by an increase in the amount and intensity of extreme rainfall, particularly in the winter.
- Surface water flooding (including sewer flooding). This covers direct runoff from rainfall and includes flooding from sewers. For the purposes of the analysis flooding from smaller watercourses that are not covered by available data for river flooding are also included. The increase in flooding is likely to be caused by an increase in the amount and intensity of extreme rainfall.
- Groundwater flooding, which is likely to increase due to an increase in winter rainfall leading to higher groundwater levels.
- Reservoir flooding. There is an increased risk of reservoir failure caused by the projected increase in flood water volumes and the impacts of drier summers on some reservoir structures.
- Increased flooding caused by combinations of flooding from different sources (for example, the combination of sea level rise and river flows causing increases in the 'backwater' effect where rivers flow into the sea).

There is overlap between these sources of flooding, particularly river, surface water and groundwater flooding which are all caused by precipitation. In addition, many areas are at risk of flooding from more than one of these sources.

There are about 2.8 million properties at risk of tidal and river flooding in the UK and about 4.2 million properties at risk of surface water flooding. Some of these properties are at risk from more than one source, and the overall number of properties at risk from tidal, river and surface water flooding in the UK is estimated to be about six million. Other sources of flooding are also significant, particularly groundwater.

Flooding from rivers and the sea

The total numbers of properties at risk of flooding from rivers and the sea in the UK are as follows:

- 2.4 million in England (Environment Agency 2009)
- 220,000 in Wales (Environment Agency Wales, 2009)
- 100,000 in Scotland (or 4% of properties, BBC News 10 September 2007)
- 60,000 in Northern Ireland (Rivers Agency, 2008).

The total number of people in the UK who live in areas at risk of flooding from rivers or the sea is estimated to be about 6 million, or 10% of the total population.

The Expected Annual Damage (EAD) to residential and non-residential properties in England as a result of flooding from rivers or the sea is estimated at more than £1.2billion (Environment Agency, 2009). This includes damage to property and contents but could be significantly higher if indirect and intangible losses are included.

The area of agricultural land (Grades 1 to 3) at risk of flooding is about 1,100,000 ha (11,000 km^2) (Defra, 2010c). This is 13% of the total area of these grades nationally (about 8,400,000 ha or 84,000 km^2). Perhaps most interestingly, but not surprisingly, 56% of the highest-value land (Grade 1) is at risk from flooding.

Infrastructure at risk of river and tidal flooding in England and Wales includes the following:

- About 10% of all major roads (4,600km)
- About 950 water treatment works and pumping stations, about 60% of the overall total
- About 15% of power generation capacity (10GW)
- About 5,600 police, fire and ambulance stations, about 14% of the overall total.

Surface water flooding

The total number of properties in England at risk of surface water flooding is estimated to be about 3.8 million. One million of these properties are also at risk from river and tidal flooding. The total number of properties at risk of tidal and river flooding is about 2.4 million, and therefore the total number of properties in England at risk of flooding from rivers, the sea and surface water is about 5.2 million.

In Wales the total number of properties at risk of surface water flooding is estimated to be about 230,000. Nearly 100,000 of these properties are also at risk from river and tidal flooding. The total number of properties at risk of tidal and river flooding is about 220,000, and therefore the total number of properties in Wales at risk of flooding from rivers, the sea and surface water is about 350,000. Less is currently known about surface water flooding in Northern Ireland or Scotland but plans are in hand to develop national surface water flood maps in both countries.

The economic risk associated with surface water flooding remains unclear but the EAD is estimated to be around £0.5billion within the UK (England, Wales, Scotland and Northern Ireland – Evans *et al.*, 2004). Whilst the property numbers are similar to those for tidal and river flooding, the EAD is likely to be lower because surface water flooding is generally shallower.

About 40% of flood damage due to surface water flooding is due to short duration rainfall (1 to 6 hours), and 80% of recent floods were due to surface water (Collier, 2009).

Coastal erosion

The length of coastline that is eroding in the UK is estimated to be about 3,000km, or 17% of the overall length. The EAD was estimated in 2004 as £14.4m (Evans *et al.*, 2004a).

Whilst coastal erosion presents a relatively small risk in terms of people and assets affected, there are potentially major impacts on coastal habitats. It is estimated that there are about 32,000 ha (320 km^2) of coastal freshwater habitats within designated sites that are at risk of inundation by the sea.

1.3.2 Consequences of flooding and coastal erosion

Potential drivers of flooding include high rainfall and river flows, high tide and surge levels, high wave heights and high groundwater levels. In recent years, there have been a number of different floods that have demonstrated the wide range of consequences that floods can have. These include the extreme river flooding of Easter 1998, the flash flood at Boscastle in 2004, the widespread floods of autumn 2000, the widespread summer floods of 2007 and the Cumbria floods of 2009.

Potential drivers of coastal erosion include storms, high tide and surge levels and high wave heights. Whilst the overall impacts of erosion are less than for floods, parts of the coastline have severe erosion problems and, once land is lost, it cannot be recovered.

The consequences of flooding and coastal erosion include the following:

- ***Impacts on people*** – The severe impacts on people who have been flooded have been well documented in recent years. The resulting stress and disruption can affect every aspect of their lives with knock-on effects on employment, health and welfare.
- ***Risk to life*** – Coastal flooding, and in particular violent wave overtopping of sea frontages, is a regular cause of death. Drowning, hypothermia or being knocked over during fluvial flood events are also significant risks.
- ***Risk to health*** – Flooding can affect the physical and mental health of people, particularly those who have had their homes flooded. Flooding can also lead to outbreaks of disease.
- ***Damage to properties*** – Flooding can cause extensive damage to all types of properties which can require months (or in some cases years) to fully repair. Coastal erosion can lead to the complete destruction of vulnerable properties.
- ***Damage to the contents of buildings*** – In addition to damage to properties, the contents can be damaged or destroyed. This can include both replaceable and irreplaceable items.
- ***Costs of emergency response*** - Flooding can place a major burden on the emergency services. Figure 1.1 shows costs associated with the autumn 2000 floods.

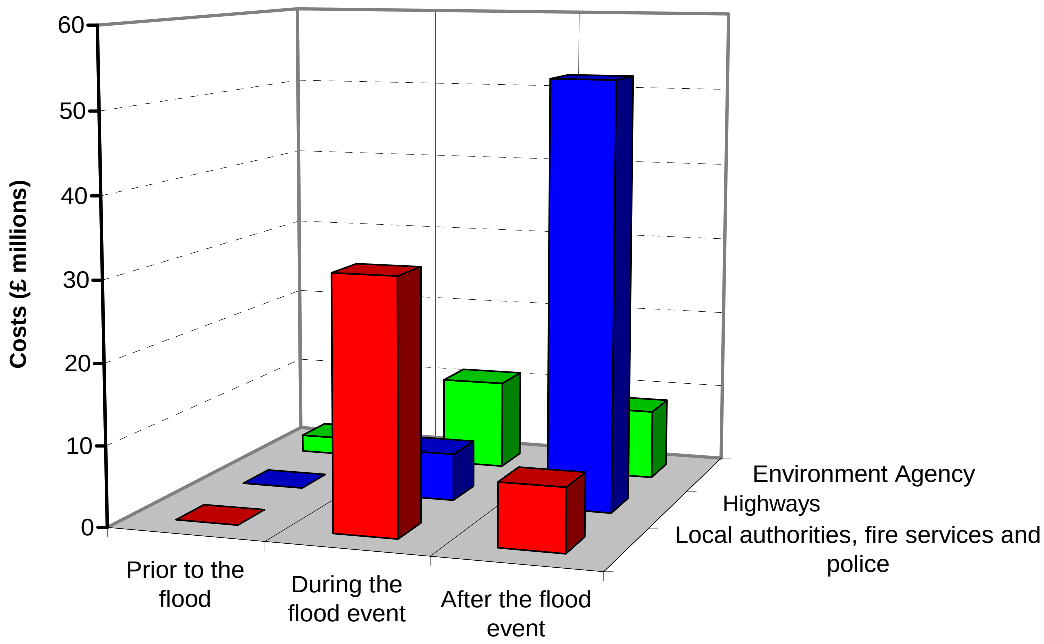


Figure 1.1 Costs incurred during autumn 2000 floods in the UK

Source: Penning-Rowsell *et al.* (2002)

- ***Impacts on business*** – Flooding can have major impacts on business including damage to business premises and disruption to business activities and supply chains. Coastal tourism is particularly vulnerable to coastal flooding and erosion. Insurance and mortgage provision are both directly affected by flood risk to properties.

- ***Agricultural impacts*** - Depending on timing, flooding can have major negative consequences on agricultural production and, potentially through changes to the frequency of flooding, can lead to changes to the grade of agricultural land. Table 1.2 shows the extent of flood risk to agricultural land in England and Wales (Defra 2010c).

Table 1.2 Area of agricultural land in England and Wales at risk of river and tidal flooding

(Source: Defra, 2010c[7])

Agricultural Land Grade	Total area in England & Wales (ha)	Area prone to flooding (ha)	Percentage of land grade	Percentage of land at risk
1	334,800	188,400	56	10
2	1,790,300	311,000	17	17
3	6,246,300	591,000	9	31
4	2,556,700	318,400	12	17
5	1,722,400	49,600	3	3
Total	12,650,500	1,458,500		100

[7] This project used Agricultural Land Classification (1974) and the Land Cover Map (2000) to calculate the baseline amount of agricultural land and hence, these figures may differ slightly from the most up-to-date measurements in the Agricultural and Horticultural Survey June 2011.

- ***Habitats and species*** - Depending on timing, flooding can have a major impact on the nature of a particular habitat and the species it supports. Coastal erosion and evolution can have both adverse and positive impacts on marine and freshwater habitats on the coast.

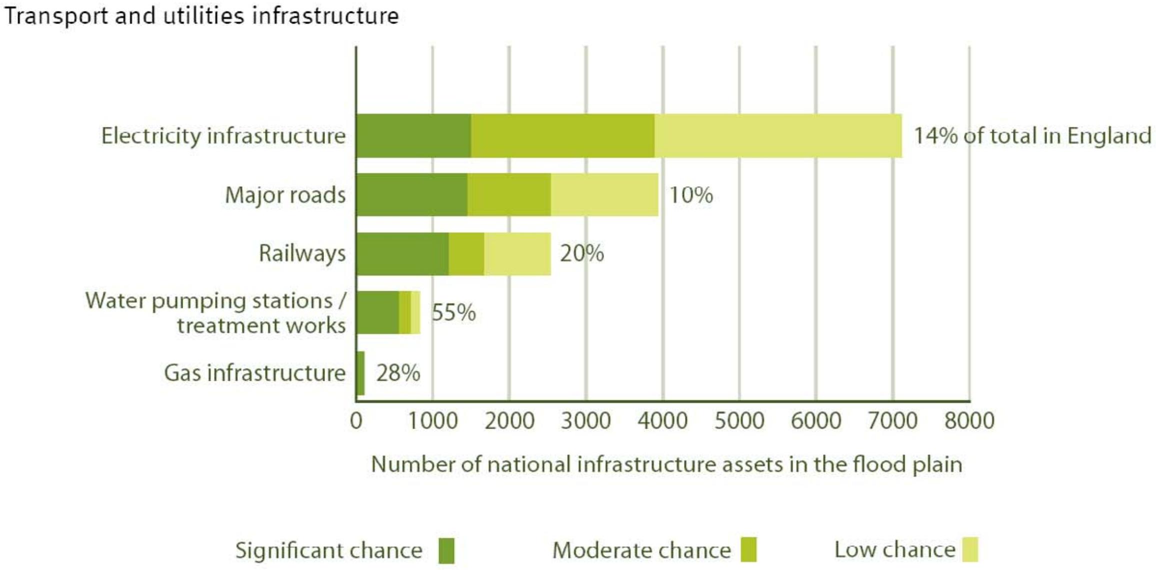
- ***Critical infrastructure*** - Flooding can affect critical infrastructure including power generation and distribution, water supply and treatment, communications including Information and Communications Technologies (ICT), health facilities, social facilities (including schools) and transport infrastructure (including roads, rail, ports and airports). Not only does this include direct damage, but also the indirect impacts of the loss of services. For example, severe failures of water and power supplies occurred in 2007. Figure 1.2 shows the percentage of infrastructure at risk of flooding in England.

- ***Heritage*** – Flooding can have very severe impacts on heritage sites because of the often high cost of repairing damage to historic buildings and landscapes.

- ***Coastal erosion and evolution*** – In addition to the impacts on buildings and habitats referred to above, coastal erosion can threaten whole communities, beyond those properties lost to the sea.

- ***Secondary impacts*** – There is a wide range of potential secondary or indirect impacts of flooding, for example the release of hazards such as pollutants or hazardous wastes into the environment.

The costs of flooding include both direct damage and indirect costs such as business disruption and costs to the emergency services and local authorities. For example the economic losses from the July 2007 floods were estimated to be £3,200 million (Environment Agency, 2010).



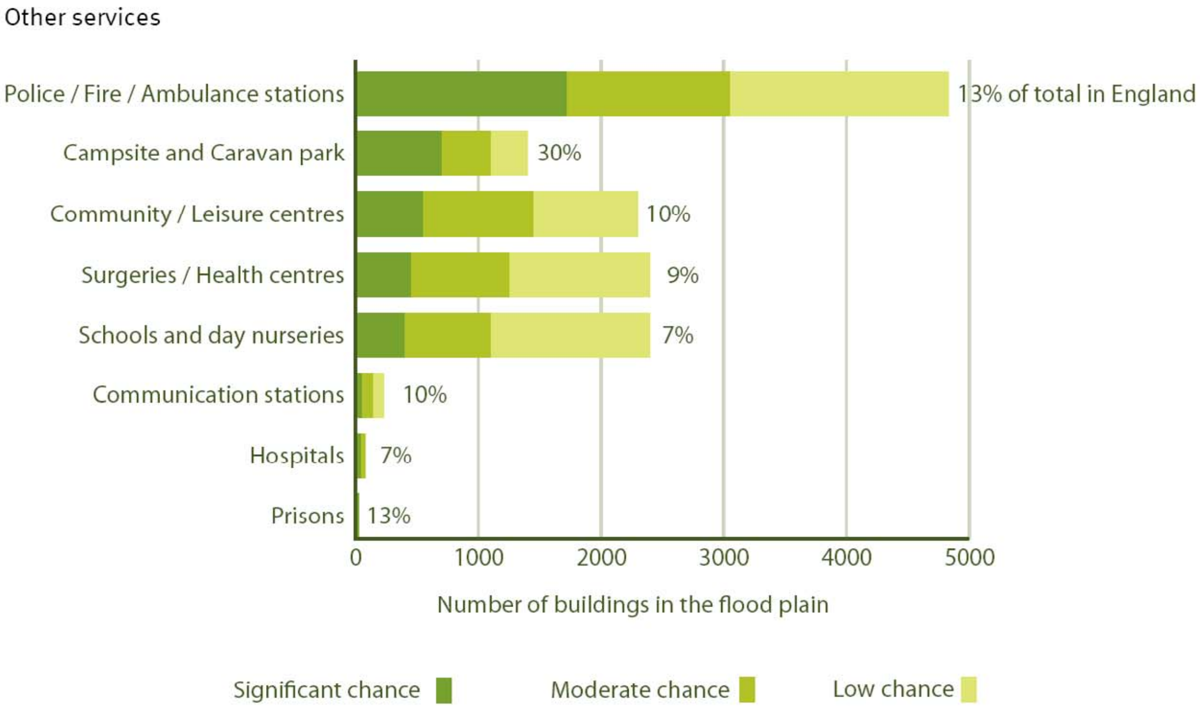


Figure 1.2 Percentage of infrastructure at risk from river and tidal flooding in England

(Source: Environment Agency, 2009)

1.4 Policy context

1.4.1 Current policy and governance structure

In the UK flood and coastal erosion risk management policy and the allocation of national resources are the responsibility of central government. The Department for Environment Food and Rural Affairs (Defra) is the responsible Government department in England. The Scottish Government, the Welsh Government and the Northern Ireland Executive have these responsibilities in their respective Devolved Administrations.

The following Government agencies have oversight of the delivery of flood and coastal erosion risk management:

- Environment Agency in England
- Environment Agency (Wales) in Wales
- Scottish Environmental Protection Agency (Scotland)
- Rivers Agency (Northern Ireland).

These agencies work in collaboration with other organisations in accordance with the requirements of legislation in each country. In England, Wales and Scotland local authorities have particular responsibilities for managing local flood risk and for coastal protection, although their exact roles differ from country to country. In Scotland, Scottish Water has particular responsibilities for surface water and sewer flooding.

There have been major changes in flood and coastal erosion risk management policy and legislation in recent years, most notably in England and Wales through the Flood and Water Management Act 2010, in Scotland through the Flood Risk Management (Scotland) Act 2009 and at EU level through the Floods Directive, which requires a plan led approach to flood risk management.

There have also been changes in the overall approach following major flood events that have caused serious damage and disruption, particularly in autumn 2000 and summer 2007. Reviews of these and other flood events have led to new policies, legislation and guidance being implemented. This includes Sector Resilience Plans that set out the current level of resilience of critical infrastructure to natural hazards.

Climate change has been taken into account in flood and coastal erosion risk management legislation, policy and guidance for several years, and the concept of responding to a changing climate is well established. For example, allowances for climate change in the planning of new capital works have been applied since the 1990s. The impacts of climate change on flood risk are also taken into account by planning authorities in local planning decisions.

A summary of current legislation, policy and guidance for the Floods and Coastal Erosion Sector for the four UK countries is contained in Appendix 3.

1.4.2 Future shape of the sector

Recent changes in policy and legislation are leading to different approaches to flood and coastal erosion risk management. The intention is to improve sustainability and reduce the reliance on more and bigger defences. Whilst flood and coastal defences will continue to be needed, they are costly to construct and adapt.

Strategic flood and coastal erosion risk management planning will continue to develop under the requirements of the Floods Directive, providing strategic approaches to managing river basins and the coast. The process of identifying the need for flood risk management schemes based on this strategic approach will continue to mature.

All possible options for flood and coastal erosion risk management will be considered when developing new schemes. For a flood scheme these might include natural flood management measures (for example, maximising the use of natural floodplains), improving the flood resilience of properties, improving flood warning and raising public awareness, flood defences, or a combination of these measures. In England the new partnership approach to funding is likely to lead to more community involvement in flood and coastal resilience decision making.

There is also a move to raise public awareness of flood risk. Flood maps are already available on the internet and the number of people who will take their own precautions against flooding is likely to increase. The increase in knowledge of flood risk may further encourage this process, for example as better information on surface water and groundwater flooding becomes available.

Efforts to prevent new developments on floodplains in the spatial planning process are likely to continue. The amount of land that is known to be affected by flooding will increase as knowledge of flooding improves, particularly surface water and groundwater flooding.

Complete avoidance of development in flood risk areas is unlikely to be achievable. Large parts of many cities are in flood risk areas but have flood defences, for example London and Glasgow. New developments in these areas will continue although flood risk is likely to be taken into account in development design.

With regard to climate change adaptation, the general approach is likely to involve increasing the awareness of flood risk and the resilience of communities. Flood defences will continue to be adapted for future change but other approaches will be adopted where possible and appropriate.

1.4.3 Status of this report

This report provides estimates of the potential change in flood and coastal erosion risk due to climate change, so that comparisons can be made with other types of climate change risk. The results are to be used in the preparation of the CCRA report required by the Climate Change Act, which will provide an overview of the potential risks from climate change to the economy, the environment and society.

This report has no other purpose. It is not intended to provide information on how to adapt to future change. Long term investment scenarios that take account of climate change have been developed for England and Wales (LTIS, 2009, and Environment Agency Wales, 2010) and flood risk management planning is in progress in Scotland and Northern Ireland.

1.5 Structure of report

This report describes the methodological steps taken in the Floods and Coastal Erosion sector analysis and includes:

- An overview of the methods used for impact selection and analysis in the CCRA (Chapter 2)

- A list of impacts from floods and coastal erosion, referred to as the ‘Tier 1’ list (Section 3.1 and Appendix 2)
- The Tier 2 list of impacts and consequences, which are the impacts selected for analysis (Section 3.2 and Appendix 4)
- Consequences of flooding and coastal erosion analysed in other sectors that are included in this report (Section 3.4)
- Risk metrics used for the analysis (Section 3.5). These are measures of the consequences of climate change
- Climate change and socio-economic scenarios used for the analysis (Section 4.2)
- Data used for the analysis (Section 4.3)
- Approach to the analysis (Section 4.4)
- Key assumptions (Section 4.5)
- Flood frequency data (Section 4.6). This was used for some of the risk metrics
- Response functions for each risk metric (Section 4.7). These show how the metric values are affected by climate change and are used to calculate the magnitude of climate change consequences
- Calculation of the consequences of climate change for the selected risks and climate change scenarios (Chapter 5)
- Calculation of the consequences of climate change for some of the selected risks taking account of future socio-economic change (Chapter 6).
- Estimation of the economic impacts of climate change for the selected consequences (Chapter 7)
- Introduction to the adaptive capacity within the sector (Chapter 8)
- Discussion of the findings (Chapter 9)
- Conclusions (Chapter 10).

The report structure broadly follows the risk assessment steps described in Chapter 2. One consequence of this structure is that individual impacts are covered in different sections, as follows:

- Selection of impact – Chapter 3
- Response function for impact – Chapter 4
- Consequences of climate change ***only*** – Chapter 5
- Consequences of climate change ***and*** socio-economic change – Chapter 6
- Economic impacts – Chapter 7.

Additional information is contained in Appendices including the numerical results for the analysis carried out in this sector (Appendix 8).

2 Methods

2.1 Introduction: CCRA Framework

The overall aim of the CCRA is to inform UK adaptation policy in 2012, by assessing the current and future risks (threats and opportunities) posed by climate change for the UK to the year 2100. The overall approach to the risk assessment and subsequent adaptation plan is based on the UK Climate Impacts Programme (UKCIP) Risk and Uncertainty Framework (UKCIP, 2003). The framework comprises eight stages as shown in Figure 2.1. The CCRA has undertaken the Stages 1, 2 and 3 as outlined below. Stages 4 and 5 will be addressed as part of a separate economic assessment of climate adaptation and the remaining stages will be implemented by the UK Government and Devolved Administrations. The framework presents a continual process that can adapt as new evidence and policy emerges; in the case of the CCRA the process will be revisited every five years.

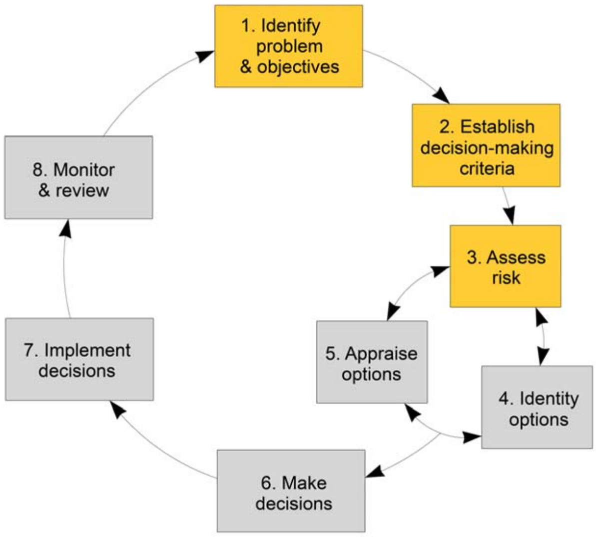


Figure 2.1 Stages of the CCRA (yellow) and other actions for Government (grey)

Adapted from UKCIP (2003).

- Stage 1 is defined by the aim of the CCRA project, to undertake an assessment of the risks (including both threats and opportunities) posed by climate change that may have social, environmental and economic consequences for the UK.
- Stage 2 established decision-making criteria for the study, which were used to inform the selection of impacts for analysis in Stage 3. These criteria are the social, environmental and economic magnitude of consequences and the urgency of taking adaptation action for UK society as a whole.
- Stage 3 covers the risk assessment process. This involved a tiered assessment of risks with Tier 1 (broad level) identifying a broad range of potential impacts and Tier 2 (detailed level) providing a more detailed analysis including quantification and monetisation of some risks. A list of climate change impacts was developed based on eleven sectors with

further impacts added to cover cross-cutting issues and impacts which fell between sectors. This list of climate change impacts is referred to as the **'Tier 1' list of impacts**. This list contained over 700 impacts – too many to analyse in detail as part of this first CCRA. A consolidated list of the highest priority climate change impacts for analysis was developed and referred to as the **'Tier 2 list of impacts'**. This report presents the risk assessment for Tier 2 impacts.

The background to the framework and the approach used for each of the first three stages is set out in more detail in the CCRA Method Report (Defra, 2010a). This chapter aims to summarise the CCRA method for the risk assessment stage (Stage 3 in the framework above) because this includes the specific steps for which results are presented in this report.

2.2 Outline of the method used to assess impacts, consequences and risks

The risk assessment presented in this report is the focus of Stage 3 in the CCRA Framework (see Figure 2.1). This was done through a series of steps as set out in Figure 2.2. These steps are explained in Sections 2.3 - 2.7 below and are discussed in more detail in the CCRA Method report for Stage 3 (Defra, 2010b).

The components of the assessment sought to:

- **Identify and characterise the impacts** of climate change

  This was achieved by developing the Tier 1 list of impacts, which included impacts across eleven sectors as well as impacts not covered by the sectors and arising from cross sector links (see Section 3.1 of this report).

- **Identify the main risks** for closer analysis

  This involved the selection of Tier 2 impacts for further analysis from the long list of impacts in Tier 1. Higher priority impacts were selected by stakeholder groups based on the social, environmental and economic magnitude of impacts and the urgency of taking action (see Section 3.2 of this report and Section 2.5 below).

- **Assess current and future risk**, using climate projections and considering socio-economic factors

  The risk assessment was done by developing 'response functions' that provide a relationship between changes in climate with specific consequences based on analysis of historic data, the use of models or expert elicitation. In some cases this was not possible, and a narrative approach was taken instead. The UKCP09 climate projections and other climate models were then applied to assess future risks. The potential impact of changes in future society and the economy was also considered to understand the combined effects for future scenarios (See Chapters 4 to 6 of this report and Section 2.6 below).

- **Assess vulnerability** of the UK as a whole

  This involved:

  i. a high level review of Government policy on climate change in the eleven sectors (see Chapter 1 of this report)

ii. a high level assessment of the social vulnerability to the climate change impacts (see Appendix 6 of this report)

iii. an assessment of the adaptive capacity of the sectors. The results of this assessment are due to be published later in 2012.

- **Report on risks** to inform action

  This report presents the results of the risk assessment for the Floods and Coastal Erosion sector. The results for the other ten sectors are presented in similar reports and the CCRA Evidence Report (CCRA, 2012) draws together the main findings from the whole project, including consideration of cross-linkages, and outlines the risks to the UK as a whole.

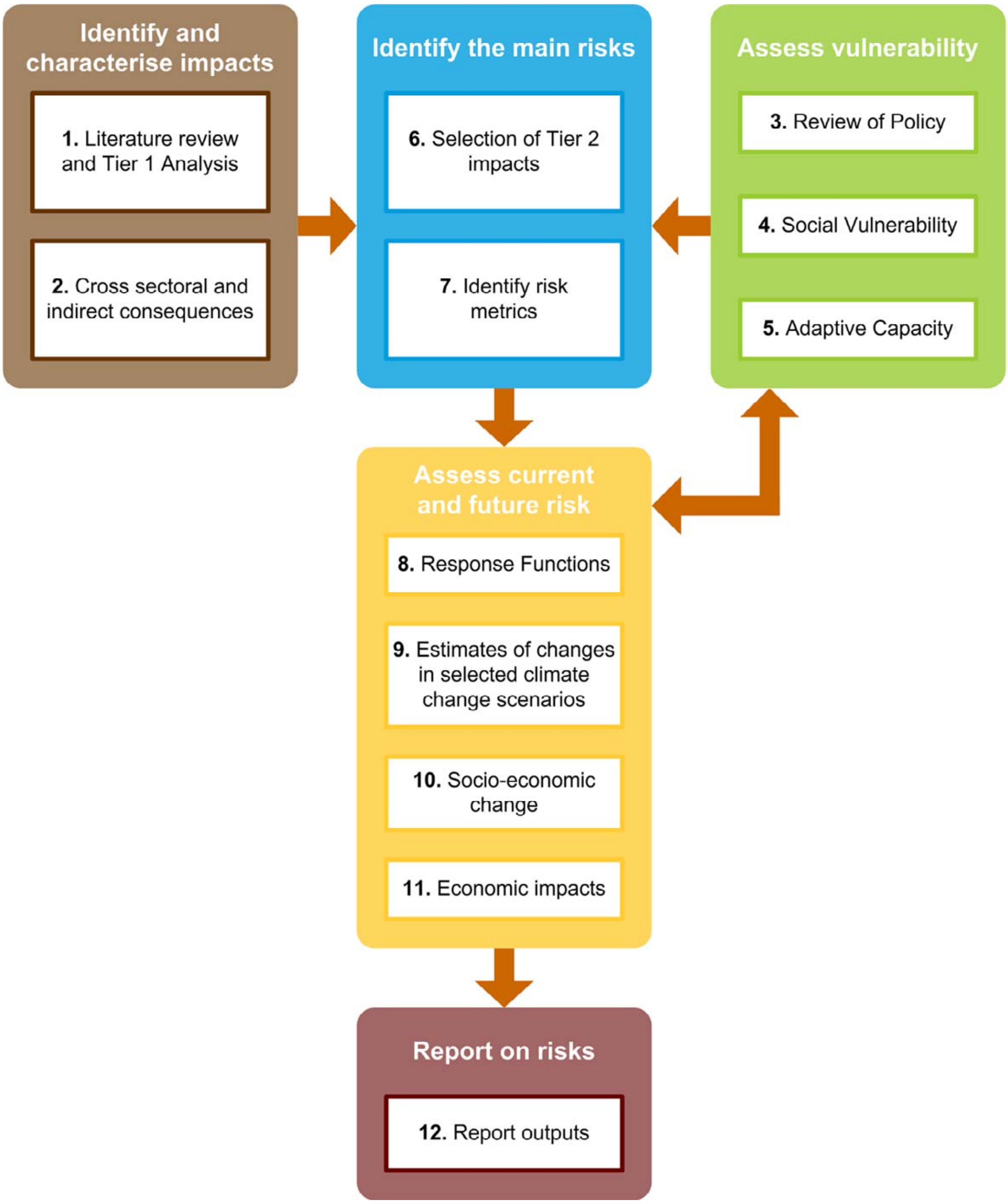


Figure 2.2 Steps of the CCRA Method (that cover Stage 3 of the CCRA Framework: Assess risks)

2.3 Identify and characterise the impacts

Step 1 – Literature review and Tier 1 analysis

This step scoped the potential impacts of climate change on the UK based on existing evidence and collating the findings from literature reviews, stakeholder participation through workshops, correspondence with wider stakeholders and soliciting expert opinion. This work developed the Tier 1 list of impacts (see Appendix 2). The Tier 1 impacts have not been analysed in detail; high level discussion of these impacts is provided in Chapter 3 of this report.

Step 2 – Cross-sectoral and indirect impacts

The Tier 1 lists for the eleven sectors in CCRA were compared and developed further to include cross-sectoral and indirect impacts. This was done by 'Systematic Mapping', which sets out a flow chart to link causes and effects in a logical process. The impacts that were identified in this step were added to the Tier 1 list of impacts.

2.4 Assess vulnerability

Step 3 – Review of Policy

Government policy on climate change develops and changes rapidly to keep pace with emerging science and understanding of how to respond through mitigation and adaptation. This report includes an overview of selected relevant policy in Chapter 1 as this provides important context for understanding how risks that are influenced by climate relate to existing policies. This information will be expanded in the Economics of Climate Resilience project and the National Adaptation Programme.

Step 4 – Social Vulnerability

The vulnerability of different groups in society to the climate change risks for each sector was considered at a high level through a check list. The completed check list for the Floods and Coastal Erosion sector is provided in Appendix 6. This information is provided for context; it is not a detailed assessment of social vulnerability to specific risks. Note that this step is different from Step 10, which considers how future changes in society may affect the risks.

Step 5 – Adaptive Capacity

The adaptive capacity of a sector is the ability of the sector as a whole, including the organisations involved in working in the sector, to devise and implement effective adaptation strategies in response to information about potential future climate impacts. The adaptive capacity of the Floods and Coastal Erosion Sector is subject to an investigation that will be reported on later in 2012.

2.5 Identify the main risks

Step 6 – Selection of Tier 2 impacts

The Tier 1 list of impacts for each sector that resulted from Step 2 (see above) was consolidated to select the higher priority impacts for analysis in Tier 2. Firstly, similar or overlapping impacts were grouped where possible in a simple cluster analysis, which is provided in Chapter 3. Secondly, the Tier 2 impacts were selected using a simple multi-criteria assessment based on the following criteria:

- the social, economic and environmental magnitude of impacts
- overall confidence in the available evidence
- the urgency with which adaptation decisions needs to be taken.

Each of these criteria were allocated a score of 1 (low), 2 (medium) or 3 (high) and the impacts with highest scores over all criteria were selected for Tier 2 analysis. The scoring for each sector was carried out based on expert judgement and feedback from expert consultation workshops (or telephone interviews). Checks were carried out to ensure that a consistent approach was taken across all the sectors. The results of the scoring process are provided in Appendix 5.

Step 7 – Identifying risk metrics

For each impact in the Tier 2 list, one or more risk metrics were identified. Risk metrics provide a measure of the consequences of climate change, related to specific climate variables or biophysical impacts. For example, one of the impacts identified is 'flooding of roads'. The risk metric that was identified to measure the consequences of this impact was length of road flooded with an annual frequency of 1.3% (once in 75 years on average). The risk metrics were developed to provide a spread of information about economic, environmental and social consequences. The metrics have been referenced using the sector acronym and a number; the Floods and Coastal Erosion Sector metrics are referenced as FL1 to FL15.

2.6 Assess current and future risk

Step 8 – Response functions

This step established how each risk metric varied with one or more climate variables using available data or previous modelling work. This step was only possible where evidence existed to relate metrics to specific climate drivers, and has not been possible for all of the tier 2 impacts. This step was carried out by developing a 'response function', which is a relationship to show how the risk metric varies with change in climate variables. Some of the response functions were qualitative, based on expert elicitation, whereas others were quantitative.

Step 9 – Estimates of changes in selected climate change scenarios

The response functions were used to assess the magnitude of consequences the UK could face due to climate change by making use of the UKCP09 climate projections. This step used the response functions to provide estimates of future risk under three different emissions scenarios (high carbon emissions, A1FI; medium emissions, A1B; low emissions, B1; see http://ukclimateprojections.defra.gov.uk/content/view/1367/687/ for further details) and three future 30-year time periods (centred on the 2020s, 2050s and 2080s) for three probability levels (10, 50 and 90 percent, see http://ukclimateprojections.defra.gov.uk/content/view/1277/500/ for further details), associated with single or combined climate variables. The probability levels are cumulative and denote the degree of confidence in the change given; for example 90% suggests that it is thought very unlikely that the change will be higher than this; 50% suggests that it is thought equally likely that the change will be higher or lower than this; and 10% suggests that it is thought very unlikely that the change will be lower than this. 90% does not mean that the change is 90% likely to occur, for example.

All of the changes given in the UKCP09 projections are from a 1961-1990 baseline.

The purpose of this step is to provide the estimates for the level of future risk (threat or opportunity), as measured by each risk metric.

Step 10 – Socio-economic change

It is recognised that many of the risk metrics in CCRA are influenced by a wide range of drivers, not just by climate change. The way in which the social and economic future of the UK develops will influence the risk metrics. Growth in population is one of the major drivers in influencing risk metrics and may result in much larger changes than if the present day population is assumed. For some of the sectors where this driver is particularly important, future projections for change in population have been considered to adjust the magnitude of the predicted risks derived in Step 9.

For all of the sectors, a broad consideration has been made of how different changes in our society and economy may influence future risks and opportunities. The dimensions of socio-economic change that were considered are:

- Population needs/demands (high/low)
- Global stability (high/low)
- Distribution of wealth (even/uneven)
- Consumer driven values and wealth (sustainable/unsustainable)
- Level of Government decision making (local/national)
- Land use change/management (high/low Government input).

The full details of these dimensions and the assessment of the influence they have on the Floods and Coastal Erosion Sector is provided in Section 6.3. Note that this step is different from Step 4, which considers how the risks may affect society; whereas this step considers how changes in society may affect the risks.

Step 11 – Economic impacts

Based on standard investment appraisal approaches (HM Treasury, 2003) and existing evidence, some of the risks were expressed as monetary values. This provides a broad estimate of the costs associated with the risks and is presented in Chapter 7 of this report. A more detailed analysis of the costs of climate change will be carried out in a study on the Economics of Climate Resilience[8].

2.7 Report on risks

Step 12 – Report outputs

The main report outputs from the work carried out for the CCRA are:

- The eleven sector reports (this is the sector report for the Floods and Coastal Erosion Sector), which present the overview of impacts developed from Tier 1 and the detailed risk analysis carried out in Tier 2.
- The Evidence Report, which draws together the main findings from all the sectors into a smaller number of overarching themes.
- Reports for the Devolved Administrations for Scotland, Wales and Northern Ireland to provide conclusions that are relevant to their country.

3 Scoping of Impacts

3.1 The Tier 1 list of impacts

Flooding occurs from several sources including rivers, surface water, ground water and the sea. Climate change is projected to cause changes in the amount of flooding in the future. The main climate change effects that are likely to cause increases in flooding are sea level rise and increased precipitation (both amount and intensity).

Section 1.3.2 lists the main consequences of flooding. The consequences of flooding can be direct or indirect: flooding of water treatment works is a direct impact but the disruption to water supplies that this causes is an indirect impact.

A long list of the impacts of climate change on flooding and coastal erosion was developed and reviewed at the sector workshop of 24 May 2010 (HR Wallingford, 2010b). Additional impacts identified at the workshop were added to the original list of impacts identified from the sector scoping report (HR Wallingford, 2010a). The updated list is referred to as the 'Tier 1' list of impacts and is contained in Appendix 3. The main impacts and consequences are summarised in this section.

The Tier 1 list contains 48 impact of flooding. Many of these could be 'clustered' together, and the main clusters include the three sources of flooding that cause the greatest amount of flood damage: river flooding, tidal flooding and surface water flooding.

The main consequences of flooding from these sources include damage to property, agriculture, transport and other services. Vulnerable people (for example the elderly, the young and the socially deprived) are particularly affected by flooding as they have a relatively low capacity to respond and cope. Flooding can also cause water contamination, particularly sewer flooding.

Agricultural impacts include direct flooding of land and increases in the frequency of flooding (which affects land use). Agricultural land is also affected by waterlogging. Saline intrusion may also increase in coastal floodplains as a result of sea level rise.

Flooding of critical infrastructure (including water supply, energy supply, communications and emergency services) can have widespread indirect consequences, for example if water or electricity supplies are cut off.

An increase in flood risk would put pressure on home insurance premiums. It may lead to a situation where increasing numbers of insurers are unwilling to offer cover for flooding in high risk areas.

Indirect consequences of flooding include social and business disruption. The knock-on effects of the loss of services, transport disruption and disruption to businesses can be very widespread affecting, for example, employment and supply chains for businesses.

Coastal erosion has much less widespread consequences than flooding, but the local economic and social consequences can be far more serious. Buildings and infrastructure can be damaged beyond repair or completely destroyed as land is permanently lost.

The environmental consequences of increases in coastal flooding and erosion include losses of intertidal habitats due to coastal squeeze and inundation of freshwater

[8] http://www.defra.gov.uk/environment/climate/government/

habitats by saline water. Changes on the coast are however difficult to predict because of the complexity of the processes including changes in sediment supply, wave energy and other factors.

Some of the main direct and indirect consequences of flooding are summarised in Table 3.1. It is apparent from the table that the consequences of flooding from different sources are similar. However there are differences, for example tidal flood water is saline and floodwater from combined sewers is polluted by sewage.

Table 3.1 Summary of the main consequences of flooding

Biophysical impacts	Consequences		
	Economic	**Social**	**Environmental**
Direct consequences			
Tidal flooding	Property (residential and business); agriculture; transport; services	People flooded; health; resettlement; demands on emergency services	Coastal habitats
River flooding	Property (residential and business); agriculture; transport; services	People flooded; health; resettlement; demands on emergency services	River habitats
Surface water (including sewer) flooding	Property (residential and business); agriculture; transport; services	People flooded; health; demands on emergency services	Contamination
Groundwater flooding	Property (residential and business); agriculture; transport; services	People flooded; health; demands on emergency services	
Coastal squeeze - Loss of inter-tidal areas			Loss of habitat
Coastal erosion	Property; transport; services; agricultural land	Loss of homes, buildings and infrastructure	Damage and loss of coastal habitats
Indirect consequences			
Damage to critical infrastructure	Disruption to services	Disruption to services	
Cost and availability of flood insurance	Properties not insured; business failure	Financial loss; mental stress	

3.2 Selection of Tier 2 impacts

With the time and resources available for the CCRA, it simply would not have been possible to undertake a detailed analysis of all of the Tier 1 risks (which numbered over 700 for all sectors), and so a selection process was carried out.

The method developed for selecting the most important impacts is set out in the CCRA Method Report (Defra 2010b) and initially involves scoring each of the impacts. Some of the impacts are very similar and therefore the impacts were clustered into groups before the scoring exercise was carried out.

Scores for the magnitude of the consequences (economic, social and environmental), likelihood of the impact occurring and urgency with which a decision needs to be made were combined to give an overall score for each impact.

The list of high scoring impacts was then modified using feedback from the sector workshop. This included taking account of the most important impacts identified by participants at the workshops. The resulting list of the selected impacts from climate change is referred to as the 'Tier 2' list.

A list of the clustered impacts together with scores for the Floods and Coastal Erosion sector is given in Appendix 4. The list shows the impacts in each cluster. Appendix 4 also shows the Tier 2 impacts with reasons for their selection. The Tier 2 list includes the following:

- Coastal flooding
- Tidal flooding
- River flooding
- Surface water flooding
- Coastal squeeze
- Coastal erosion
- Flooding of critical infrastructure
- Insurance availability.

The Tier 2 impacts identified by this process consist of a mixture of biophysical impacts and consequences. The biophysical impacts include the main sources of flooding and the main natural processes associated with erosion and evolution of the coastline. The consequences include flooding of critical infrastructure and insurance.

It was decided to focus the analysis on the main consequences of flooding and coastal evolution including people, property, infrastructure and habitats. The consequences selected for analysis and their relationship with the Tier 2 impacts are listed in Table 3.2. Many of the consequences affect other sectors, reflecting the cross-sectoral nature of the Floods and Coastal Erosion sector.

Table 3.2 Floods and Coastal Erosion Sector – Tier 2 impacts and consequences

Consequences	Biophysical impacts of climate change on the Tier 2 list:			
	Tidal/ coastal flooding	River flooding	Surface water flooding	Coastal evolution
People affected by flooding				
Vulnerable people affected by flooding				
Impact of flooding and on agriculture				
Properties affected by flooding				
Flooding of roads and rail				
Flood damage to critical infrastructure: water distribution and treatment				
Flood damage to critical infrastructure: energy generation and distribution				
Flood damage to critical infrastructure: health and education facilities				
Insurance costs for residential properties (indirect consequence)				
Loss of land due to coastal erosion (including agriculture and habitats)				

In the analysis ‘tidal’ and ‘coastal’ flooding are combined, and referred to throughout as ‘tidal flooding’.

A number of the other Tier 1 impacts were considered for the Tier 2 analysis but were not included because their score was not high enough or because they were analysed in other sectors. Those impacts that fall into this category in the Floods and Coastal Erosion sector are:

- Coastal squeeze (analysed in the biodiversity sector). This refers to the reduction in area of intertidal habitats on coasts and estuaries as the sea level rises.
- Loss of natural resilience and ecosystem function (analysed in the biodiversity sector). This refers to a cluster of potential impacts on freshwater and marine habitats that could be caused by climate change.
- Inland erosion and accretion. This includes erosion of rive banks as river flows change, and accretion of sediment that could reduce the conveyance capacity of rivers and structures, thus increasing flood risk.
- Flood season for agriculture. Changes in the timing of rainfall could lead to changes in growing seasons, with potentially positive consequences for agricultural production.
- Opportunities presented by changes in the timing and magnitude of high river flows, for example the potential reduction in snow-related flood events.
- Release of pollutants caused by flooding of contaminated sites including mines and waste management sites.
- Resettlement of people affected by flooding caused by the long lengths of time often needed to repair flood damaged properties.
- Groundwater flooding. This is potentially an important source of flooding but the overall magnitude is much less than flooding from tidal, river or surface water sources.
- Reservoir flooding. This is a low probability but very high consequence source of flood risk that is managed by dam inspection and maintenance.
- Land drainage. This is particularly concerned with pumped drainage systems where the amount of flood water to be discharged could increase in the future.
- Estuary stability, where the shores of estuaries could suffer slippage and erosion as a result of sea level rise and increased flooding.
- Loss or damage to sites of archaeological or cultural importance as a result of flooding and erosion. Whilst this is not on the Tier 2 list, Scheduled Ancient Monuments were included in the list of consequences to be analysed as a suitable dataset was available.
- Change in recreational activities as a result of flood or erosion damage to facilities and public amenity areas.

In addition, the following impacts were recognised as potentially important consequences that were not covered by the analysis:

- Flooding of other critical infrastructure and social facilities including police stations, fire stations and health centres (see for example Pitt, 2008).
- Waterlogging of agricultural land and the impacts of saline intrusion on agriculture.

- Increases in flood risk caused by combined flooding from different sources.

3.3 Indirect consequences of flooding

Most of the consequences listed in Table 3.2 are direct consequences of flooding. There are however a wide range of indirect consequences including for example:

- Loss of water supplies to people and business as a result of flooding of water supply infrastructure. Loss of water can then lead to further indirect consequences, for example health issues.
- The indirect consequences of the loss of other services such as energy supply as a result of flooding.
- The effects of flooding on vulnerable people who may not have property or household contents insurance, and may not have the capacity to recover. An increase in flood risk could result in an increase in the number of vulnerable people becoming dependent on state support if their existing support and coping strategies fail.

A process of systematic mapping was undertaken to identify the main potential indirect consequences of flooding. Some of these have been identified in other sectors and are listed in Section 3.4.

Whilst many of these potential indirect consequences could have greater social and economic consequences than the direct consequences of flooding, there is currently a lack of information to support a UK analysis in many cases. However the collection of information from recent floods will help to remedy this problem in the future. For example, a wide range of information related to the social and economic costs of flooding have been estimated for the July 2007 floods (Environment Agency 2010).

An approach to considering the links between the direct consequences of flooding and the social, economic and environmental consequences of climate change is presented in Appendix 5. Whilst this has not been fully implemented in this CCRA, it provides a potential approach to the systematic identification of indirect consequences.

3.4 Consequences identified in other sectors

Many of the impacts and consequences examined in the Floods and Coastal Erosion sector are linked or interact with consequences of flooding and coastal erosion that have been included on the Tier 2 lists in other sectors.

Consequences of flooding and coastal erosion that have been included on the Tier 2 lists in other sectors are listed below. Analysis of these impacts has been carried out within the relevant sector, in some cases using information from the Floods and Coastal Erosion sector.

<u>Direct consequences of flooding and coastal erosion</u>

- Deaths caused by flooding (Health Sector). This includes overtopping of sea defences by wave action.
- Injuries caused by flooding (Health Sector).
- Flooding of natural and built tourist assets (Business Sector).

- Flooding of business assets (Business Sector). Flooding of assets is a direct consequence of flooding but this metric also includes the indirect consequence of business interruption costs.
- Scour at bridges which can cause bridge failure, thus temporarily destroying transport links (Transport Sector).
- Spills from Combined Sewer Overflows, which provide an indication of the potential increase in flood risk from surface water flooding in urban areas (Water Sector).
- Coastal evolution including the combined effects of coastal flooding, coastal squeeze and coastal erosion (Biodiversity Sector). This is a direct consequence that covers impacts on coastal habitats including intertidal areas and coastal grazing marsh.

<u>Indirect consequences of flooding and coastal erosion</u>

- Mental health impacts on people who have been flooded (Health Sector).
- Supply chain disruption to business activity caused by flooding (Business Sector).
- Damage and disruption to road transport as a result of flooding of roads (Transport Sector).
- Effects of the disruption of ICT systems caused by flooding of components of the systems including electricity supplies (Business Sector).
- Flood impacts on mortgage revenues as a result of difficulties obtaining insurance for properties in flood risk areas (Business Sector).
- Increase in insurance payout costs and the potential financial burden on the insurance industry as a result of increases in flooding (Business Sector).

3.5 Risk metrics

3.5.1 Definition

The CCRA includes an analysis of the most important impacts of climate change (the Tier 2 impacts) including quantification of consequences where it is possible to do so using available information.

In order to undertake the analysis it is first necessary to identify ‘risk metrics’, which are measures of the consequences of climate change. Estimates of the magnitude of the consequences of climate change are expressed in terms of the risk metrics.

For national risk assessment, ‘good’ metrics are likely to have a number of criteria, i.e. they:

- Are sensitive to climate but also allow the disaggregation of climate and socio-economic effects.
- Provide a measure of changing probability or consequences relevant to a baseline, so historical data are required to establish the current situation.
- Can be presented at the national and regional scales, based on high quality data that are collected and held by Government departments, agencies or

research institutes. The use of Government data should provide consistency between sectors and allow the metrics to be repeatable in subsequent CCRA cycles.

- Reflect economic, environmental and social consequences of climate change; some metrics may be monetised but others may simply indicate the areas affected or consequences for vulnerable groups of society.
- Are relevant/have legitimacy to the relevant Government policy.

3.5.2 Selected risk metrics

The selected risk metrics for the Tier 2 impacts are summarised below together with the rationale for selection. This includes metrics assessed in the Floods and Coastal Erosion sector and metrics assessed in other sectors. The metric number prefixes for each sector are as follows:

FL: Flood

HE: Health

BU: Business

TR: Transport

WA: Water

BD: Biodiversity

Consequence: People affected by flooding

Metric: **FL1** No. of people at significant likelihood of flooding

People are affected by all forms of flooding. Managing flood risk is fundamentally associated with human wellbeing and safety – as such this metric provides a primary building block of the assessment. Significant likelihood of flooding is defined as exposure to an annual flood frequency (to any depth) of greater than 1.3% or 1 in 75 years.

Consequence: Vulnerable people affected by flooding

Metric: **FL2** No. of vulnerable people at significant likelihood of flooding (based on the number of people at risk of flooding in the most deprived areas)

Vulnerable people are affected by all forms of flooding. Equity and fairness are principles that underpin Flood and Coastal Erosion Risk Management (FCERM) policies. The metric provides an insight into any potential bias towards the disadvantaged. It also provides an indicator as to the potential magnitude of flood risk to people who are least able to cope.

Consequence: Extreme flood event mortality

Metric: **HE3** Flood related deaths

As levels of flooding increase (both magnitude and frequency), there may be an increase in the level of risk to people and hence potential mortality rates of people affected by flooding. There is also an additional risk associated with coastal flooding as a result of people getting washed out to sea during periods of heavy wave action. This consequence was analysed in the Health sector.

Consequence: Extreme flood event morbidity

Metric: **HE7** Flood related injuries

In addition to potential increases in flood related mortality, there is also the potential for an increase in the number of injuries as a result of flooding. This consequence was analysed in the Health sector.

Consequence: Effect of floods on mental health

Metric: **HE10** Mental stress caused by flooding

Flooding causes mental stress to those who are affected and the mental impacts of flooding can be severe. As levels of flooding are projected to increase due to climate change, there is likely to be an increase in the numbers suffering mental health problems as a result. This consequence was analysed in the Health sector.

Consequence: Impact of flooding on agriculture

Metric: **FL4a** Area of agricultural land at 10% or greater annual probability of flooding: flood inundation depth 0.5 m or greater (km^2)

FL4b Area of agricultural land at 33% or greater annual probability of flooding: flood inundation depth 0.5 m or greater (km^2)

Agricultural land is at risk from all sources of flooding. The consequences of flooding include damage and loss of crops. Frequent flooding may also change the suitability of land for different agricultural purposes. There is also a concern that increases in flooding and waterlogging of agricultural land could affect national productivity.

Flooding of agricultural land presents a potential opportunity to reduce flood risk elsewhere, although the potential benefit of this flood risk management measure is outside the scope of the risk assessment.

Consequence: Flooding of residential properties

Metric: **FL6a** No. of residential properties at significant likelihood of flooding

FL6b Expected Annual Damage EAD to residential property

Residential properties are at risk from all forms of flooding. Assessing the number of residential properties affected by flooding and the associated economic damage provides an important indicator of flood risk. EAD is based on present day property and contents damages. It should be noted that whilst EAD provides an average annual figure for flood damage, it can hide extreme shocks in terms of damage caused by major events. EAD also does not cover economic or social disruption.

Consequence: Flooding of non-residential properties

Metric: **FL7a** No. of non-residential properties at significant likelihood of flooding

FL7b Expected Annual Damage (EAD) to non-residential property

Non-residential properties are at risk from all forms of flooding. Assessing the flood impacts on non-residential properties provides a useful insight into the likely economic impact of flooding on the UK. EAD covers damage to property but not economic or social disruption.

Consequence: Coastal flooding of natural and tourist assets

Metric: **BU2** UK beaches and fixed tourist assets at risk from flooding

Tourism is one of the largest industries in the UK, worth over £100bn to the UK economy. Tourism represents about 9% of UK GDP taking account of direct and indirect impacts.

Tourism is highly climate-sensitive industry as it is closely related to the climate and the environment. Although tourist assets are dispersed across the UK, there are concentrations in certain locations, for example along the coast and rivers. This makes them particularly susceptible to coastal and river flooding.

This metric is particularly concerned with coastal tourism and the increase in risk resulting from sea level rise. It was assessed in the Business sector.

Consequence: Flooding of business and industry assets

Metric: **BU4** Flood damage and interruption costs to business

Flooding is a major risk for UK businesses which can be affected by all forms of flooding. The impacts include damage to premises and other assets, and disruption to business activities.

This metric considers the cost of flooding to business based on insurance claims, and was assessed in the Business sector.

Consequence: Supply chain disruption caused by flooding

Metric: **BU9** Change in output for UK businesses due to an increase in supply chain disruption.

Flooding of transport links, distribution centres and other facilities has the potential to disrupt UK businesses' supply chains by affecting availability of natural resources and raw materials, or by causing distribution delays.

This metric considers the effect of flood related disruption to supply chains on business output, and was assessed in the Business sector.

Consequence: Flooding of roads and rail

Metric: **FL8a** Roads at significant likelihood of flooding (km)
FL8b Rail at significant likelihood of flooding (km)

Transport links can be affected by all forms of flooding. To date little quantified information exists on the impact of floods on transport. Although highly simplified, this metric provides a useful insight by providing estimates of road and rail lengths affected by flooding.

It is recognised that the number of roads and railways affected may be a more appropriate metric, but is difficult to define and quantify.

Consequence: Disruption and delay to road transport caused by flooding

Metric: **TR1** Disruption and delay caused by flooding of roads

Flooding of roads causes delay and disruption to transport users. This affects many aspects of society including business, emergency services and social activities. This metric provides estimates of the costs of road transport disruption due to flooding, and was assessed in the Transport sector.

Flooding also cause disruption to other forms of transport, particularly railways and airports. However, roads were selected as they represent about 90% of transport within the UK.

Consequence: Scour at bridges caused by high river flows

Metric: **TR6** Scour of bridge foundations

Winter precipitation and river flood flows are projected to increase. This in turn could lead to an increase in the amount of scour at bridges across rivers and an increase in the potential number of bridge failures from this cause. This metric considers the impacts of increasing river flows on the number of bridge failures, and was assessed in the Transport sector.

Consequence: Flooding of water distribution and treatment installations

Metric: **FL10** Water distribution and treatment installations at risk of flooding.

Water supply is a vital service to society and business. Flooding of water distribution and treatment installations not only causes damage but can also result in the loss of water supply and sewage treatment services for areas that are both inside and outside the floodplains. Water installations are particularly vulnerable as they are often sited close to rivers or the sea.

Consequence: Flooding of energy generation and distribution installations

Metric: **FL11a** Power stations at significant likelihood of flooding (number and capacity)
FL 11b Electricity substations at significant likelihood of flooding (number)

Power supply is a vital service to society and business. Flooding of energy generation and distribution installations not only causes damage but can also lead to loss of power in areas both inside and outside the floodplains. Consequences can be wide ranging and include loss of lighting, heating and communications. It also affects society's ability to cope during and after a flood event as this relies, in part, on the ability of critical infrastructure to continue to work. This metric provides an overview of the potential for loss of power during or after a flood event.

Consequence: Flooding of health facilities

Metric: **FL12a** Hospitals at significant likelihood of flooding (number)

During times of emergency it is vital that emergency services operate effectively. The number of times emergency services are affected by events they are there to service is surprising high.

This metric provides a simple indication of the impacts of flooding on health facilities by providing an estimate of the number of hospitals that might become at risk from flooding as the climate changes. It does not cover other emergency services, other health facilities or transport access to hospitals.

Consequence: Flooding of education facilities

Metric: **FL12b** Schools at significant likelihood of flooding (number)

Schools form an important element of society and any disruption has wide effects. Not only is education disrupted but there are widespread social impacts on pupils and families. This metric does not cover other facilities for education including pre-school facilities or higher education establishments.

Consequence: Flood disruption to ICT systems

Metric: **BU5** Disruption of Information and Communication Technologies (ICT) due to flooding

ICT is an integral and vital part of the operations of all types of businesses, with over 80% of businesses being 'heavily dependent' on ICT systems. Any disruption to these systems could therefore have a major impact.

Climate change could potentially disrupt ICT systems, with increases in rainfall, flooding and temperature affecting parts of the systems. Elements of ICT systems that are at risk of flood damage include cables, control panels and power supplies.

This metric was assessed in the Business sector.

Consequence: Effects of flooding on insurance of residential properties

Metric: **FL13** No of residential properties at significant likelihood of flooding (to assess insurance impacts)

Residential properties are at risk from all forms of flooding. In England the Government and the ABI have agreed a *statement of principles* in relation to the continued provision of insurance against flood risk for most households. In this agreement, significant likelihood of flooding (i.e. 1:75 years or more frequent) is identified as the threshold that insurers use to consider their approach to the provision of insurance cover.

There is a risk that the cost of insurance may increase and in some cases become unaffordable as flood risk increases. This metric is intended to provide an indication of the number of properties where insurance arrangements might be affected.

Consequence: Flood impacts on property mortgages

Metric: **BU6** Value of mortgages at risk

Insurance for properties at risk of flooding may become more difficult to obtain as flood risk increases. As a result, mortgages may become more difficult to obtain for these properties.

This risk relates to the reduction in potential revenue that may be realised by mortgage lenders, both in terms of the opportunity to provide new mortgages, and also in terms of the risks to existing mortgages if properties become uninsurable. This metric was assessed in the Business sector.

Consequence: Larger insurance and reinsurance payouts as a result of increases in flooding

Metric: **BU7** Increase in payout costs by the insurance industry

Major climate events result in large payouts by the insurance industry. Whilst there is awareness of the risk following recent major flood events, there could be large increases in insurance payouts as a result of future climate events.

Whilst increases in the cost of insurance are often passed on to customers, large events might occur that result in large payouts and an immediate loss to the industry, as happened in summer 2007. This metric was assessed in the Business sector.

Consequence: Flooding of cultural heritage sites

Metric: **FL15** Area of SAM sites at significant likelihood of flooding

Impacts on cultural heritage are complex because of the number of different sites that could be affected by flooding. Sites are vulnerable to all forms of flooding. For example, buried archaeological remains might be vulnerable to changes in ground water. Things in wet ground can be as vulnerable to drainage and drying as things in dry ground which may be vulnerable to wetting. Therefore changes in flood risk can have positive or adverse effects depending on the circumstances.

A simple metric is provided here through a count of the areas of Scheduled Ancient Monuments (SAMs) exposed to a significant likelihood of flooding. This provides an indication of potential impacts but does not include the wide range of other heritage sites such as listed buildings.

Consequence: <u>Sewer flooding and CSO spills</u>

Metric: **WA10** Change in CSO spill frequency

The primary concern regarding increases in the spill frequency of Combined Sewer Overflows (CSOs) is an increase in pollution. However this also provides an indication of increases in sewer flooding, as it is linked to the frequency with which sewer systems become overloaded with storm water. This metric was assessed in the Water sector.

Consequence: <u>Land lost due to coastal erosion</u>

Metric: **FL14** Coastal Erosion: Area of land (including agricultural land and BAP habitats) affected

Coastal erosion poses a different kind of threat compared with flooding – once land is lost to erosion it cannot be recovered. This metric provides an indication of the effects of erosion on agricultural land and BAP habitats. This metric does not however cover all designated sites. It therefore only provides a partial indication of the impacts of coastal erosion on habitats.

Consequence: <u>Coastal evolution impacts on habitats including 'coastal squeeze'.</u>

Metric: **BD2** Coastal evolution impacts on coastal and estuary habitats

The complex dynamics of the UK coast depend on the interaction of sea levels, sediment supply/demand and climate forcing (winds, waves, tides and river discharges) with features such as cliffs and saltmarsh which are also dependent on rainfall and temperature.

This metric considers the combined influence of a range of factors on coastal habitats that lead to incremental change, and was assessed in the Biodiversity sector.

Consequence: <u>Flood impacts on coastal habitats</u>

Metric: **BD7** Major coastal flood / reconfiguration

There are extensive freshwater and brackish habitats including coastal grazing marshes on estuaries and the coast that are immediately behind the natural or defended shoreline. Storm events on the coast have the potential to cause extensive saline inundation of these areas and put the habitats at risk.

This metric considers the potential impact of increasing saline inundation on these habitats, and was assessed in the Biodiversity sector.

4 Response Functions

4.1 Summary

The analysis involves the following steps:

- Develop response functions for each metric. These are plots of the value of a risk metric against a climate variable (Step 8 on the flow chart in Figure 2.2).
- Apply the response functions for selected climate scenarios, to identify changes in value of each metric with changes in the climate variable for each scenario (Step 9 on the flow chart).
- Apply socio-economic scenarios to the values calculated for climate scenarios, to identify the likely total change taking account of future socio-economic conditions (Step 10 on the flow chart).

This Chapter describes then analysis that was carried out and the response functions that were developed. Chapters 5 and 6 cover the subsequent calculation of metric values.

4.2 Climate change and socio-economic scenarios

4.2.1 Scenarios used for the analysis

Three epochs are used for the analysis in addition to present day (2020s, 2050s and 2080s). These three epochs are those used for the climate projections in UKCP09.

Future UKCP09 projections are available for three emissions scenarios: Low, Medium and High (which correspond to the IPCC B1, A1B and A1FI emission scenarios). In the 2020s only the Medium scenario is used since the projections are relatively insensitive to the choice of emissions scenario (due to the inertia of the climate system), but in the 2050s and 2080s projections from all three scenarios are analysed.

As the projections are probabilistic it is important to explore the full range of probability; to do this the 10%, 50% and 90% probability levels of the projections are used (labelled p10, p50 and p90) to provide a range of possible future projections. Taking into consideration all of these possible choices of projections, the following thirteen selected climate scenarios are applied:

- 2020s : p10 Medium, p50 Medium, p90 Medium
- 2050s: p10 Low, p50 Low, p50 Medium, p50 High, p90 High
- 2080s: p10 Low, p50 Low, p50 Medium, p50 High, p90 High.

Three socio-economic scenarios have been selected for the analysis: Low, Principal and High, following the naming convention of population forecasts developed by the Office of National Statistics (ONS, 2008). Details of these scenarios are given in Appendix 7. No correlation has been assumed between the emissions scenarios and the socio-economics scenarios, and results have been produced for all combinations.

In order to support the analysis, the following information was prepared (and is summarised in Appendix 8):

- Flow increases by Region. This information was also used to calculate the change in return period for river flows and therefore the increase in flood frequency.
- Sea level rise by Region. This information was also used to calculate the change in return period for peak sea levels and therefore the increase in frequency of extreme high water levels.

All data related to river flow takes account of increases in both overall amount and intensity of rainfall. Sea level rise projections are relative to land level, and take account of both the changes in absolute sea level and changes in land level.

4.2.2 The High++ sea level rise scenario

In addition to the UKCP09 scenarios referred to in Section 4.2.1, a High++ (extreme) scenario range for sea level rise and storm surges was developed. This provides an additional amount of change above the likely range of current models.

The extra sea level rise in High++ results from faster melting of ice sheets. Although the rate that this could happen cannot be currently predicted, it is possible to make estimates of its likely maximum size based on observations of the past and plausible constraints on ice sheet dynamics.

The High ++ scenario is intended to provide an extreme but physically plausible range of change for users wishing to investigate contingency planning and the limits of adaptation. However, it is thought very unlikely that the upper end of the High ++ ranges for sea level rise and surge will be realised during the 21st century.

For the Thames Estuary in the 21st century, the UKCP09 High++ surge increase range is approximately 0.2–0.95 m and the H++ mean sea level increase range is 0.93–1.9 m.

This concept was applied in the Thames Estuary 2100 project (TE2100, 2007) to assess the maximum extreme sea levels that might occur for the long term planning of flood risk management measures.

4.3 Data

4.3.1 Data used

Much of the data used for the analysis in the Floods and Coastal Erosion sector were available for English Areas and Wales, and therefore results were prepared for these areas. The data used are summarised in Table 4.1.

Table 4.1 Summary of data sets and models used

Dataset	Source / Owner	Use	Assumptions / uncertainty
National flood modelling (England and Wales)	Environment Agency (EA)	To establish relationships between the climate drivers and future risks for FL1, FL2, FL6, FL7 and FL13.	Available for England and Wales. In areas where flooding may be from both river and tidal sources, the counts are divided into river and tidal contributions via area weighting of individual 50 m cells.
Census	Office for National Statistics	To determine the mean occupancy per residential property for FL1 and FL2.	Assumes that present occupancy rates remain constant in the future.
NaFRA	EA	To estimate the baseline and future flooding risks for Metrics FL4, FL8, FL11, FL12 and FL15.	Probability of the onset of flooding obtained from raw modelled Risk Assessment for Strategic Planning (RASP) results.
NRD – Property Layer	EA	To provide the location of hospitals and schools in England and Wales.	Typically the point is located at the post box or centre of the property. Hospitals and schools are large sites. The flood probability at other locations on the sites may differ to that at the "centroid".
NRD – Transport Layer	EA	FL8 risks to rail, motorway, A road and B road.	Assumes that within each 100 m x 100 m cell each road or railway is a straight line and an estimated length was applied for each cell.
Power stations	Derived from EA IPCC licences	FL11 Risk to power stations.	Typically the point is located at the post box or centre of the property. Power stations are large but located on reasonably flat sites. Thus this is likely to of minimal concern.
Substations	National Grid	FL11 Risk to substations.	Very reliable dataset acquired from the National Grid.
NRD – Heritage Layer	EA	FL15 Scheduled Ancient Monuments.	Areas of SAM mapped onto 100 m x 100 m grid to quantify risk.
ALC		Flooding and erosion risk to agricultural land.	Data from 1974. Also the data are at low resolution which has poor match against detailed coastline.
BAPS	Entec	Erosion risk to Biodiversity Habitats.	Saline lagoons occasionally located seaward of detailed coastline.
Coastline	Environment Agency	Coastal erosion baseline.	Very detailed data in places.
Future coast	Defra	Coastal units and present day undefended erosion rates.	Erosion rates are banded into 5 classes. Median values were used.
Foresight	OST	Coastal regions and future erosion rates given for sea level rise – scaled to give future erosion zones for CCRA scenarios.	Limited number of regions (27) covering England and Wales.

4.3.2 Data limitations

The main limitations in the data used for the analysis are summarised below. These should be addressed in time for the next CCRA.

Surface water flooding

Metrics have been calculated for river and tidal flooding, but not for surface water flooding owing to a lack of suitable information.

There are national data available on present day flood risk for surface water flooding including a simple (and approximate) allowance for sewer flooding. This provides estimates of present day flood risk for 0.5% (1:200) annual probability using flood depth categories of <0.3m, 0.3 – 1.0 m and >1.0 m . However data are not available for other flood frequencies or future projections of surface water flooding.

In order to provide future projections for surface water flood risk, it would be necessary to undertake modelling for future climate change scenarios which would show both the increase in flood extent and the increase in the number of receptors affected. This information is currently not available and therefore it was not possible to provide projections for future surface water flood risk.

This is a major limitation as the risk associated with surface water flooding is similar in magnitude to that from river and tidal flooding, as discussed in Section 1.3.1.

Geographical coverage of results

The calculated values in most of the metrics cover England and Wales but not Scotland and Northern Ireland. This is because the analysis was based on modelling undertaken for England and Wales only and similar datasets do not exist for Scotland and Northern Ireland.

Water distribution and treatment installations

Information on water distribution and treatment installations was not available for the analysis. Suitable data should be available in the OS based functions of the National Receptor database (NRD), due to be available in 2011.

Coastal erosion data

The quality of coastal erosion data is poor. The best available data are from the National Coastal Erosion Risk Map (NCERM) but this was not available for the CCRA because of the potential sensitivity of using this unpublished data.

4.4 Approach to the analysis

The calculations have been carried out using spreadsheets that provide relationships between metrics of flooding and drivers of climate change based on the Environment Agency's national flood modelling for England and Wales. This provides the basis for the Agency’s long term investment strategies for England and Wales (LTIS 2009 and Environment Agency Wales 2010) and the National Flood Risk Assessment 2008 (NaFRA08).

The model results provide estimates of present and future flood risk from river and tidal flooding for both England and Wales. However, equivalent information for Scotland and Northern Ireland is not available and these DAs were therefore not included in most of the analysis.

The model results provide numbers of properties at risk, categorised by likelihood of risk (Significant, Moderate or Low, see Table 4.2) and Expected Annual Damage. The data were processed using the ‘Risk Assessment for Strategic Planning’ or ‘RASP’ Methods[9].

[9] http://www.rasp-project.net/Information.htm

The national flood modelling does not cover future risk from surface water flooding although present day risk has been assessed.

Table 4.2 Likelihood bands for categorising properties

Source: Environment Agency (2009)

Risk category for a location	The chance of flooding in any year at that location	
Low	Less than 0.5 per cent	One in 200 chance in any given year
Moderate	0.5-1.3 per cent	One in 200 to 1 in 75 chance in any given year
Significant	More than 1.3 per cent	One in 75 chance in an given year

The results represent the likelihood categorisation of all properties in the Flood Map (1:1000 year flood outline) in England and Wales and include the consideration of defence standard, performance, type and deterioration over time. The results take account of different options for maintenance and replacement of defences. Five policy options were considered for three future epochs. The Policy Scenarios are described in Table 4.3.

Table 4.3 Policy Options

Policy Option	Change to expenditure	Change to risk
1) No active intervention. Sometimes referred to as 'Do nothing'.	No expenditure on maintenance or repair / replacement of assets.	Assets degrade and fail over a short period of time. The level of flood risk may increase quickly over time as assets fail.
2) Reduce existing flood risk management actions (accepting that flood risk will increase over time). Sometimes referred to as 'Do Minimum'.	Maintain existing assets, do not replace when they fail.	The level of flood risk may increase slowly in the short term and then accelerate as assets begin to fail.
3) Continue with existing (or equivalent alternative) actions to manage flood risk (accepting that flood risk will increase over time). This includes maintaining flood defences at their current crest level.	Maintain and replace current assets to their existing crest levels.	The level of flood risk may increase over time due to climate change.
4) Take further action to maintain the current level of flood risk taking account of climate change.	Maintain current assets; replace with larger/longer/more robust structures; build new assets.	The level of flood risk may remain static as the size of defences keeps pace with climate change.

Policy Option	Change to expenditure	Change to risk
5) Take further action to reduce the risk of flooding.	Maintain and replace current assets. Assets to be improved or replaced with larger/longer/more robust structures. Build new assets.	The level of flood risk reduces as assets are replaced by assets that provide a better standard of protection.

The data were provided to the CCRA project as counts of property by likelihood band.

For the CCRA analysis, the model results were summarised into total counts by UKCP09 Administrative Region (see Figure 4.1). The project adopted Policy Option three to provide the change in risk associated with climate change since this scenario assumed that defences are maintained and replaced when necessary but with no increase in crest levels. Thus any increases in risk can be associated with increasing river flows and sea levels.

Figure 4.1 UKCP09 Administrative Regions

Source: UKCP09

The climate change projections used in the modelling were based on Environment Agency Regions. For the CCRA analysis presented here, they have been converted to rates for each UKCP09 Administrative Region by using an area weighted approach.

The data were provided as aggregated counts of property from both river and tidal sources of flooding. However, in order to produce climate driver related functions there was the need to separate the data into those from river flooding and those from tidal flooding. A disaggregation method was developed and applied to provide the disaggregated data.

Response functions were then developed by Region. The data are presented for England and Wales only. Equivalent data for Scotland and Northern Ireland were not available.

The climate projections assumed by the CCRA for peak flow and sea level rise are given in Appendix 7, Tables A7.1 and A7.2 respectively. The peak flow data were obtained from recent Defra/Environment Agency research using UKCP09 and regionalisation of increases in peak flows (Kay *et al.*, 2010) and refer to a 1961-90 baseline. The sea level data were obtained directly from UKCP09 and refer to a 2008 baseline.

The regional changes in river flow and sea level were applied to the relevant response functions in order to provide projections by region. These projected values were then aggregated to provide national totals.

In order to support the analysis for some metrics, future flood frequency data have been prepared for both river and tidal floods from the climate projections. This provides estimates of the increasing frequency of floods as river flows and tidal water levels increase. The flood frequency data are shown in Tables A7.3 and A7.4 for river and tidal flooding respectively. The river frequency analysis builds on the recent work on regionalisation of flows referred to above and the tidal frequency work was undertaken as part of the CCRA by HR Wallingford.

Population and residential property growth projections are shown in Tables A7.5 to A7.9 based on projections from the Office of National Statistics (ONS, 2008). The calculated risk metrics are presented in Appendix 8 for each epoch for the selected climate change emissions scenarios and socio economic scenarios.

The approach adopted for coastal erosion was based on the 'Futurecoast' present day undefended rates of erosion per 'Coastal Behavioural Unit'. The Foresight analysis reported future erosion rates for different coastal regions in England and Wales under four different rates of sea level rise. These have been used to develop relationships between sea level rise and erosion which were used to estimate the regions lost to erosion under the different future scenarios. These regions have been spatially related to the receptor data and areas lost were calculated by Region.

Some of the main limitations to the analysis are as follows:

- Surface water flooding not covered (see data limitations, Section 4.3.2)
- England and Wales only and not Scotland and Northern Ireland (see data limitations, Section 4.3.2)
- Coastal erosion analysis could be improved (see data limitations, Section 4.3.2)
- The combined impact of erosion and flooding on the coast is not considered.

4.5 Key assumptions in the analysis

4.5.1 Choice of method

The objective of the analysis is to provide a high level national assessment of present day and future flood risk. The Ministry of Agriculture, Fisheries and Food (MAFF) commenced a programme of research into national assets at risk (for England and Wales) in the late 1990s. This work has been developed by Defra and the Environment Agency including the National Flood Risk Assessment (NaFRA), and includes both present day and projected future flood risk. A recent output from this process is the Long Term Investment Strategy for England (LTIS, 2009) and possible long term investment scenarios for Wales (Environment Agency Wales, 2010).

The use of the modelling results that have been used for these studies was considered to be the most appropriate method of obtaining the results required by the CCRA. Whilst these studies have been used to develop investment strategies, the CCRA has used the basic modelling data and results to obtain projections of future flood risk.

Results for some metrics were not available from the model outputs. In these cases a method based on change in flood frequency was used to derive future projections.

Other strategic planning initiatives were considered including Shoreline Management Plans (SMPs), Catchment Floods Management Plans (CFMPs) and Surface Water Management Plans (SWMPs). However, these are regional (or sub-regional) studies, and are therefore not suited to the needs of a national assessment.

The method does not cover Scotland and Northern Ireland, and there is no equivalent information for these countries (although work is in progress to develop flood risk information building on existing flood maps). The analysis therefore does not cover these countries, which represent about 6% of the overall flood risk.

The modelling and other analysis are high level and provide indicative projections that are appropriate for the UK risk assessment. The results should not be used for re-analysis or interpretation at a regional, local or site-specific scale.

4.5.2 Types of flooding

The modelling data and results cover river and tidal flooding, but not surface water flooding. This means that the analysis presented in this report covers river and tidal flooding only (unless otherwise stated).

Surface water flooding is very important and accounts for over 50% of properties at risk of flooding in England and Wales, see Section 1.3.1. However, suitable information for assessing changes in risk caused by climate change was not available. Surface water flooding is therefore excluded from most of the analysis.

4.5.3 Flood extents

The analysis covers all areas at risk from flooding including both defended and undefended areas.

It is assumed that the limit of the floodplain is fixed. The analysis is based on properties and other assets contained within the present day natural floodplain, as defined by the 0.1% annual probability (1:1000) flood extent in the absence of defences. Flood extents for higher flood probabilities can increase within this overall limit.

It is recognised that the extent of the floodplain will increase with rising sea levels and river levels. However, the above limit is considered to be a reasonable assumption in most areas, because flood areas generally extend to the edge of flat ground at the sides of valleys and coastal plains. An increase in depth beyond the 1,000 year event typically only causes a small increase in area. The vast majority of the future change is caused by the increase in probability of flooding across the existing floodplain rather than the extension of the floodplain.

4.5.4 Baseline for climate drivers

The risk assessments completed in the Floods sector uses the most up to date national data sets available for relative sea level and for estimation of peak river flows. The baseline for sea level rise was derived from UKCP09 and is 2008. The increases in sea level used in the analysis (and presented in Appendix 7, Table A7.2) are therefore relative to 2008 levels. Whilst there is variability in sea level rise from year to year, the variation is relatively small and the 2008 baseline level was derived from the mean sea level trend line.

The situation is more complicated for river flows. The UKCP09 precipitation projections are relative to a baseline period of 1961-90 whereas the National Flood Risk Assessment (NaFRA) for England and Wales uses a mixture of the best available local and national data sets with different start and end dates. In addition:

- It is difficult to determine any trends in peak river flows from the 1970s to the present because natural variations mask any underlying trend due to climate change, and therefore, the CCRA assumes that the various baselines underpinning NaFRA are equivalent to the 1961-1990 climate.
- Estimation of extreme flood flows and depths is subject to considerable uncertainty, related to the length of records available, statistical methods used for flood estimation and methods for estimating flood depths, and the uncertainties related to small differences in baselines are minor (almost negligible) compared to other factors.

The effect of these assumptions is that the potential risks for the 2020s may appear to be large compared to the present day values. In future CCRA cycles, improved climate models, flood estimation techniques or climate change detection and attribution studies may provide new and improved approaches for understanding current risks and changes in the short term (2020s).

4.5.5 Baseline defence condition: flooding

It was assumed for the analysis that the existing fixed flood defences are maintained in their present condition over the long term for tidal and river flooding, though under this scenario there may be some deterioration in the short term before repairs are carried out. The locations of the defences and their crest levels are therefore assumed to remain unchanged from present day. Flood barriers are assumed to operate under present day rules but, as for the fixed defences, the frequency of overflow and overtopping may increase as a result of rising coastal and river levels associated with climate change. This corresponds to Policy 3 (Table 4.3).

Baseline information for this assumption can be abstracted from the modelling dataset. Because the flood defences do not change, the results of the analysis reflect the impacts of climate change effects only (i.e. increases in river flows and sea level).

The model results include defence deterioration and repair. The results could therefore be affected by flood defence deterioration, particularly in the 2020s when it was thought that a defence will have deteriorated but may not have been improved. An independent assessment of changes in assumed defence condition over the next 25 years showed that the number of defences in worse condition was similar to the number of defences in better condition. It was therefore concluded that the defence deterioration and improvement assumptions within the model would not significantly affect the results.

This baseline enables the change in flood risk due to climate change to be compared with climate change risks for other sectors that have less well developed adaptation policies. This was considered to be the best means of understanding the relative significance of different risks.

This baseline does not, however, take account of current measures to reduce flood risk or the ongoing deterioration of defences. Flood risk reduction and climate change adaptation measures will, if/when implemented, reduce the level of risk. Deterioration of defences would lead to an increase in flood risk if maintenance and repairs are not carried out.

There are programmes in place to improve/upgrade existing flood defences and to construct new flood defences. Other ongoing measures to reduce flood risk that are also not taken into account include the prevention of new development in floodplains (see Section 4.5.10) and local measures including flood resistance and resilience for properties.

Consideration was given to using a baseline that took account of measures to reduce flood risk and defence deterioration. However, this would involve assumptions about future approaches and investment in flood risk management that could not be justified. Approaches to managing flood risk will be included in the adaptation assessment.

4.5.6 Baseline defence condition: coastal erosion

The following assumptions were made for the baseline condition of defences for coastal erosion:

- Defences affected by erosion in rural areas will not be effective after 30 years.
- Defences for urban areas will be maintained on their present alignment. This means that urban areas will not be affected by coastal erosion, and reflects the ‘hold the line’ policies generally adopted for urban areas in SMPs.

This reflects the fact that coastal towns are generally protected against flooding and erosion from the sea using various techniques including hard defences and beach recharge. It is however recognised that this requirement could increase in the future and may not be sustainable in some locations, as discussed in Section 4.5.7 below.

Whilst retreat of the coastal defence line may not be acceptable for large coastal communities, and investment in defences will continue, there are likely to be communities where retreat of the frontage becomes necessary. This would require a more detailed assessment of coastal erosion that is beyond the scope of this high level analysis. However, the new NCERM data referred to in Section 4.3.2 might be an appropriate starting point for a more detailed analysis that could be included in the next CCRA.

4.5.7 Coastal and estuary towns

Coastal and estuary towns are particularly vulnerable to the effects of sea level rise and erosion. Areas of coastal and estuary towns that are below high tide level require flood defences. Areas that are open to wave attack and erosion often have coastal protection, particularly tourist resorts on the open coast. Many coastal and estuary communities do not have defences, for example those on raised ground in sheltered bays.

The assumptions in Sections 4.5.5 and 4.5.6 above for coastal and estuary towns are as follows:

- Flood defences are assumed to remain as existing including location, crest level and condition.
- Coast protection is assumed to be unaffected by climate change, so that no erosion occurs.
- For communities that have no protection, flooding is assumed to occur but not coastal erosion.

It is apparent that these assumptions may underestimate the impacts of increases in coastal erosion on coastal and estuary communities. There are some communities that are already threatened by erosion and this problem may get worse as a result of climate change. It is recommended that a more detailed assessment is carried out for the next CCRA using the NCERM information referred to in Section 4.3.2.

4.5.8 Methods of analysis

Two basic methods are applied in the analysis: interrogation of the Environment Agency's national flood modelling dataset and flood frequency analysis.

Use of the modelling dataset

The modelling results have been used for estimating people and property at risk (metrics FL1, FL2, FL6, FL7 and FL13). This includes flood modelling for both defended and undefended areas. The results therefore include:

- Overtopping and breaching of flood defences that would occur as sea levels rise and river flows increase.
- Overbank inundation from rivers, estuaries and the sea in areas where there are no defences.

Flood frequency analysis

Where metrics are not available from the modelling dataset, they have been calculated based on the assumption that the increase in flood frequency at each location on the floodplain is proportional to the increase in frequency of river flows and tidal water levels. This is a simplification, particularly for defended areas, because the relationship between flood probability at a particular location on the floodplain and the frequency of the river flow or extreme sea level is not linear.

4.5.9 Selected flood frequency for the analysis

The analysis of people and property at risk is based on the 1.3% (1:75) annual probability of flooding (defined as 'significant likelihood of flooding'). This probability has been chosen because it provides a convenient level of risk for assessing future change and can be extracted from the modelling dataset, which forms the basis of much of the analysis undertaken here.

'Significant likelihood of flooding' in the modelling dataset represents high flood risk. Other bands of risk used in the modelling dataset are 'Moderate' (1.3% to 0.5% annual probability) and 'Low' (0.5% to 0.1% annual probability). 1.3% is also the annual flood probability in the statement of principles on flood insurance agreed between Defra and the Association of British Insurers (ABI) below which flood insurance is available as a feature of standard household and small business policies. Whilst this agreement is due to end in June 2013, it supports the use of this flood frequency.

Flood mapping for Scotland has been prepared for a 0.5% annual probability and analysis in progress (January 2011) is based on this. This annual flood probability would therefore provide a suitable basis for combining flood information for England, Wales and Scotland in the future.

The criterion used for selecting flood frequencies to be used for agriculture was potential disruption to crops and livestock. Relatively frequent floods have been selected for the analysis as these have the potential to damage crops or prevent grazing on a regular basis (33%, 20% and 10% annual probabilities of occurrence). Larger floods, whilst disruptive, do not occur so often and have less overall impact.

4.5.10 Socio-economic scenarios

The analysis uses the assumption that population growth will take place in the areas where the population lives at present, and there is space for the growth. This avoids the need to make assumptions about where future population growth might take place.

It is recognised that this assumption is simplistic, as Government policy is to ensure that development is located away from flood risk whenever possible. However, using this assumption allows the analysis to produce an underlying level of risk from climate change, on to which different policy options can be assessed. It also ensures that the overall level of flood risk is not artificially reduced compared to climate change risks in other sectors; where in some cases policies are less well developed.

The same occupancy (i.e. number of people per residential property) rates are also used for each Devolved Administration and English Area.

4.5.11 Social vulnerability

A social vulnerability assessment has been carried out and is reported in Appendix 6, where additional information on the nature of social vulnerability in relation to floods can be found. There are a numbers of vulnerabilities associated with flood risk including:

- Individual vulnerabilities, where individuals in a community have greater difficulty dealing with floods than others. These include the elderly (over 75s), young children and their carers, people on low incomes and the long term sick.

- Vulnerable communities, where vulnerability is affected by economic and social deprivation.

Individuals who are vulnerable to flooding are present in all areas of society. An approach to vulnerability based on individual vulnerabilities was used in the Environment Agency's Modelling and Decision Support Framework (MDSF, Defra/WAG/Environment Agency, 2004).

A Social Flood Vulnerability Index was developed and used in the MDSF to identify social vulnerability. It was based on lone parents, people aged 75+, the long term sick, non-home owners, the unemployed, non car owners and overcrowding. The results showed a wide spread of vulnerability which made it difficult to interpret the results in the form of flood risk management actions.

The alternative approach of using vulnerable communities identifies those relatively deprived communities in flood risk areas where houses may not be insured and residents have low resilience to shocks including flood damage. Flooding of such communities could result in social deprivation and a high support burden on Local Authorities and other services.

Recent research has shown that there is a disproportionate concentration of deprived communities in zones at risk from sea flooding (Environment Agency, 2006). It was decided to base social vulnerability in the CCRA floods analysis on deprived communities as this identifies communities that are particularly vulnerable to flooding and provides a clearer focus for action to reduce vulnerability. Hence a metric was chosen based on properties in deprived areas.

4.5.12 Extremes events

There is a concern that future extreme events may become more extreme and the rate of change may be greater than the values of climate drivers used in this analysis (particularly sea level rise and precipitation).

This analysis is based on the projection of extremes using a range of scenarios. These extremes include:

- Extreme sea levels
- Extreme river flows, which take account of the duration and intensity of extreme rainfall.

For example, the median sea level rise projection for the 2080s in East Anglia is 0.35 m but the range of scenarios tested is 0.19 m to 0.59 m . Thus the analysis already covers a range of future projections.

In some studies a so-called 'High++' scenario has been used, to indicate what could happen in the future. For example, for the Thames Estuary, a rise in peak surge tide level (combination of mean sea level rise and surge residual increase) of 4.2 m was used to assess what could happen and help to plan future adaptation. Other studies (for example, the Foresight Future Flooding analysis) have assessed the impacts of extreme widespread flood events.

However, whilst these types of scenarios are useful in considering the direction that adaptation should take, they have not been considered in this analysis because of the difficulty of assigning probabilities to such events. An approximate estimate of the effects on properties that a High++ sea level rise scenario occur might have is made in Section 5.30.

Another concern that has arisen in the consultation process is that wind storms could increase leading to higher waves. The UKCP09 projections and more recent work by the Met Office (Met Office, 2010) indicate that there will be little change in average wind speeds. However it is understood that this work does not cover extreme wind speeds and this remains as an evidence gap.

4.5.13 Data and information

Much of the analyses are based on data sets and derived information from flood modelling for England and Wales. Data for Scotland and Northern Ireland have generally not been incorporated at this stage because suitable comparable data are not currently available.

Much of the data have been derived using broad-scale assumptions. Whilst it provides a national assessment it is not suitable for use at a detailed level. For example, specific assets such as power stations may have local defences that provide a higher standard of protection than assumed in the national overview.

Other data and information has been used as outlined in Section 4.3. However some data sets that would enhance the analysis either do not currently exist or could not be made available for the study. These include recent work on coastal erosion and ongoing work related to critical water infrastructure. These data sets should be made available for the next CCRA.

4.5.14 Assumptions for specific calculations

Specific assumptions have been made in the calculation of each metric. Methods and assumptions for individual metrics are summarised in Section 5.

4.6 Flood frequency data

As explained in Section 4.5.6, some metrics which are not included in the national flood modelling results have been calculated using regional flood frequency data, which provides information on the expected increase in the frequency of flooding based on sea level rise and the change in river flows.

For example, a coastal flood with an annual probability of occurrence of 0.5% (1:200) today may have an annual probability of occurrence of 2% (1:50) in 50 years time. This means that a flood of this magnitude is projected to occur four times more frequently in 50 years time (in this example).

One reason for adopting this approach is the assumption (stated in Section 4.5.3) that the overall flood area will not increase beyond the existing 0.1% annual probability (1:1,000) flood extent. Increasing flood risk therefore becomes to a large degree a function of increased flood frequency within the floodplain area.

As mentioned in Section 4.2.1 above, detailed flood frequency data have been prepared using UKCP09 projections for river and tidal flooding. These data are summarised in Tables A7.3 and A7.4 in Appendix 7, together with examples.

Table A7.3 (rivers) provides data for p10, p50 and p90 Medium emissions scenario. Table A7.4 (tidal) only provides data for the p50 Medium emissions scenario, although the full range of data for all scenarios is available.

Some specific examples from the data are as follows:

- A 1% (1:100) river flood in Northumberland could occur about 3.7 times more frequently in the 2080s compared with 1961-90 based on a P50 Medium Emissions Scenario. The range for different scenarios is about 3.2 to 5 times the present day frequency.
- A 1% (1:100) river flood in the South-East could occur about 2.4 times more frequently in the 2080s compared with 1961-90 based on a P50 Medium Emissions Scenario. The range for different scenarios is about 1.8 to 3.1 times the present day frequency.
- A 0.01% (1:1000) tidal flood in the East of England could occur about 5 times more frequently in the 2080s based on a P50 Medium Emissions Scenario. The range for different scenarios is about 2.4 to 14 times the present day frequency.
- A 0.01% (1:1000) tidal flood in Wales could occur about 8 times more frequently in the 2080s based on a P50 Medium Emissions Scenario. The range for different scenarios is about 3 to 40 times the present day frequency.

4.7 Response functions

4.7.1 Analysis in the Floods and Coastal Erosion Sector

Two different approaches were used for the analysis: the use of flood modelling results and the use of flood frequency data.

Use of national flood modelling results

National modelling data were available for the number of properties at significant likelihood of being flooded, properties in deprived wards at significant likelihood of being flooded and EAD. The national modelling study had calculated the risk under a suitable scenario (maintain crest level) for the dates 2008, 2033, 2058, 2083 and 2108.

It is however important not to think in terms of these dates but to think in terms of the increases in river flows and sea levels and the corresponding increases in metric values (for example, the number of properties at significant likelihood of flooding).

The relationships between sea level rise or river flow were plotted against metric values in order to create the response functions. Separate curves were plotted for each region. When calculating total numbers for each metric, the increase in climate driver for each region was used with the regional response function to determine regional values of metrics. These were then combined to provide national values.

The national values provide a reasonable indication of the overall magnitude of the risks and the way that they might change in the future. However the modelling was not considered accurate enough to present the results by region, as this would give a false impression of the accuracy of the results.

Thus the response function curves for the CCRA show the risk to the particular metric versus the relevant climate change driver values (i.e. risk versus sea level rise or risk versus % change in peak flow). Projections for the thirteen climate change scenarios used in the analysis can then be read off the curves using the values of climate drivers presented in Tables A7.1 and A7.2 in Appendix 7. These show that:

- The relative change in peak river flow as a percentage increase above the 1961-90 baseline (Table A7.1).
- The relative change in sea level is in metres above the 2008 baseline (Table A7.2).

The response functions only apply to the calculated scenarios and should not be extrapolated beyond their maximum values.

Use of flood frequency data

Where national modelling data were not available (e.g. agriculture, transport, energy, hospitals, schools, and cultural heritage) the raw NaFRA 08 probability data (i.e. not the categorisation into low, moderate, significant but the actual probability values calculated in the present day NaFRA 08 model runs) were modified using regional growth curves to determine the future probabilities of river flows and extreme sea levels for the future climate scenarios. The flood frequency data are described in Section 4.6 above.

The new probability values were used to identify those receptors that fall into the significant likelihood category, thus providing a measure of the risk to the metric being considered for each future scenario. In these cases separate response functions were not derived.

4.7.2 Analysis in other sectors

The method of analysis in other sectors is described in the relevant sectors reports, as follows:

Health:	Hames, D. and Vardoulakis, S. (2012)
Business:	Baglee, A., Haworth, A. and Anastasi, S. (2012)
Transport:	Thornes, J., Rennie, M., Marsden, H. and Chapman, L. (2012)
Water:	Rance, J., Wade, S.D., Hurford, A.P., Bottius, E. and Reynard, N.S. (2012)
Biodiversity:	Brown, I., Ridder, B., Alumbaugh, P., Barnett, C., Brooks, A., Duffy, L., Webbon, C., Nash, E., Townend, I., Black, H. and Hough, R. (2012)

4.7.3 Response functions for each metric

The way in which each response function has been derived is outlined below. In many cases the coverage is limited to England and Wales (see Section 4.3.2).

FL1 No. of people at significant likelihood of flooding

The response function has been calculated using the number of residential properties by region (FL6), and the average number of people per property derived from national census data.

The function has been calculated for tidal and river flooding but not surface water flooding. The function applies to England and Wales, but does not include Scotland and Northern Ireland.

FL2 No. of vulnerable people at significant likelihood of flooding

The response function has been calculated for the number of properties in the highest 20% of deprived areas and data for the average number of people per household. This provides an indicator of the number of vulnerable people but not a direct value. Deprived areas are identified using the Government Indices of Multiple Deprivation. The metric is based on the number of properties in the highest 20% of deprived areas that are at significant likelihood of flooding.

This metric has been calculated for tidal and river flooding but not surface water flooding. Figures 4.2 and 4.3 show the response functions for river and tidal flooding respectively. The functions apply to England and Wales, but do not include Scotland and Northern Ireland.

These functions have been developed from the national modelling results. The data points on the graphs correspond to the changes in river flows and sea levels that have been applied in the modelling for each English Area and Wales. In order to obtain the changes in numbers of properties for the 2020s, 2050s and 2080s, the numbers of properties that correspond to the values of increases in river flows and sea levels shown in Tables A7.1 and A7.2 respectively have been read off the graphs.

The functions have been developed for each English Area and Wales, and the results summed to give overall values for England and Wales. The same process has been followed for metrics FL6 and FL7, although in these cases data for Expected Annual Damages have also been obtained from the modelling.

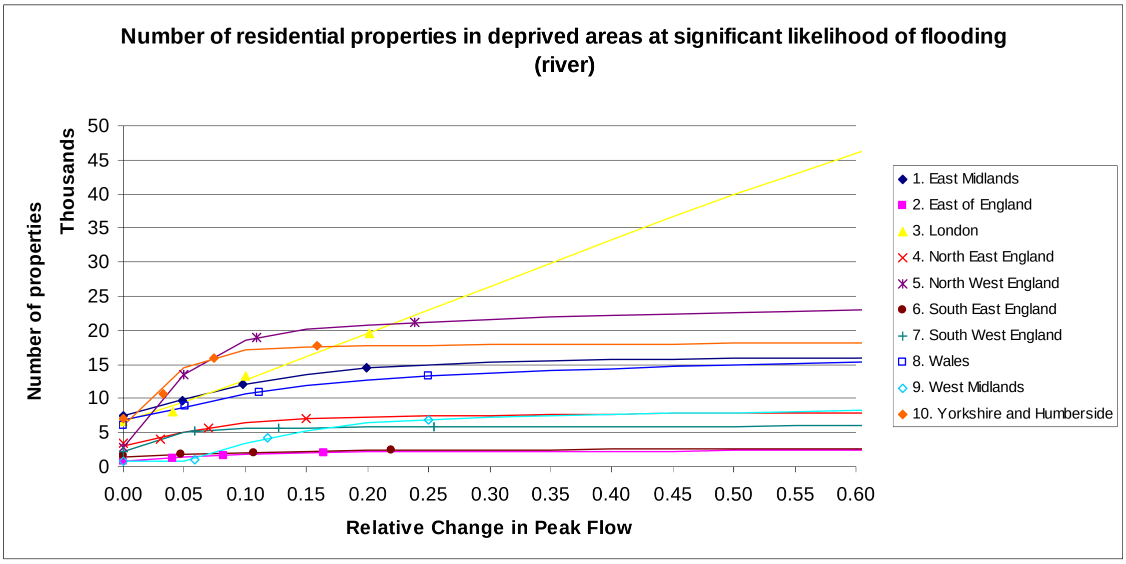


Figure 4.2 Residential properties in deprived areas at significant likelihood of river flooding

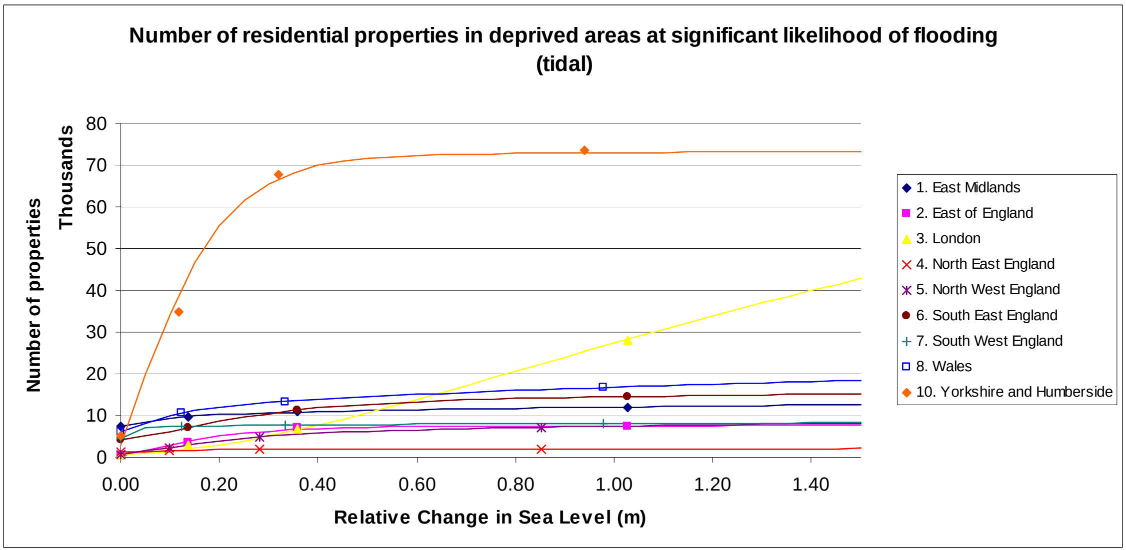


Figure 4.3 Residential properties in deprived areas at significant likelihood of tidal flooding

HE3 Flood related deaths

A detailed discussion of flood related deaths is given in the Health Sector Report. Response functions have been derived for river and tidal flooding, and the risk of fatalities caused by overtopping of sea walls. These are shown in Figures 4.4, 4.5 and 4.6 respectively. The analysis uses baseline figures for the UK and can therefore be applied to the whole of the UK.

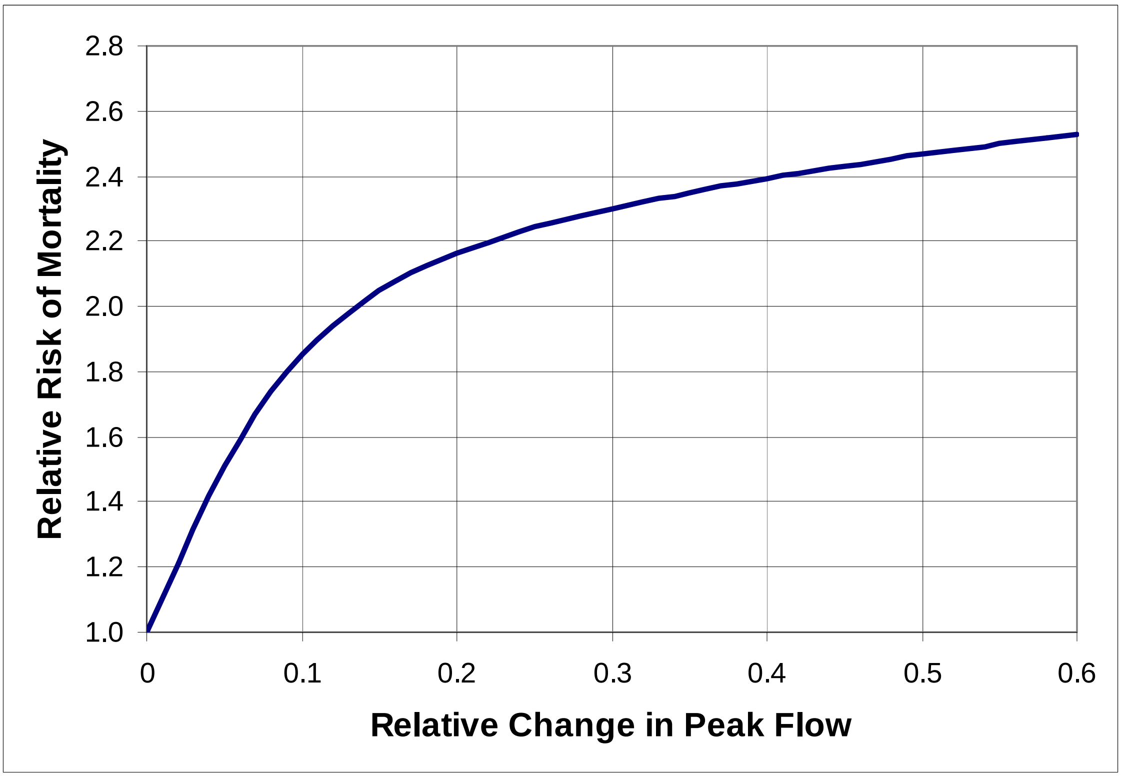


Figure 4.4 Relative risk of mortality due to relative change in peak fluvial flows

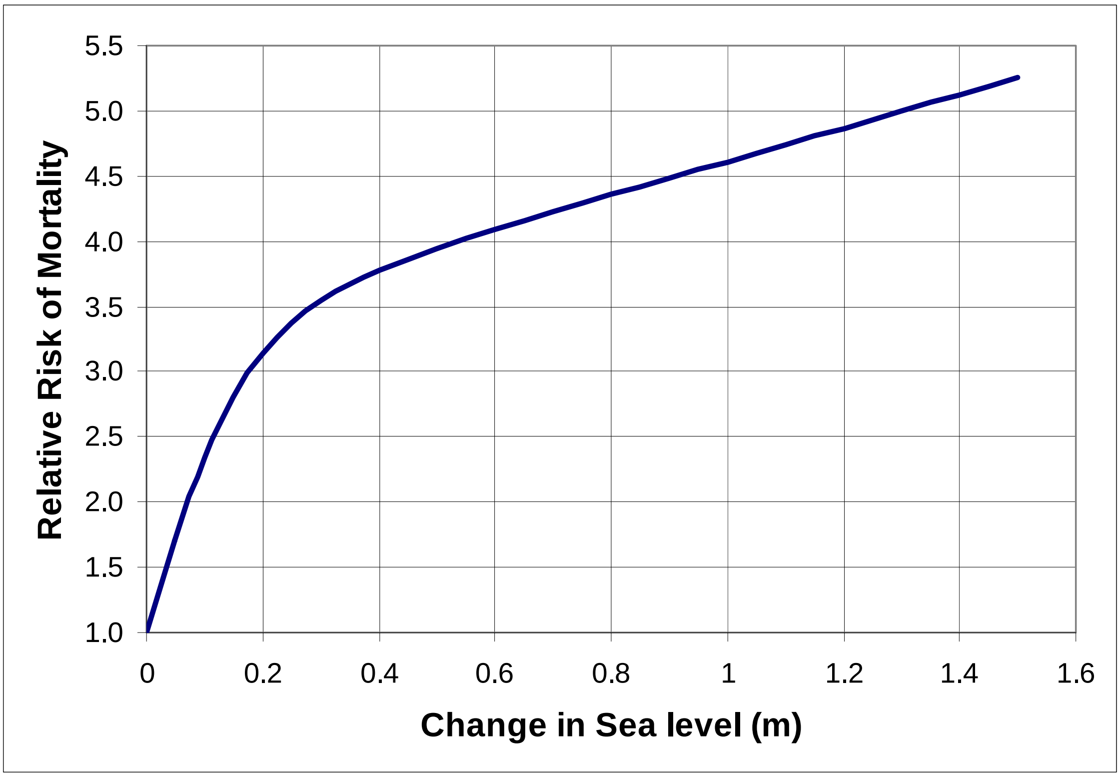


Figure 4.5 Relative risk of mortality due to change in sea levels

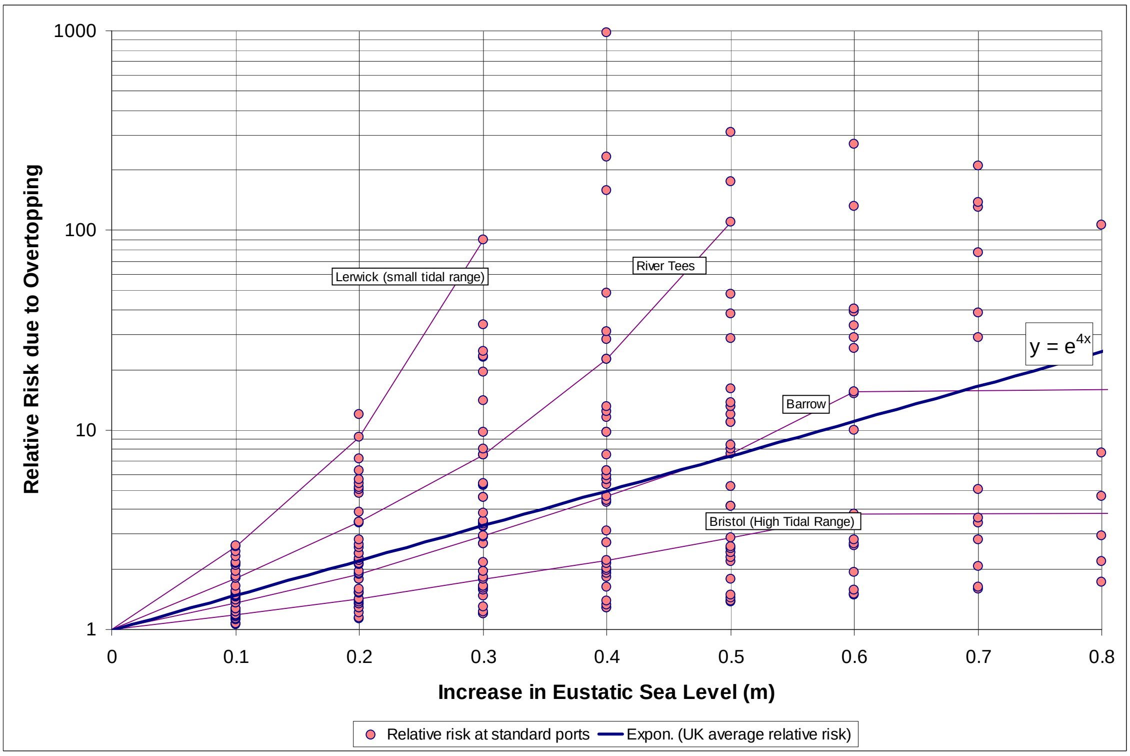


Figure 4.6 Change in relative risk of fatalities due to overtopping of seawalls

HE7 Flood related injuries

Little evidence exists that indicates how many people are at risk of injury as a result of extreme flooding, particularly in relation to coastal flooding. This is because injuries can be difficult to quantify, and often levels of injuries are not reported, or difficult to associate with a flood event. However, despite this some evidence does exist, and an attempt to quantify injuries has been given by Defra/Environment Agency (2003). This has been used together with information from recent floods to establish a relationship between extreme weather event flooding and injuries.

Based on this methodology, a simple linear relationship between injuries and floods was assumed with 20 injuries for every 1 death. Results were derived using metric HE3 and the associated response functions. This metric applies to the UK.

HE10 Mental stress caused by flooding

A baseline value of the number of people suffering mental stress as a result of flooding was calculated for the UK in the Health Sector Report. Future projections were obtained by multiplying the baseline figure by the projected increases in population at risk from metric FL1. This was based on the response function for metric FL6. The analysis provides approximate figures for the UK.

FL4 Agricultural land at risk of flooding

The consequences were calculated directly using the flood frequency data referred to in Section 4.6 above. As the frequency of flooding increases with climate change, the area of land inundated more frequently than the thresholds specified in the analysis (33.3% and 10% annual probabilities) will increase. Separate response functions were not calculated. The analysis covers England and Wales but not Scotland and Northern Ireland.

FL6 Residential properties at significant likelihood of flooding (number and EAD)

The response functions have been calculated using the number of residential properties by region and the associated EAD. The functions have been calculated for tidal and river flooding but not surface water flooding.

Figures 4.7 and 4.8 show the response functions for the number of residential properties at significant likelihood of river and tidal flooding respectively. Figures 4.9 and 4.10 show the corresponding information for EAD. The functions apply to England and Wales, but do not include Scotland and Northern Ireland.

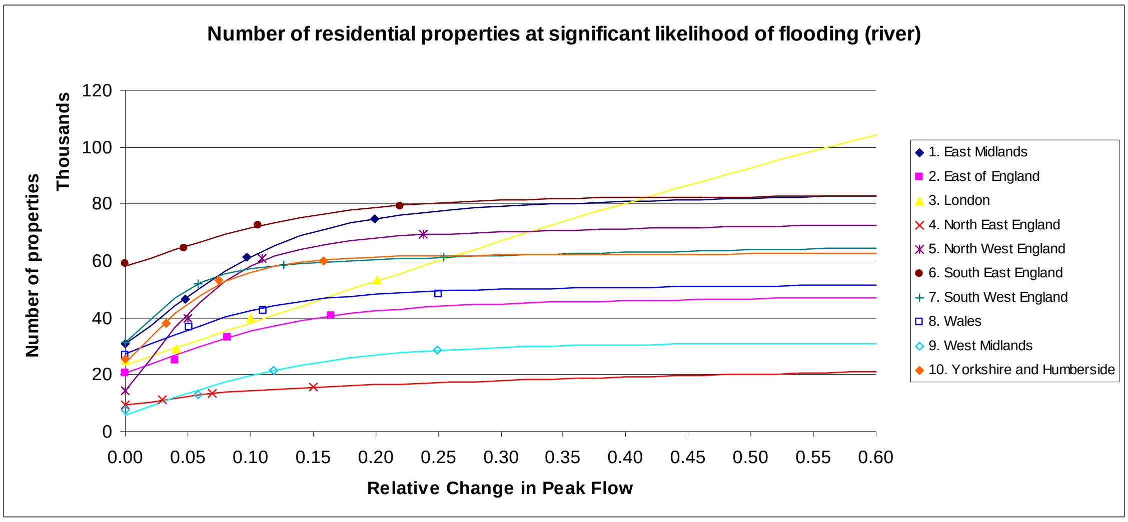


Figure 4.7 Residential properties at significant likelihood of river flooding

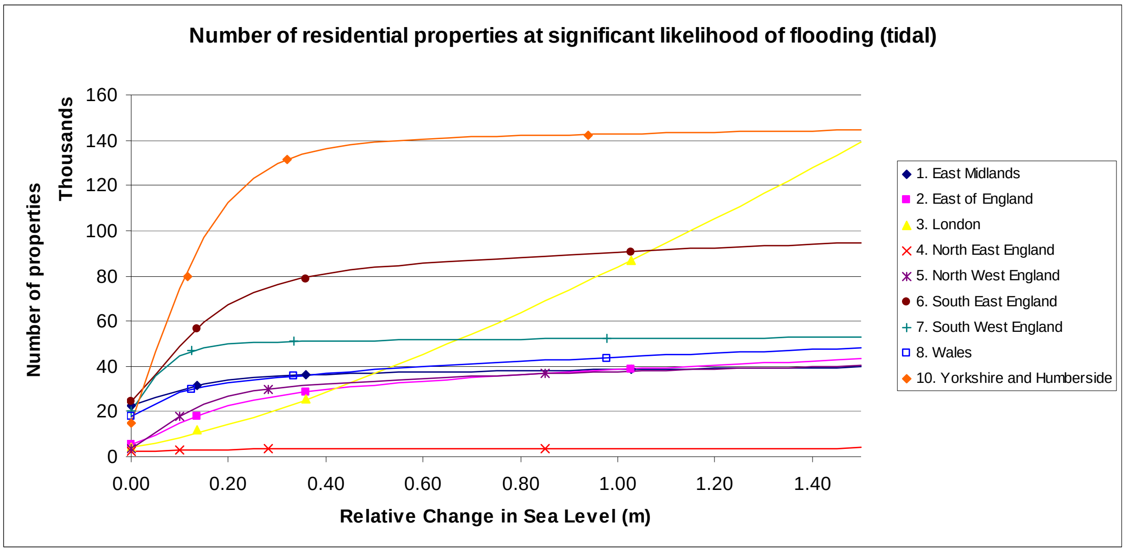


Figure 4.8 Residential properties at significant likelihood of tidal flooding

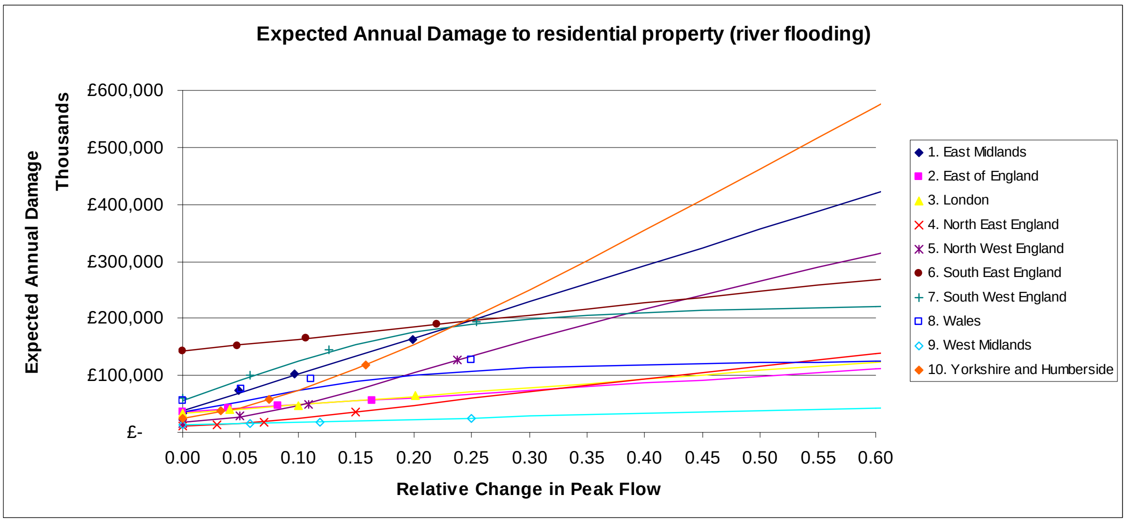


Figure 4.9 EAD for residential properties: river flooding

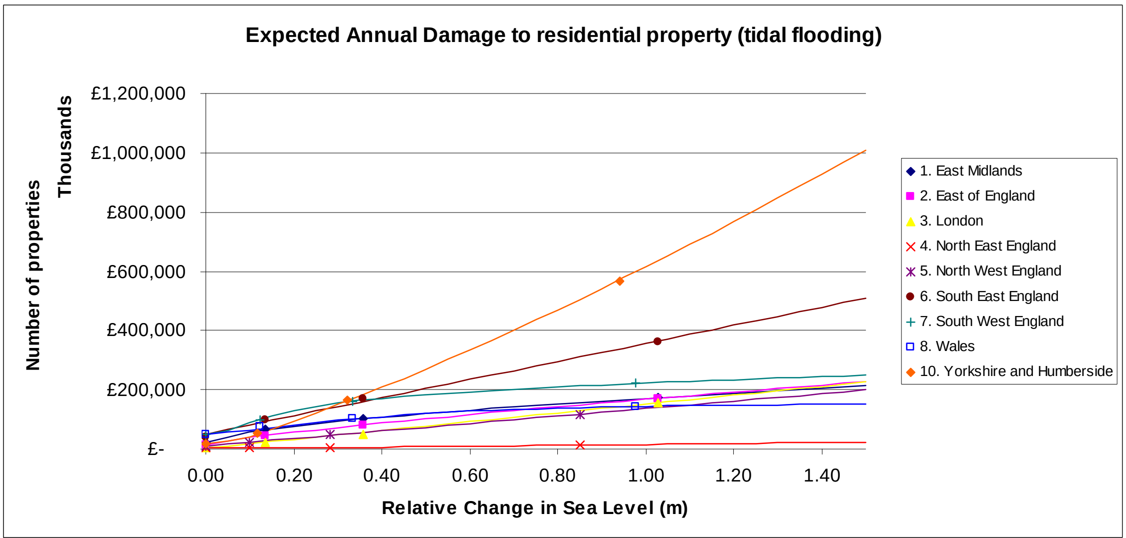


Figure 4.10 EAD for residential properties: tidal flooding

FL7 Non-residential properties at significant likelihood of flooding (number and EAD)

The response functions have been calculated using counts of the number of non-residential properties by region and the associated EAD. The functions have been calculated for tidal and river flooding but not surface water flooding.

Figures 4.11 and 4.12 show the response functions for the number of non-residential properties at significant likelihood of river and tidal flooding respectively. Figures 4.13 and 4.14 show the corresponding information for EAD. The functions apply to England and Wales but do not include Scotland and Northern Ireland.

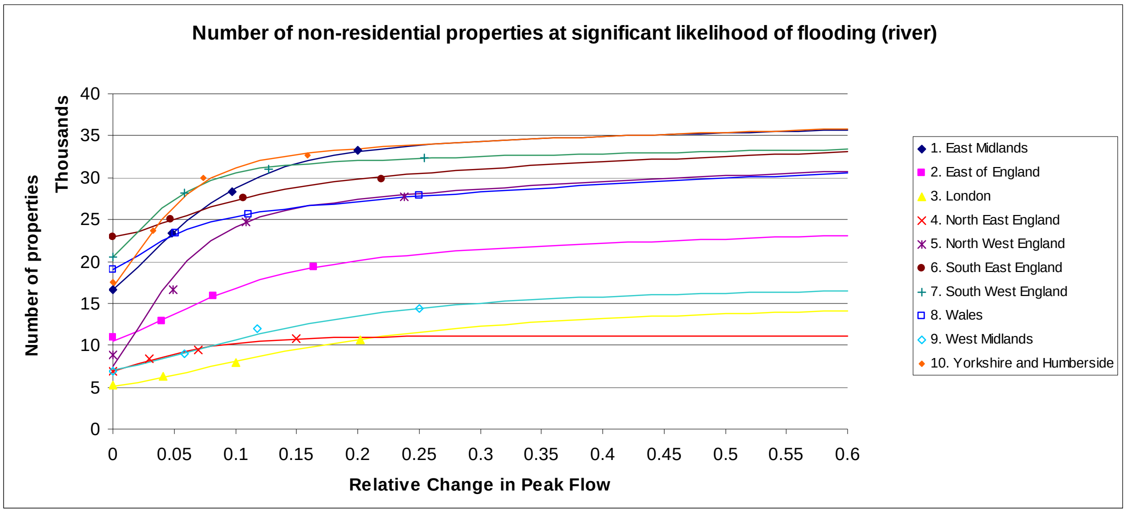


Figure 4.11 Non-residential properties at significant likelihood of river flooding

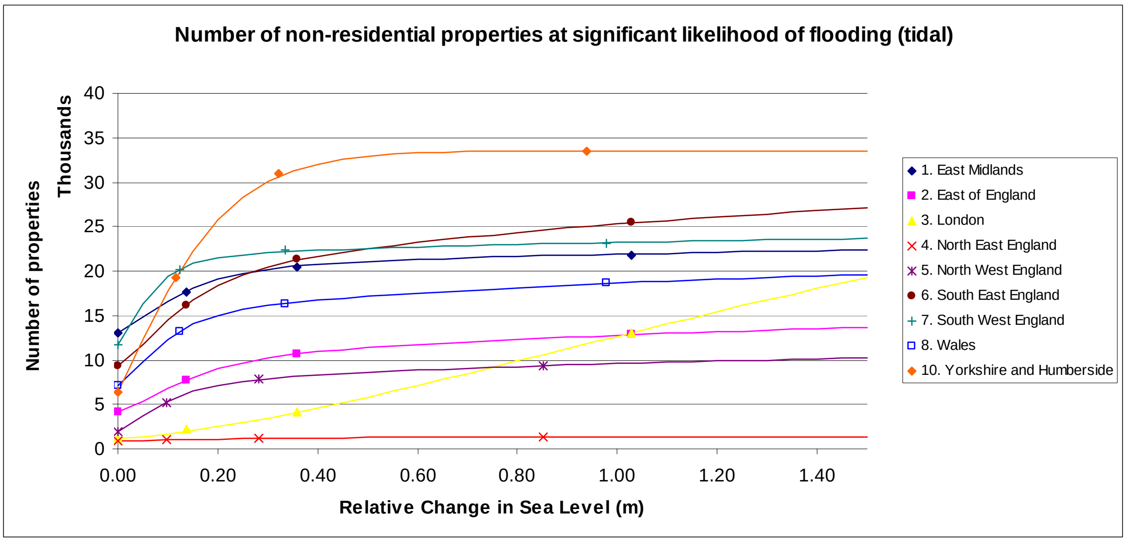


Figure 4.12 Non-residential properties at significant likelihood of tidal flooding

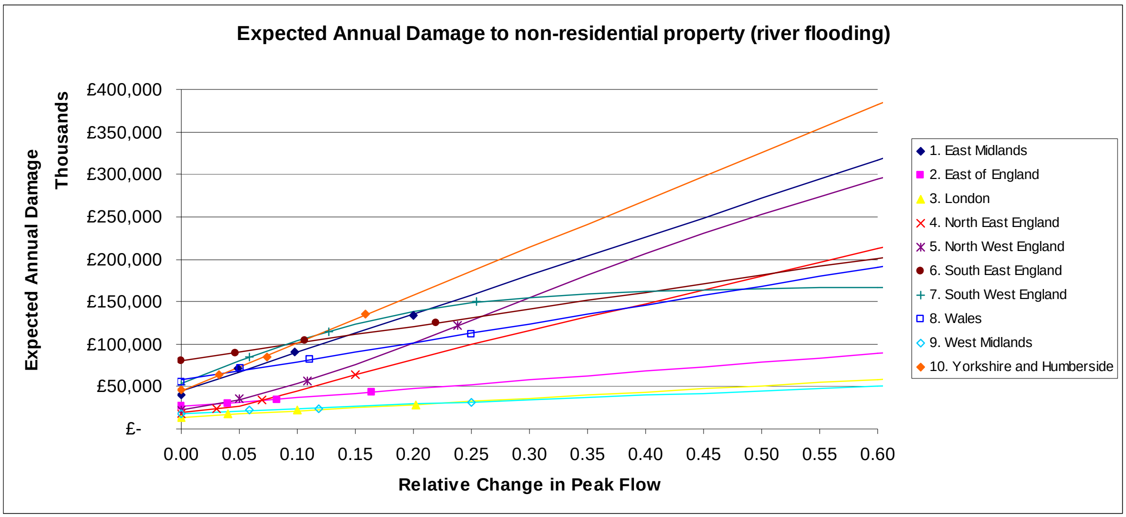


Figure 4.13 EAD for non-residential properties: river flooding

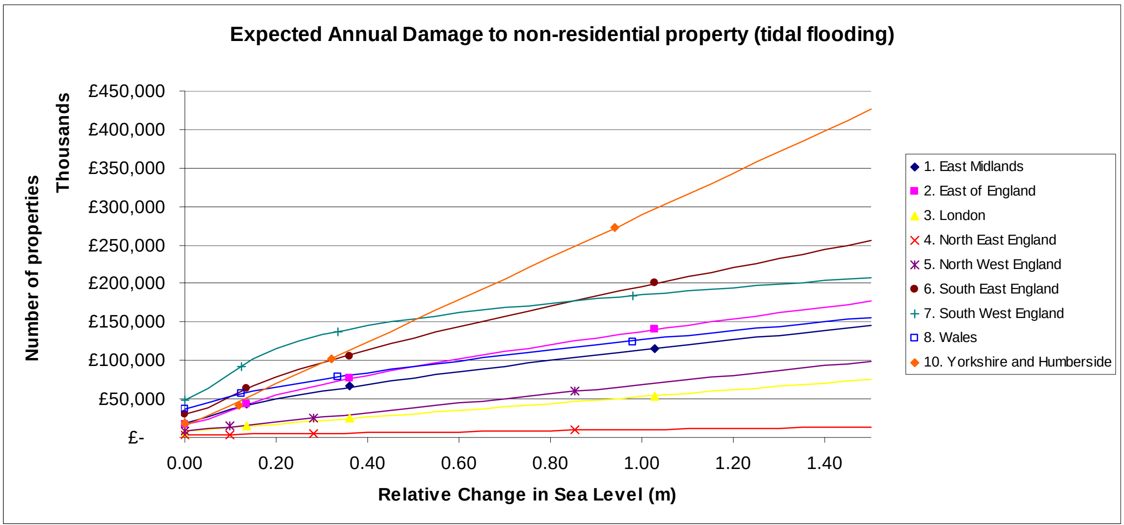


Figure 4.14 EAD for non-residential properties: tidal flooding

Interpretation of response functions for properties

Figures 4.7, 4.8, 4.11 and 4.12 show the number of existing properties with a significant likelihood of flooding (1.3% annual probability of flooding or 1 in 75 year return period). As the area of the floodplain is assumed not to increase, the total number of properties that can potentially be at risk of flooding is fixed. As the flood risk increases the point is eventually reached where all the properties are at significant likelihood of flooding. Hence there is an asymptotic relationship which approaches the total number of properties in the floodplain as the flow or sea level continues to increase.

The shape of the response function for London differs compared with other parts of the UK. This reflects the fact that the tidal flood defences for London and the Thames Estuary provide a higher standard of protection than elsewhere in the UK (annual probability of flooding of 0.1%, or 1 in 1000 years). As the sea level rises and river flows increase, the area at significant likelihood of flooding increases, but more gradually than in other areas and a smaller proportion of defences are overtopped. As a result, flooding does not cover the full extent of the floodplain by the 2080s, and flood risk continues to rise (rather than levelling off).

Figures 4.9, 4.10, 4.13 and 4.14 show a different pattern in which the Expected Annual Damage (EAD) shows a continuous upward trend in all areas. This is because the damage increases for each property as the flood depth increases.

The important assumption regarding flood extent is considered to be a realistic assumption for this high level analysis, as discussed in Section 4.5.3.

BU2 UK beaches and fixed tourist assets at risk from flooding

The impact of sea level rise on beach area was calculated directly from the length of beaches around the UK and generalised assumptions about the beach slopes and sea level rise. A response function was therefore not calculated.

It was not possible to calculate a response function for tourism assets at risk of flooding owing to a lack of detailed information on the location of the assets and the corresponding flood risk. A qualitative assessment was therefore undertaken.

BU4 Flood damage and interruption costs to business

The analysis for business premises was based on the response functions for metric FL7. The analysis therefore applies to England and Wales but not Scotland and Northern Ireland.

Business interruption costs were estimated by calculating a baseline using data from recent events, and obtaining indicative future projections using metric FL7.

An estimate was also made of the loss of staff time using IDBR Standard Industry Classification (SIC) data. Future projections of the impacts of flooding were produced by direct calculation.

BU9 Change in output for UK businesses due to an increase in supply chain disruption

Because retail supply chains are complex and dependent on a network of interconnected, yet independent, elements, it was not possible to develop a clear and direct causal link between climate change and supply chain disruption.

FL8 Roads and rail at significant likelihood of flooding

The consequences were calculated directly using the flood frequency data referred to in Section 4.6 above. As the frequency of flooding increases with climate change, the length of road (by type) and rail inundated more frequently than the threshold specified in the analysis (1.3% annual probability of flooding) will increase. Separate response functions were not calculated. The analysis covers England and Wales but not Scotland and Northern Ireland because of a lack of suitable data.

TR1 Disruption and delay caused by flooding of roads

The impacts of disruption and delay to road traffic are discussed in the Transport Sector Report. A response function was developed based on the costs of disruption, and is shown in Figure 4.15. The response function applies to England only.

Magnitude class	Estimated change in metric Numbers in boxes are the percentage probability of each class being realised						Estimated cost of disruption for each magnitude class (£m)
Very High	0	0	0	30	60	80	400
High	0	10	40	50	30	20	100
Medium	0	60	50	20	10	0	10
Low	20	30	10	0	0	0	1
Very Low	80	0	0	0	0	0	-10
	-10%	10%	30%	50%	70%	90%	
	Change in winter precipitation from present day (%) - UK average[10]						

Figure 4.15 Cost of delay and disruption to road transport as a result of flooding

TR6 Scour of bridge foundations

As river flows increase the risk of scour failure at bridges will also increase. River flows are projected to increase under the climate change scenarios and therefore an increase in the number of bridge failures could occur. However it was not possible to derive a response function in terms of number of bridge failures compared with flow increases because of a lack of detailed information on the foundations of existing bridges.

However examples of bridges were used to derive curves showing the increase in scour for particular structures for increasing river flow. These are shown in Figures 4.16 to 4.18. Modern bridges generally have deep foundations and therefore this impact applies mainly to older existing bridges.

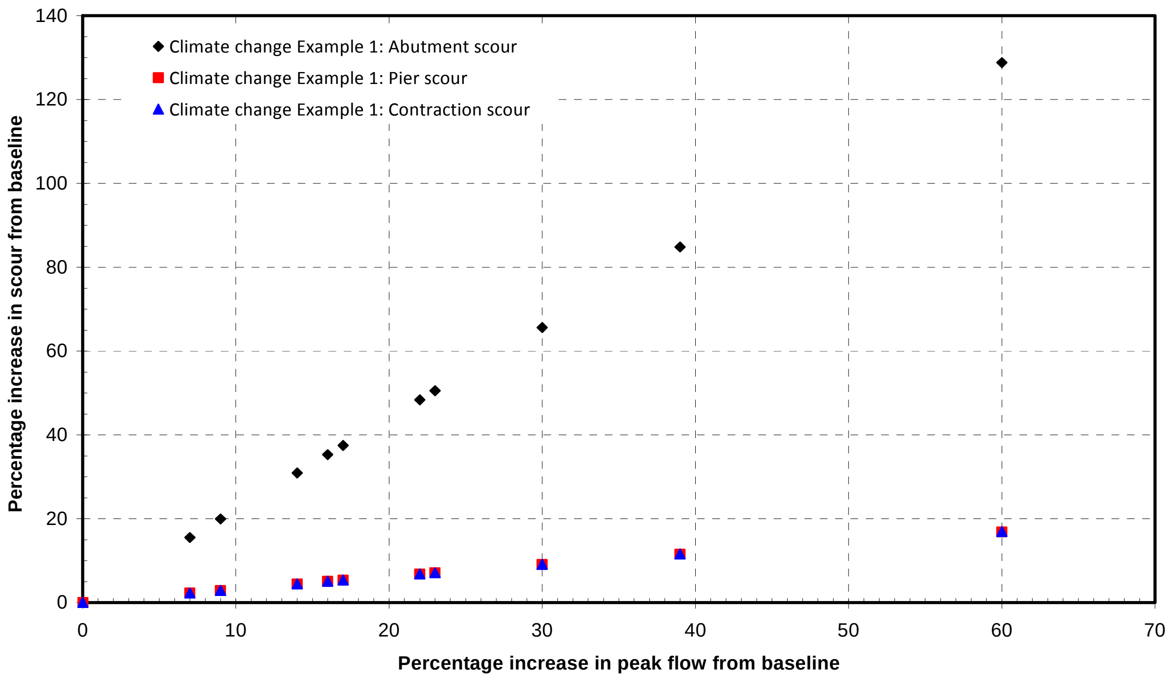


Figure 4.16 Increase in scour depth against flow for a gravel bed river

[10] This range of change values was developed using the minimum and maximum values from all emission scenarios and all probability values for all regions in the UKCP09 output.

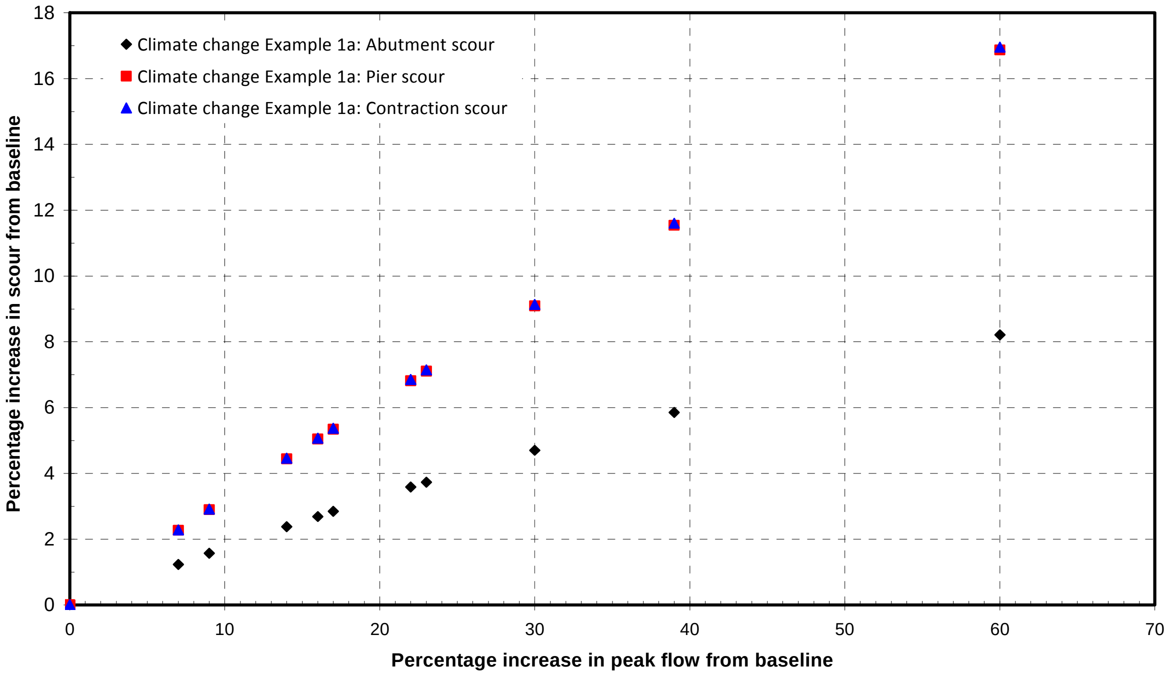


Figure 4.17 Increase in scour depth against flow for a sand bed river

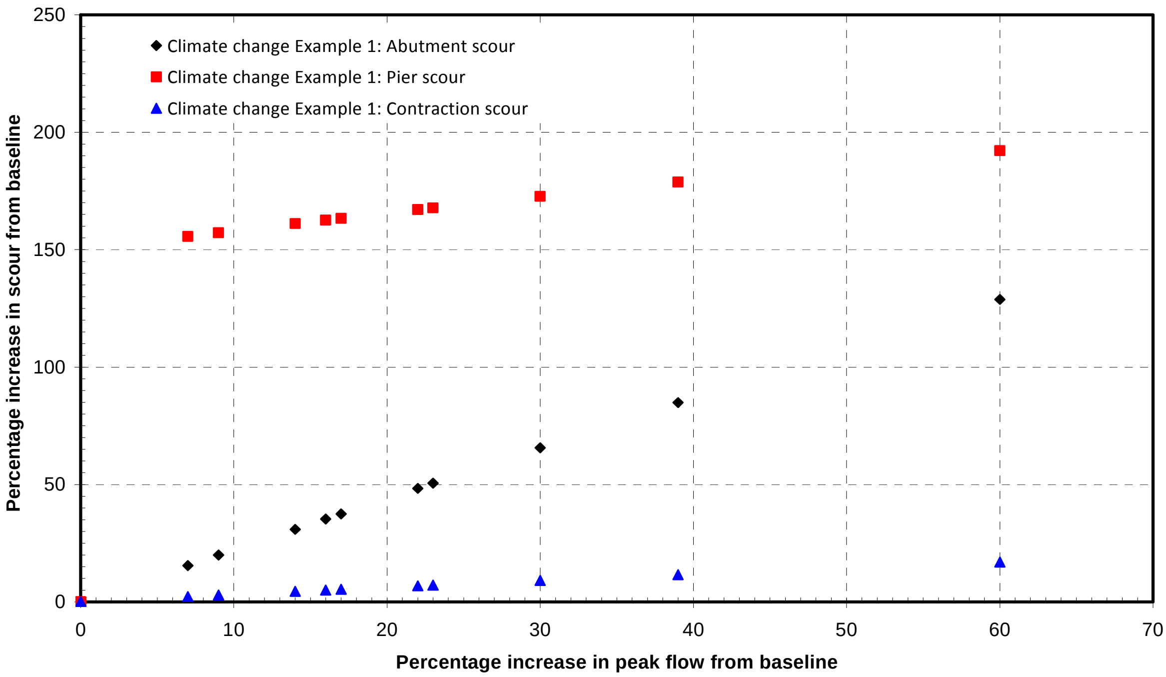


Figure 4.18 Increase in scour depth against flow for a gravel bed river with natural bed armouring

FL10 Water distribution and treatment installations at risk of flooding

It was not possible to calculate a response function for this metric owing to a lack of suitable information on water installations.

FL11 Power stations and electricity substations at significant likelihood of flooding

The consequences were calculated directly using the flood frequency data referred to in Section 4.6 above. As the frequency of flooding increases with climate change, the number of installations inundated more frequently than the threshold specified in the analysis (1.3% annual probability of flooding) will increase.

The number of installations is based on the National Property Database v3 (NPD3) and National Grid data. Separate response functions were not calculated. The analysis covers England and Wales but not Scotland and Northern Ireland.

FL12 Hospitals and schools at significant likelihood of flooding

The consequences were calculated directly using the flood frequency data referred to in Section 4.6 above. As the frequency of flooding increases with climate change, the number of hospitals and schools inundated more frequently than the threshold specified in the analysis (1.3% annual probability of flooding) will increase.

The numbers are based on NPD3 and National Grid data. Separate response functions were not calculated. The analysis covers England and Wales but not Scotland and Northern Ireland.

BU5 Disruption of Information and Communication Technologies (ICT) due to flooding

Weather already has the potential to interrupt or reduce the quality of ICT services and this could potentially get worse as the climate changes. However there is as yet very little prior work that specifically considers the potential impacts of climate change on ICT and its knock-on effects to business. For this reason it has not been possible to produce a response function.

FL13 No. of residential properties at significant likelihood of flooding (to assess insurance impacts)

This metric is used to provide an indication of the impact of increases in flood risk on property insurance. This is based on the response function for metric FL6a (Number of residential properties at significant likelihood of flooding). The analysis covers England and Wales but not Scotland and Northern Ireland.

BU6 Number of homes where mortgage provision may be at risk

The number of residential properties at significant likelihood of flooding (i.e. coastal and fluvial) is used as an indicator of the impact of flooding on the availability of insurance, and consequently on the level of mortgage lending exposed. Thus the response function for metric FL13 has been used in this case. The value of the mortgage fund at risk in England and Wales is then estimated by taking a proportion of the value of residential mortgages at significant likelihood of flooding.

BU7 Increase in payout costs by the insurance industry

Baseline insurance claim data for the UK is used to provide a baseline for insurance payouts to industry as a result of flooding. The baseline number of residential and non-residential properties deemed at significant likelihood of flooding is also calculated (using metrics FL6 and FL7). The change in the number of properties at significant likelihood of flooding is then used as the basis of estimating increases in insurance payouts, and the insurance claims are scaled accordingly.

This metric applies to the UK as the baseline has been obtained from UK data. The rates of increase are however based on projections of property flooding for England and Wales.

FL15 Area of SAM sites at significant likelihood of flooding

The consequences were calculated directly using the flood frequency data referred to in Section 4.6 above. As the frequency of flooding increases with climate change, the area of SAM sites inundated more frequently than the threshold specified in the analysis (1.3% annual probability of flooding) will increase.

The areas are based on NPD3 data for individual sites. Separate response functions were not calculated. The analysis covers England and Wales but not Scotland and Northern Ireland.

WA10 Change in CSO spill frequency

For the change in CSO spill frequency, UKCP09 Weather Generator outputs were analysed to estimate the frequency of heavy rainfall events that may cause CSO spills. Therefore there was no response function developed for this metric.

FL14 Coastal Erosion: Area of land lost (including agricultural land and BAP habitats)

The consequences were calculated directly using erosion rates that vary with sea level rise and location in the UK. Separate response functions were not calculated. The analysis covers England but not Wales, Scotland and Northern Ireland.

BD2 Coastal evolution impacts on coastal and estuary habitats

A response function was not calculated because coastal evolution impacts are caused by a combination of climate and other drivers including sea level, wave climate and sediment supply/demand. This impact uses literature review and the assessment made in FL14, area of BAP habitat lost, to estimate coastal evolution impacts.

BD7 Major coastal flood / reconfiguration

The effects of flooding of coastal habitats depend on a number of factors including frequency of flooding, duration of flooding and the freshwater regime. Information is available on the area of freshwater habitats that are vulnerable to coastal flooding, and modelling from another project was used to assess the impact of future climate change.

5 Estimated Consequences of Climate Change

5.1 Introduction

The estimates of the potential change in flood and coastal erosion risk due to climate change are intended to be used for comparison with other types of climate change risk. No account is taken of any adaptation actions.

Flood management policies include climate change adaptation. Therefore great care is needed in interpreting these results since they do not reflect current or future policies. The results are not *predictions* of what will happen and this should be borne in mind throughout the report.

The consequences of climate change are tabulated in Appendix 8. The consequences summarised in this section apply to tidal flooding and river flooding in England and Wales. The figures do not apply to surface water flooding (see Section 4.3.2).

For people and property at risk, the values for tidal and river flooding have been added. In the analysis each individual property could either be tidal or river but not both.

Many of the metrics have been calculated for receptors at significant likelihood of flooding. This means that the annual probability of flooding will equal or exceed 1.3%. The corresponding return period is 1 in 75 years.

For each metric a scorecard is given at the start of each section to indicate the confidence in the estimates given and the level of risk or opportunity. Confidence is assessed as high (H), medium (M) or low (L). Risks and opportunities are scored either high (3) medium (2) or low (1) (shown to the right). These are given for the lower (l), central (c) and upper (u) estimates for the 2020s, 2050s and 2080s. Further information is provided in Appendix 9. Where estimates are uncertain, or no data is available, this is stated in the scorecard.

M	Confidence assessment from high (H) to low (L)
3	High opportunity (positive)
2	Medium opportunity (positive)
1	Low opportunity (positive)
1	Low risk (negative)
2	Medium risk (negative)
3	High risk (negative)

5.2 Surface water flooding

It is estimated that there are about 4 million properties in the UK at risk of surface water flooding (Section 1.3.1). This exceeds the number of properties estimated to be at risk from rivers and the sea. Much of the flooding in the major events of 2000 and summer 2007 was caused by surface water flooding, indicating the existing magnitude of the problem.

The technologies that have been used to develop surface water flood maps are relatively new and much of the data has not been verified by observations from historical flooding. The estimates are therefore subject to a high degree of uncertainty and work is underway to reduce this uncertainty. There is however no doubt that surface water flooding is a serious problem.

No information on future changes in surface water flood risk due to climate change at a national level was available at the time of writing this report. It was therefore not possible to provide future projections of surface water flood risk. However, information is available that provides an indication of how the risk might change in the future.

The main driver of surface water flooding is storm rainfall. The UKCP09 projections indicate that mean winter rainfall might increase by about 8 to 20% by the 2050s and 12 to 30% by the 2080s with similar increases in the wettest days. Mean summer rainfall is projected to reduce but little change is projected for the wettest days in summer.

These projections indicate that surface water flooding might increase, particularly as a result of increases in winter rainfall.

In addition, an analysis of UKCP09 Weather Generator outputs was undertaken to estimate the frequency of heavy rainfall events that may cause CSO spills (Section 5.26). This analysis was completed for London, Glasgow, Cardiff and Belfast, and simply counted the number of storms of different rainfall depths up to a total storm depth of 60 mm.

The results shown in Table 5.1 show the increase in frequency of storms that exceed three different thresholds (>20 mm in 3 hours; >30 mm in 6 hours; >40 mm for the total storm). A value of 1.0 in the table means no change and a value of 2.0 means that the frequency has doubled. The data are shown in Figure 5.7.

Table 5.1 Change in frequency of heavy rainfall events between 1961-90 and the 2080s

Location	> 20 mm rainfall in 3 hours			> 30 mm rainfall in 6 hours			>40 mm total storm rainfall		
	P10	P50	P90	P10	P50	P90	P10	P50	P90
London	0.9	1.2	1.5	1.6	2.0	2.1	3.0	2.1	2.4
Cardiff	1.0	1.2	1.3	1.8	1.5	1.7	1.6	1.8	2.1
Glasgow	1.3	1.4	1.7	3.5	3.0	2.2	1.9	1.9	2.0
Belfast	1.3	1.4	1.5	1.6	1.8	1.6	1.5	1.5	1.6
Average	1.1	1.3	1.5	2.1	2.1	1.9	2.0	1.8	2.0

The results indicate that the frequency of heavy rainfall events could double by the 2080s leading to an increase in the frequency of surface water flooding.

Overall it can be concluded that surface water flooding is a serious problem that is projected to increase. Whilst a quantitative estimate of the magnitude of the increase cannot be made, projections of a 12 to 30% increase in mean winter rainfall and a doubling of the frequency of heavy rainfall events suggest that the increase could be significant.

The consequences of an increase in surface water flooding include an increase in the overall number of properties and other assets at risk, and an increase in frequency of flooding in areas that are already at risk. The problem could be exacerbated if the area of impermeable surfaces in urban areas is increased.

Surface water flooding could affect a wide range of receptors including:

- People (metrics FL1, FL2, HE3, HE7 and HE10)
- Agricultural land (metric FL4)
- Properties (metrics FL6 and FL7)
- Business (metrics BU4 and BU9)
- Transport (metrics FL8 and TR1)
- Infrastructure and essential services (metrics FL10, FL11, FL12, and BU5)
- Insurance (metrics FL13, BU6 and BU7)
- Heritage sites (metric FL15).

5.3 Number of people at significant likelihood of flooding (Metric FL1)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	l	c	u
FL1	Number of people at significant likelihood of flooding (river)	H	2	2	2	2	2	2	2	2	3
FL1	Number of people at significant likelihood of flooding (tidal)	H	1	2	2	2	2	2	2	2	3

The projected number of people at significant likelihood of flooding is shown on Figure 5.1.

The number of people at significant likelihood of flooding is projected to range from about 1.1 to 2 million in the 2020s compared with a baseline figure of 900,000, rising to 1.7 to 2.6 million by the 2080s for the range of climate change scenarios selected.

The total number of people at risk from river or tidal flooding in England and Wales (including those where the annual probability of flooding is less frequent than 1.3%) is currently estimated to be about 5.5 million. This compares with the number of people at significant likelihood of river or tidal flooding of about 900,000. The reasons for the differences between these figures are the presence of flood defences and the fact that the total number includes all flood frequencies. As sea levels rise and river flows increase, the frequency of overtopping of defences may increase and the number of people at significant likelihood of flooding will go up.

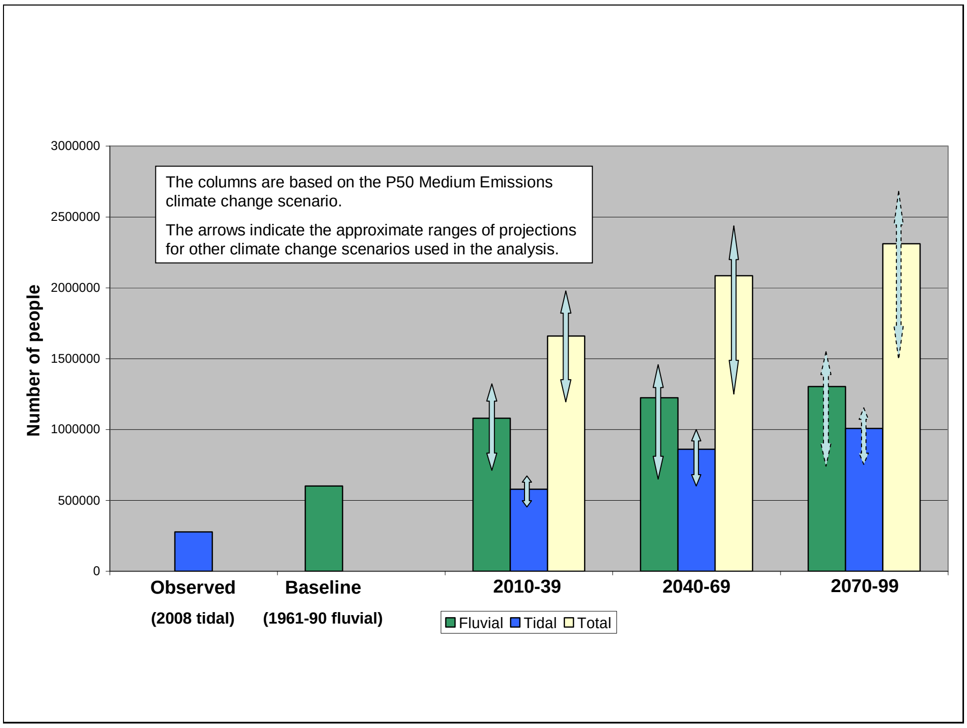


Figure 5.1 Number of people at significant likelihood of tidal or river flooding

These figures cover tidal and river flooding, but not surface water flooding. Based on property numbers in Section 1.3.1, it is estimated that there are more than 6 million people at risk from surface water flooding, many of whom are also at risk from tidal or river flooding. Whilst this type of flooding is very disruptive, flood depths and damage are generally lower than those associated with rivers and the sea.

Similar numbers of people are exposed to the risks of surface water flooding and river/coastal flooding. There is therefore an urgent need to develop projections of future surface water flood risk for the next CCRA.

The results for metric FL1 were used in the Health sector in the assessment of metrics HE3, HE7 and HE10.

Re-settlement

One of the main concerns identified at the sector workshop was the temporary re-settlement of people whose homes have been flooded. Whilst re-settlement is generally temporary, the lengths of time that people are not able to live in their homes can exceed one year in some cases. In extreme cases where properties are flooded very frequently, re-settlement may become permanent.

In Hull in 2007, for example, 8,600 properties were flooded and 6,300 people had to leave their homes (about one third of all those affected). In Lewes in the 2000 floods, 397 of the 613 flooded residential properties were evacuated (65%). Of these, 58 were still vacant after one year (about 10%).

Re-settlement occurs in all types of floods, ranging from major tidal and river floods to flash floods and sewer floods. Whilst the number of people who may require re-settlement as a result of flooding has not been assessed in the CCRA, it is clear from the above examples that re-settlement is a potentially serious problem that could get worse if the projected increases in flooding occur. This potential increase could be off-set by improving the flood resilience of properties, thus reducing flood damage.

As flood risk increases the number of people requiring re-settlement may also increase. Whilst data are not available to assess potential future numbers, this could become a more serious problem in the future. This remains a significant evidence gap.

5.4 Number of vulnerable people at significant likelihood of flooding (Metric FL2)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	L	c	U
FL2	Number of vulnerable people at significant likelihood of flooding (river)	M	2	2	2	2	2	3	2	2	3
FL2	Number of vulnerable people at significant likelihood of flooding (tidal)	M	2	2	2	2	2	3	2	3	3

The number of properties in the top 20% of deprived areas at significant likelihood of river or tidal flooding is projected to range from about 100,000 to 200,000 in the 2020s compared with a baseline figure of about 70,000, rising to 170,000 to 300,000 by the 2080s for the range of climate change scenarios selected.

It has not been possible to establish a link between the number of properties in the most deprived areas and the number of vulnerable people. Further work is needed to identify the total numbers of vulnerable people in flood risk areas.

A tentative assessment of the number of vulnerable people is as follows:

- The percentage of total population in Deprivation decile 1 in flood zones 2 and 3 is about 12.5% (Environment Agency, 2006).
- Using the figure of 12.5%, and assuming that Deprivation decile 1 corresponds to 'vulnerable people', the total number of vulnerable people at significant likelihood of flooding from river and tidal flooding is about 120,000.
- Based on the analysis for metric FL2, the number of vulnerable people at significant likelihood of flooding might rise to about 200,000 to 500,000 by the 2080s assuming no change in overall population.

This makes the broad assumption that everyone in Deprivation decile 1 is vulnerable, which is not the case. In addition, many vulnerable people live in less deprived areas. This figure is therefore at best a very rough approximation but gives an indication of the potential magnitude of the vulnerable population at significant likelihood of flooding.

5.5 Flood related deaths (Metric HE3)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	l	c	U
HE3	Flood related deaths	H	1	2	2	2	2	2	2	2	2

The number of flood related deaths was assessed in the Health Sector (Hames and Vardoulakis, 2012). The analysis not only takes account of flooding from all sources but also overtopping of seawalls by wave action during storms. Flood related deaths as a result of a changing climate are assumed to be proportional to the number of people at risk due to river or tidal flooding. For overtopping of seawalls, flood related deaths are assumed to increase exponentially in relation to changes in mean sea levels. Changes in deaths due to storms are assumed to be negligible. The baseline rate for deaths due to extreme event flooding and storms has been assessed using historic data as 18 per year.

Table 5.2 gives the estimated number of deaths due to future extreme event flooding and storms for the different scenarios, time periods and probability bands considered.

Table 5.2 Annual Additional Flood Related Deaths due to Extreme Event Flooding and Storms

Scenario	2020s			2050s					2080s				
	Med	Med	Med	Low	Low	Med	High	High	Low	Low	Med	High	High
	p_{10}	p_{50}	p_{90}	p_{10}	p_{50}	p_{50}	p_{50}	p_{90}	p_{10}	p_{50}	p_{50}	p_{50}	p_{90}
Total (present day demographics)	22	30	35	24	36	39	42	52	31	44	49	57	87
Climate change effect	4	12	17	6	18	21	24	34	13	26	31	39	69

Note: The climate change effect is those deaths from the total that are attributed to climate change. The difference between the figures is the current baseline estimate of 18 deaths per year.

5.6 Flood related injuries (Metric HE7)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	l	c	u
HE7	Flood related injuries	M	1	1	1	1	2	2	1	2	2

The number of flood related injuries was assessed in the Health Sector. Flood related injuries as a result of a changing climate are assumed to be proportional to the number of deaths due to river and coastal flooding. The baseline rate for injuries due to extreme event flooding and storms is estimated to be 360 per year.

Table 5.3 gives the estimated number of injuries due to future extreme event flooding and storms for the different scenarios, time periods and probability bands considered therefore.

Table 5.3 Annual Additional Flood Related Injuries due to Extreme Event Flooding and Storms

Scenario	2020s			2050s					2080s				
	Med	Med	Med	Low	Low	Med	High	High	Low	Low	Med	High	High
	p_{10}	p_{50}	p_{90}	p_{10}	p_{50}	p_{50}	p_{50}	p_{90}	p_{10}	p_{50}	p_{50}	p_{50}	p_{90}
Total (present day demographics)	440	592	695	485	711	774	834	1043	627	884	984	1131	1742
Climate change Effect	80	232	335	125	351	414	474	683	267	524	624	771	1382

Note: The climate change effect is those injuries from the total that are attributed to climate change. The difference between the figures is the current baseline estimate of 360 injuries per year.

5.7 Mental stress caused by flooding (Metric HE10)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	l	c	u
HE10	Mental stress caused by flooding	M	3	3	3	3	3	3	3	3	3

The effect of floods on mental health was assessed in the Health Sector. Similar to flood related deaths, the effect of floods / storms on mental health as a result of a changing climate are assumed to be proportional to the number of people at risk due to fluvial or tidal flooding.

This metric has been assessed as the number of people who go from a GHQ-12 score of below 4 to 4 or above as a result of a flood event. This is assessed as being between 30-40% of those flooded each year. These results are given in Table 5.4.

Table 5.4 Number of people suffering mental stress as a result of flooding

Annual Number of *Additional* Flood Victims who go from a GHQ-12 score of below 4 to 4 or above as a result of Climate Change (p_{50} estimates only)

Scenario	2020s	2050s			2080s		
	Medium	Low	Medium	High	Low	Medium	High
Total (present day demographics)	3127 - 4169	4309 - 5745	4829 - 6439	5166 - 6887	5392 - 7189	5732 - 7642	6103 - 8138

It should be noted that there is a significant increase by the 2020s (approximately double) from the current baseline of 3512-4683. This is due in part to the considerable number of properties, particularly in regions around the River Humber where a small change in risk may result in a noticeable change in risk of flooding.

5.8 Agricultural land at risk of flooding (Metric FL4)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	l	c	u
FL4a	Agricultural land at risk of flooding (1 in 10 years)	H	2	2	2	2	2	3	2	3	3
FL4b	Agricultural land at risk of regular flooding	H	2	2	2	2	2	3	2	3	3

Figure 5.2 shows the projected increases in area of agricultural land affected by frequent flooding (annual probability 10% or greater) based on the P50 Medium Emissions climate change scenario. The data refer to the area of land with an inundation depth of 0.5 m or greater, and therefore does not include shallow flooding or waterlogging.

The data for Figure 5.2 is contained in Appendix 8. Detailed data for English Areas and Wales for all climate change scenarios is available but is not included in this report.

The data are divided into two Agricultural Land Classification (ALC) categories: Grades 1 to 3, and 4 and 5. Land use in Grades 1 to 3 is mostly arable and horticulture, whereas Grades 4 and 5 are mostly grazing land for livestock. Thus the figures provide an indication of the effects of climate change on arable/horticulture and livestock.

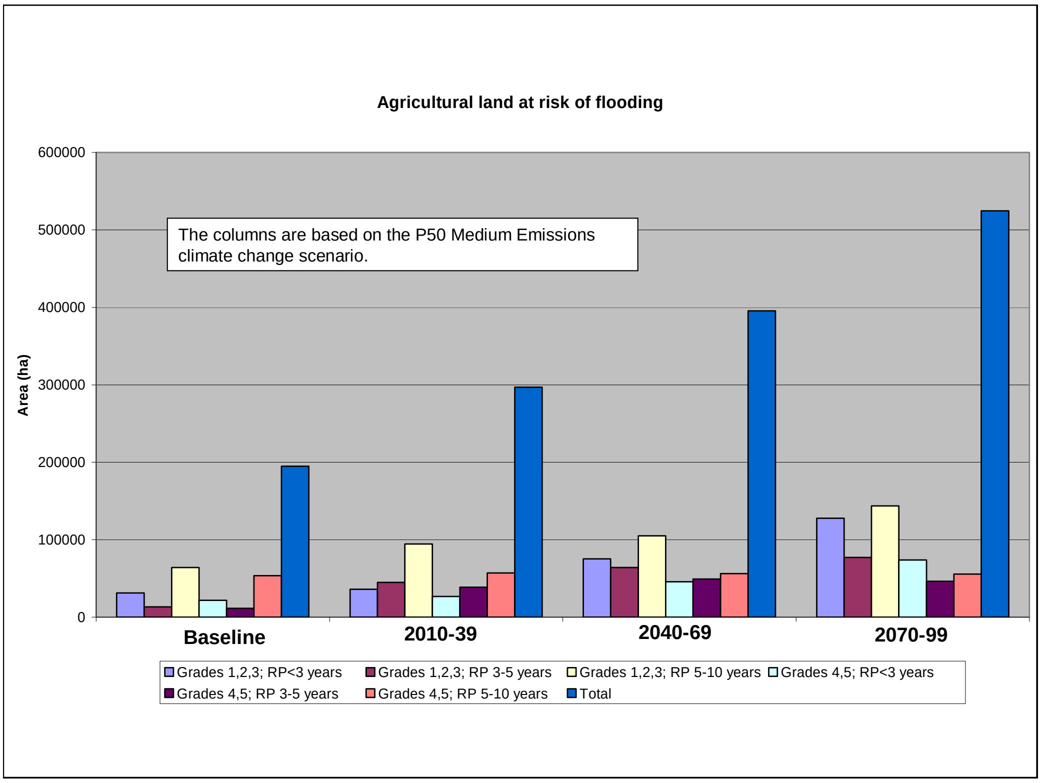


Figure 5.2 Agricultural land at risk of river or tidal flooding

The total amount of agricultural land in England and Wales that has an annual probability of flooding of 10% (1:10) or greater is estimated to be about 200,000 ha (2,000 km^2). It is projected that this may rise to more than 500,000 ha (5,000 km^2) by the 2080s based on the P50 Medium Emissions climate change scenario. This corresponds to an increase from approximately 2% of total agricultural land to about approximately 5% based on the current agricultural land area (11,000,000 ha or 110,000 km^2 in England and Wales (Defra, 2011b)).

Figure 5.2 also shows the projected breakdown between land with different frequencies of flooding. The rate of increase in area of land that could be very frequently flooded (annual probability of flooding of 33% (1:3) or greater) is greater than the overall rate of increase. For example, the amount of land in categories 1, 2 and 3 that could be very frequently flooded is projected to increase from a baseline of about 30,000 ha (300 km^2) to over 120,000 ha (1,200 km^2) in the 2080s. Thus the likely interference to agriculture caused by frequent flooding may increase significantly.

The data are based upon regional growth curves which are used to uplift the present day flood probabilities. The Agricultural Land Classes are based on the ALC, version 1, dated 10/01/2002; however, the original source data was surveyed in 1974. The areas are based on a count of one hectare grid cells where the annual flood probability falls into given return period classes.

This analysis does not cover surface water flooding or waterlogging, which both have a severe impact on agricultural land and production. The results for metric FL4 were used in the Agriculture sector in the assessment of metric AG2. The analysis also does not consider the potential flood risk reduction that could be achieved by flooding of agricultural land as this flood risk management measure is outside the scope of the risk assessment.

5.9 Residential properties at significant likelihood of flooding (Metric FL6)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	l	c	u
FL6a	Number of residential properties at significant likelihood of flooding (tidal and river)	H	2	2	2	2	3	3	2	3	3
FL6b	EAD for residential properties (tidal and river)	H	3	3	3	3	3	3	3	3	3

No. of residential properties at significant likelihood of flooding (Metric FL6a)

The number of residential properties at significant likelihood of river and tidal flooding is projected to range from about 500,000 to 800,000 by the 2020s compared with the baseline of 370,000, rising to between 700,000 to 1.1 million by the 2080s for the range of climate change scenarios selected.

EAD for residential properties (Metric FL6b)

The Expected Annual Damage for residential properties is projected to range from about £750 million to £1.6 billion by the 2020s compared with the baseline of £640 million, rising to about £1.1billion to £3.4 billion by the 2080s for the range of climate change scenarios selected (at present day prices).

These figures cover tidal and river flooding, but not surface water flooding. Further details are given in Section 5.11 below.

5.10 Non-residential properties at significant likelihood of flooding (Metric FL7)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	l	c	u
FL7a	Number of non-residential properties at significant likelihood of flooding (tidal and river)	H	1	3	3	2	3	3	2	3	3
FL7b	EAD for non-residential properties (river and tidal)	H	2	3	3	3	3	3	3	3	3

No. of non-residential properties at significant likelihood of flooding (Metric FL7a)

The number of non-residential properties at significant likelihood of river and tidal flooding is projected to range from about 200,000 to 350,000 by the 2020s compared with the baseline of 190,000, rising to about 300,000 to 400,000 by the 2080s for the range of climate change scenarios selected.

EAD for non-residential properties (Metric FL7b)

The Expected Annual Damage for non-residential properties is projected to range from about £650 million to £1.4 billion by the 2020s compared with the baseline of £560 million, rising to about £1 billion to £2.7 billion by the 2080s for the range of climate change scenarios selected (at present day prices).

These figures cover tidal and river flooding, but not surface water flooding. Further details are given in Section 5.11 below. The results for metric FL7 were used in the Business sector in the assessment of metric BU4.

5.11 Total numbers of properties and EAD

The number of properties (residential and non-residential) at significant likelihood of river or tidal flooding is shown on Figure 5.3 and the EAD is shown on Figure 5.4. The total numbers of properties and EAD are summarised in Table 5.5.

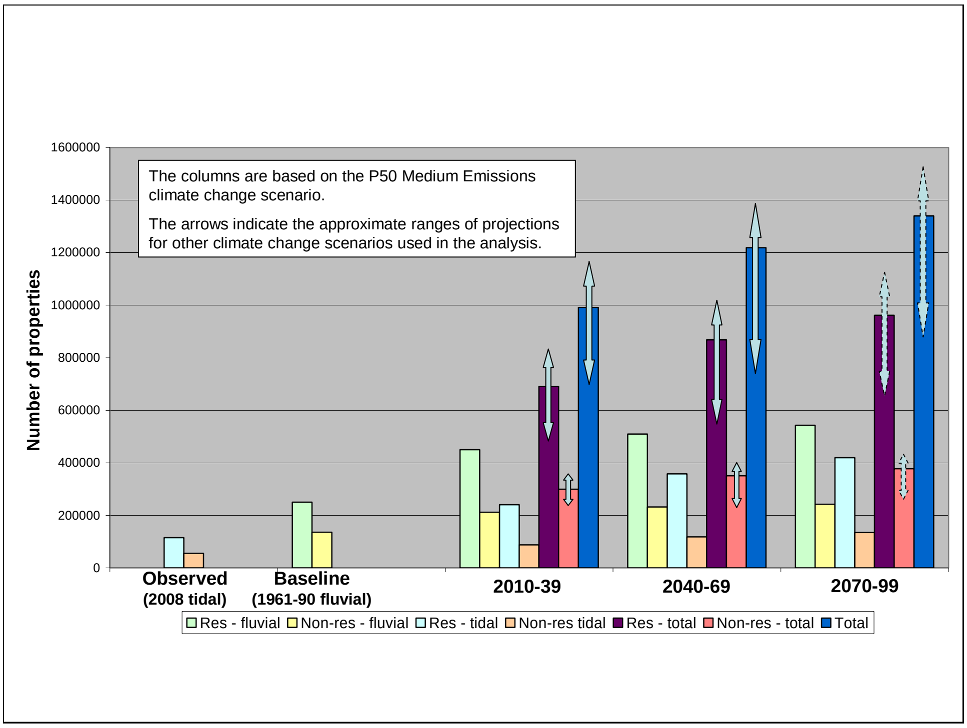


Figure 5.3 Number of properties at significant likelihood of river or tidal flooding

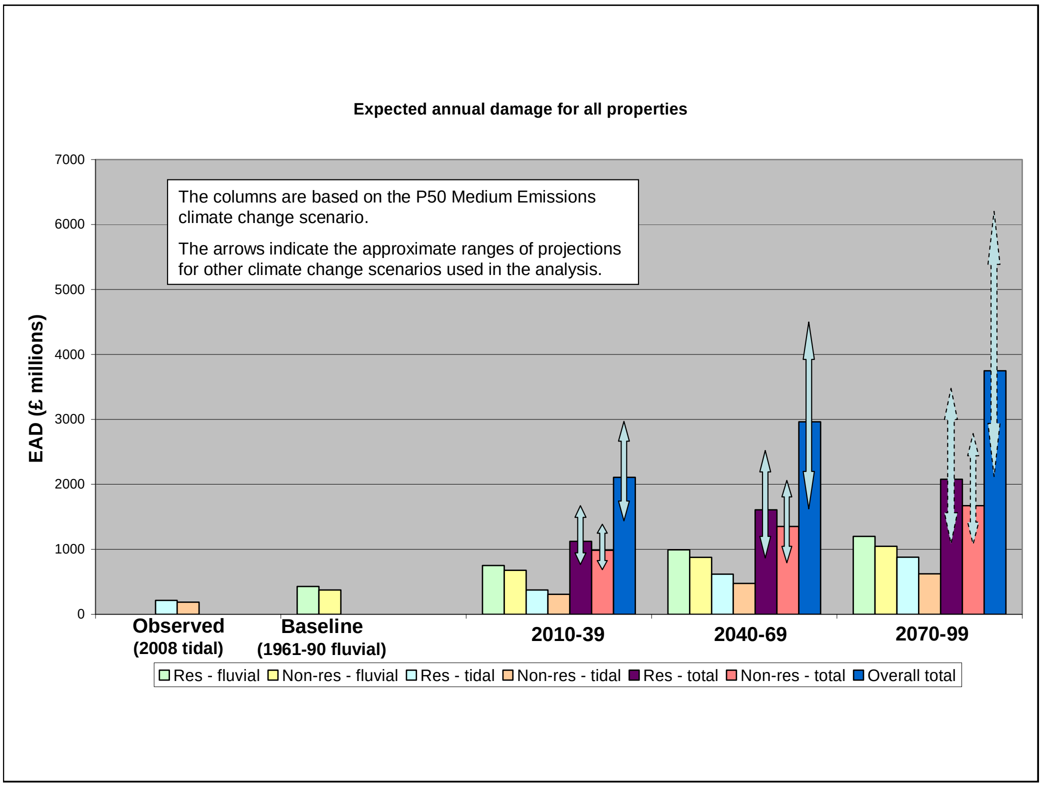


Figure 5.4 Property EAD for river or tidal flooding (residential and non-residential)

Table 5.5 Total properties and EAD from metrics FL6 and FL7
River and tidal flooding only; climate change only
Baseline: 1961-90 (river); 2008 (tidal)

Year	Properties (thousands)			EAD (£ millions)		
	Res	Non-res	Total	Res	Non-res	Total
Baseline	370	190	560	640	560	1200
2020s	470 – 820	230 – 340	700 – 1160	750 – 1600	650 – 1350	1400 – 2950
2050s	530 – 1000	240 – 380	770 – 1380	900 – 2450	750 – 2000	1650 – 4450
2080s	690 – 1090	290 – 410	980 – 1500	1150 – 3450	950 – 2700	2100 – 6150

It may be concluded that:

- The median projection for the total number of properties at significant likelihood of flooding is an increase to about 1.3 million by the 2080s if the defences are maintained to present crest levels and condition.
- The median projection for the total number of properties at significant likelihood of flooding shows an increase of about 35% between the 2020s and the 2080s.
- The median projection for the Expected Annual Damage to properties from flooding is an increase to over £3.5 billion by the 2080s if the defences are maintained to present crest levels and condition.
- The median projection for the Expected Annual Damage to properties from flooding shows an increase of about 75% between the 2020s and the 2080s.

These figures cover tidal and river flooding, but not surface water flooding. It is provisionally estimated that there is a total of about 2.8 million properties at risk from river and tidal flooding in the UK. It is also estimated that there are about 4.2 million properties at risk from surface water flooding, about a million of which are also at risk from tidal or river flooding (Section 1.3.1).

Work is being undertaken by the Environment Agency to improve the estimates for surface water flooding and provide projections for future flooding. Most properties at risk of surface water flooding are not protected by defences. The rate of growth in the number of properties at significant likelihood of surface water flooding is therefore likely to differ from that for river and tidal flooding.

There are estimated to be more properties exposed to the risk of surface water flooding than river and tidal flooding. There is therefore an urgent need to develop projections of future surface water flood risk for the next CCRA.

5.12 An increase in monetary losses as a result of an increasing proportion of UK tourist assets (natural and built) at risk from flooding (Metric BU2)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	U	l	c	U
BU2	An increase in monetary losses as a result of an increasing proportion of UK tourist assets (natural and built) at risk from flooding.	H	1	1	2	2	2	3	2	3	3

This metric was assessed in the Business sector and considers the impact of climate change on:

1. Natural tourism assets, by exploring the impact of sea level rise on beach area.
2. Built tourism assets and infrastructure, by assessing the numbers of tourist visitor attractions and facilities that are at risk from flooding and the associated increase in monetary losses.

Loss of beach area due to sea level rise

In order to gain an appreciation of the magnitude of the risk from projected sea level rise to natural tourist assets, a high level assessment of the potential loss of beach area was undertaken.

The results showed that 3 to 16 km^2 (300-1600 hectares) of beach is projected to be lost by the 2020s, rising to between 12 and 61 km^2 (1,200 – 6,100 hectares) by the 2080s, which is between approximately 3% and 7% of total beach area. The consequence of the estimated change in beach area is to contribute to increased pressure for space on beaches, particularly where demand is already high in the summer months and potentially may increase in the future. Beaches provide a natural defence against wave action and erosion, and the loss of beach area could contribute to an increase in flooding and erosion damage.

The analysis did not include most of the inhabited islands around the UK. The Environment Agency is in the process of compiling a more detailed dataset which would enable a more detailed estimate to be made for England and Wales. This information should be available for the next CCRA.

Flood risk to tourist visitor attractions and facilities

Flooding is expected to increase in the winter as a result of increased winter rainfall. The increasing trend in the UK to cater for visitors all year round means that the tourism industry may be impacted, with tourist attractions and facilities damaged by floods. In addition, as the temperature rises it is likely that the frequency and magnitude of intense summer storms may increase.

Tourists are particularly active in the outdoors during the summer season and as a consequence may be impacted by this change in the climate. As an illustration, the box below describes the impacts of the floods of 2007 on the UK's tourism and leisure sector.

Impacts of floods of summer 2007 on tourism and leisure sector
During the 2007 floods, businesses in the tourism and leisure sector suffered with an overall reduction in customers and lost revenue. There were some benefits for the industry, for example some hotels benefited from people displaced by the floods and the demand for takeaways increased with people unable to cook. English Heritage and National Trust visitor attractions were significantly affected by the floods as well as a number of World Heritage Sites, suffering both physical damage and lost revenue. World Heritage Sites affected included Birdoswald Roman Fort (part of the Hadrian's Wall Site), Fountains Abbey, Ironbridge Gorge, Derwent Valley Mills and Blenheim Palace. Many listed properties were also affected.

(Source: Pitt, 2008)

About 33,000 buildings within the tourism and leisure sector were identified as being within Flood Zone 3 (High Risk) based on Environment Agency mapping. These include Listed Buildings, churches, a range of tourist buildings and assets, art galleries, theatres and museums.

The flood frequency data referred to in Section 4.6 indicates that the frequency of flooding will increase. In terms of the 1 in 100 year flood (the threshold for assets at risk of fluvial flooding in Flood Zone 3), this is projected on average over the whole of the UK to become approximately twice as frequent by the 2050s and 3 to 5 times more frequent by the 2080s. This provides an approximate indication of the increase in frequency of flooding of tourist assets, although the Flood Zones do not take account of protection provided by the defences.

It was not possible to undertake a more detailed analysis of the impacts because detailed information on flood risk for each of the assets was not available when this assessment was carried out. The financial impact on the tourist industry of flooding of tourism assets was also not fully assessed owing to a lack of suitable information, particularly for historic sites (Baglee *et al.*, 2012).

5.13 Flood damage and interruption costs to business (Metric BU4)

Metric code	**Metric name**	**Confidence**	**Summary Class**								
			2020s			**2050s**			**2080s**		
			l	**c**	**u**	**l**	**c**	**U**	**l**	**c**	**u**
BU4	Flood damage and interruption costs to business	M	1	1	2	1	2	2	2	2	2

The impacts of flooding on business were assessed in the Business sector. The financial impacts of flooding on business and industry assets include:

- Direct damage to buildings, materials and other assets
- Business interruption.

Information from the 2007 floods given below indicates the magnitude of economic costs associated with business activity as a result of a major flood.

Impact of 2007 floods on businesses
Many business properties were flooded during the summer 2007 floods, resulting in damage to premises, equipment and fittings, and loss of stock. They also suffered disruption of business. Estimates of the number of commercial properties flooded were of the order of 7,300 (Pitt, 2008). The ABI subsequently estimated that 8,000 business premises had been affected. In addition to damage costs, some businesses claimed compensation from insurance for disruption to businesses where this involved extra costs and lost income. Overall, the total economic costs associated with business impacts caused by the 2007 floods were estimated as £740 million.

(Source: Environment Agency, 2010)

Metric FL7 provides information on damage to non-residential property, and this gives an indication of the potential increase in damage to industrial and other buildings used by businesses. This metric therefore focuses upon the financial impact on industry arising from business interruption.

The total business interruption costs in the UK for the eight-year period 2002 to 2009 is approximately £150 million, based on insurance claims. The average claims for business interruption for any one year associated with flooding were therefore estimated to be £20m. This provides a baseline for business continuity losses due to flooding at present.

Metric FL7b provides projected increases in Expected Annual Damage (EAD) for non-residential properties in England and Wales. If it is assumed that business interruption costs increase at the same rate as EAD, the costs would increase by about 75% by the 2020s, 140% by the 2050s and 200% by the 2080s (based on the p50 Medium Emissions climate change scenario). These figures do not include socio-economic change.

If it is assumed that the baseline present day business interruption cost is £20 million per year, this would indicate that annual costs could increase to about £35 million by the 2020s, £50 million by the 2050s and £60 million by the 2080s. Whilst these figures are indicative only, they provide an initial suggestion of how business interruption costs could change.

Impacts on sections and divisions of industries

An analysis of business interruption costs caused by flooding for sections and selected divisions of industries was carried out in the Business Sector using the IDBR Standard Industry Classification (SIC) data.

A simplistic approach was adopted in which the average length of business disruption per event was estimated to be 3 days and a number of other simplifying assumptions were made. The resulting costs given are estimates of the cost of lost staff time and do not include other losses, such as those due to damage to buildings or stock, or disruption in the supply chain.

The data covers businesses with a total turnover of about £150 billion and over one million staff. Currently the annual average days lost, based on the analysis set out above, is some 105,000, which is around 0.05% of the staff days of businesses in the floodplain. Using the lost staff days and an average staff cost of £150 (ONS web site) this suggests a value of about £5.8 million. Central estimates for the 2020s, 2050s and 2080s suggest that this may increase by around 30, 40 and 50% respectively.

The most vulnerable section of industry is wholesale and retail followed by finance, insurance and manufacturing. Under various climate change projections this exposure is projected to double by the end of the century.

5.14 Change in output for UK businesses due to an increase in supply chain disruption (Metric BU9)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	C	u	l	c	u	l	c	u
BU9	Change in output for UK businesses due to an increase in supply chain disruption	L	Too Uncertain								

The effects of flooding on supply chains were considered in the Business sector. In recent years, lean supply chains have become the standard. Businesses have invested considerable effort in maximizing efficiency by delivering products to the customer with minimal waste. This is achieved by streamlining operations across all links in the supply chain, from procurement and manufacturing to warehousing and transportation.

Leanness has brought efficiency and cost savings, but it has also resulted in increased risk of disruption. A survey from the Business Continuity Institute, which analysed responses from businesses in 35 countries, showed that over 70% of respondents recorded at least one supply chain disruption in 2010 (BCI, 2010). Adverse weather was the main cause of disruption, with 53% of businesses citing this as contributing to recent supply chain disruption.

Because retail supply chains are complex and dependent on a network of interconnected, yet independent, elements, it is not possible to develop a clear and direct causal link between climate change and supply chain disruption. Many climatic factors (e.g. heat, precipitation, melting, flooding) can disrupt supply chains, making a single response function too simplistic. It was also not possible to identify information that could be used to estimate the cost of supply chain disruption.

It may, however, be concluded that supply chain disruptions are costly to business and can affect company stock price, return on assets, and return on sales. Businesses do not tend to recover quickly from supply chain disruptions. A study on supply chain integrity showed that the share prices of companies affected by supply chain disruptions dropped 9% below the benchmark group, and two-thirds of affected companies were lagging their peers in stock price performance a year after the disruption (PWC, 2008).

Climate change may cause shifts in both average conditions and the frequency and severity of extreme climate events. It may be more difficult to map out and understand supplier relationships (supply chain visibility) and contain costs under continuing climate change. Climate-related disruptions all over the globe may affect suppliers in their own locations, with knock-on risks for UK businesses.

5.15 Roads and railways at significant likelihood of flooding (Metric FL8)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	L	c	u
FL8a	Roads at significant likelihood of flooding (tidal and river)	H	2	2	2	2	2	3	2	3	3
FL8b	Railways at significant likelihood of flooding (tidal and river)	H	2	2	2	2	2	3	2	3	3

The lengths of road and railway at significant likelihood of flooding in England and Wales for different climate change scenarios are given in Appendix 8.

The results show that the projected length of road at significant likelihood of flooding might be between 13,000 and 18,000 km by the 2050s, compared with a baseline of 12,000km, rising to between 14,000 and 19,000 km by the 2080s. The corresponding lengths for rail are between 2,000 and 2,900 km by the 2050s rising to between 2,300 and 3,100 km by the 2080s.

In addition to an increase in the overall length of transport infrastructure that could be affected by flooding, the frequency of flooding of infrastructure that is already in the floodplains is projected to increase.

Major roads and railways in floodplains are often raised above the ground surface on embankments. These embankments are sometimes, but not always, identified in the flood modelling and mapping. There is therefore an added uncertainty in the lengths of road and rail at risk from flooding and it is possible that the length of road and rail at significant likelihood of flooding is overestimated. This uncertainty is likely to reduce with climate change as some raised roads and railways may be overtopped more frequently.

The data are based upon regional growth curves which are used to uplift the present day flood probabilities, which in turn are based on modelled baseline flood probabilities. The present day flood probabilities are aggregated from the base 50 m grid to a mean probability in 100 m grid cells.

Road and rail data are based on the Environment Agency's National Receptor Database which has been converted to a hectare grid coincident with the 100 m probability grid. Roads and rail lengths are based on a count of the hectare grid cells where the annual flood probability exceeds 0.0133 (1:75 year).

This has been converted to a length by assuming a mean length through each cell of 85.25 m . This assumes that within each 100 m x 100 m cell, the road or railway line is a straight line. Each 100 m x 100 m grid cell is counted once for railways and per road class (motorway, A-road, B-Road, minor road) and thus the method does not count multiple railway lines or roads of the same class that run through the same 100 m x 100 m grid cell.

5.16 Disruption and delay caused by flooding of roads (Metric TR1)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	U	L	c	U	l	c	u
TR1	Disruption and delay caused by flooding of roads	L	1	1	1	1	1	2	1	2	3

Disruption and delay caused by flooding of roads was assessed in the Transport sector. The qualitative response function developed for this metric is presented in Section 4.7. Although there is not a direct link between increase in winter precipitation and the number or severity of flooding events, it is likely that increased average winter precipitation would mean an elevated risk.

Bearing this in mind, a qualitative estimate (based on existing literature and expert elicitation) of the level of costs associated with the impact on road users arising from flood related delay and disruption was developed. Based upon this qualitative response function an estimate of potential future risk has been derived through application of the UKCP09 scenarios (see Table 5.6).

The outcome of the assessment shows that cost of disruption from flood is projected to remain relatively low until the 2050s when there may be more significant consequences (at the p90 level for Medium and High Emissions scenarios). By the 2080s, this qualitative estimate indicates a potential for Medium to High risk, equating to an event each year of comparable cost to the summer 2007 flood, or multiple events like the 2000 floods. This risk is calculated at today's costs but it must be underlined that this estimate is highly uncertain.

Table 5.6 Metric TR1 assessment - England

(Qualitative assessment of the impact of delays and disruption arising from flooding)

	Low Emissions			Medium Emissions			High Emissions		
	p10 (dry)	P50 (mid)	p90 (wet)	p10 (dry)	p50 (mid)	p90 (wet)	p10 (dry)	p50 (mid)	p90 (wet)
2020s	0	1	1	0	1	1	0	1	1
2050s	0	1	1	0	1	2	0	1	2
2080s	1	1	2	1	2	3	1	2	3

0	Very low – less than £1 million cost of disruption per year
1	Low – £1 million to £10 million per year
2	Medium – £10 million to £100 million per year
3	High – £100 million to £400 million per year
4	Very high – >£400 million per year

This metric is focused upon risk of flood arising from a wet winter and therefore is likely to underestimate total costs, given the potential for summer flooding such as that experienced in 2007. Coastal impacts associated with sea level rise are also excluded from this estimate.

This metric is focused upon delay and disruption to road users but this is only one element of the cost of the transport related cost of a significant flooding event. Other costs would arise from delays and disruption to rail users and to users of other forms of transport.

The potential for autonomous adaptation via change in driver behaviours is also excluded from this analysis. However, with improved communications networks and the ability to adapt travel routes in response to real time information provided direct to drivers, there is potential for delay costs to be minimised in any one event.

5.17 Scour of bridge foundations (Metric TR6)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	l	c	u
TR6	Scour of bridge foundations	M	1	1	2	1	2	3	1	2	3

Scour of bridge foundations was considered in the Transport sector. There are approximately 155,000 bridges in the UK (Bridle and Sims, 2009). These bridges vary widely in size, type and date with a few dating back to the Middle Ages. With advances in structural design and the understanding of scour, major modern bridges are rarely vulnerable to scour.

In general, it is likely to be pre-20th Century bridges that are most at risk as it is more likely that these structures have shallow foundations and are of unknown construction. For example, old masonry arch bridges may consist of soil fill behind the bridge piers, which when exposed to flowing water is easily washed away.

The continuing failure of bridges shows that under existing conditions there are still a number of bridges that are vulnerable to scour. In the last 10 years there have been at least 9 bridge failures in the UK. This corresponds to a current rate of bridge failures due to scour of about one failure per year. The projected increases in peak flood flow as a result of climate change would increase the scour at bridges and the potential risk of failure.

There is no national bridge register and for many bridges the nature and depth of the foundations are unknown. This means that the data is not available with which to assess the current scour risk at UK bridges. It also implies that data is not available with which to assess the potential increase in risk of scour as a result of climate change. At this stage it is therefore not possible to provide projections of future numbers of bridge failures.

Scour is one of several mechanisms that can lead to bridge failure due to flooding. Flooding events can result in a range of different forcing mechanisms including impact loading on bridges due to floating debris (including vehicles), wash-out of masonry and fill material due to poor maintenance, or a combination of scour and structural failure.

Many of the pre 20th Century bridges are likely to be masonry arch bridges, although an actual number is not possible to determine currently. Bridle and Sims (2009) categorise UK bridge stock into three types of structure: masonry, metal and concrete. Based on data for 1980 and a sample of 48,879 UK bridges out of an estimated 155,000 bridges, about 45% of these structures were brick or masonry arches. These are the bridge type most at risk from scour, suggesting that 45% of bridges are most at risk.

The scour estimates in Section 4.7 have demonstrated the sensitivity of scouring at bridges both to the hydrodynamic forcing from peak flow and also the sediment properties of the site. Scour has been shown to increase linearly with the percentage increase in peak flow from the baseline for gravel and sand bed rivers. However for gravel bed rivers with natural bed armouring, there is the potential for a rapid increase in scour once the armour layer is eroded.

Evaluation of the potential number of bridge failures due to climate change will require information on the bridge assets including foundation depth, hydraulic conditions at each bridge and river channel bed sediment properties. The systematic collection of this information could provide the basis of an improved analysis for the next CCRA.

5.18 Water distribution and treatment installations at risk of flooding (Metric FL10)

There are of the order of 1,000 water pumping stations and treatment works at risk of flooding with an annual probability of 0.1% (1 in 1,000 years) or greater in England and Wales (Environment Agency 2009, Environment Agency Wales, 2009). This represents about 60% of all water installations. About 700 installations are at significant likelihood of flooding.

Projections of the future number of water installations at risk of flooding have not been made owing to a lack of suitable data. One possibility would be to use information from other metrics to estimate the future flood risk to water installations. As the proportion of water installations already in the floodplains is much greater than for other infrastructure, and such an approach would not be suitable. It may however be concluded that:

- The number of water installations in the floodplain is currently very high with about 700 installations at significant likelihood of river and tidal flooding in England and Wales, about 40% of the overall total.
- The number of installations at significant likelihood of flooding is likely to increase under the projected increases in sea level and river flows.
- The frequency of flooding of installations already in the floodplain is likely to increase.

5.19 Power stations and electricity substations at significant likelihood of flooding (Metric FL11)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	l	c	u
FL11a	Power stations at significant likelihood of flooding	M	2	2	2	2	2	3	2	3	3
FL11b	Electricity substations at significant likelihood of flooding	H	2	3	3	2	3	3	3	3	3

Energy generation and distribution installations include power stations and distribution substations. The different types of substations (and total numbers in the UK) are outlined in Table 5.7.

Table 5.7 Types of electricity substations and customers supplied

Substation type	Typical voltage transformation levels	Number of substations in the UK	Typical size	Typical number of customers supplied
National Grid supply point	400kV to 132kV	377	250 m x 250 m	200,000 to 500,000
Grid	132kV to 33kV	1,000	75 m x 75 m	50,000 to 125,000
Primary	33kV to 11kV	4,800	25 m x 25 m	5,000 to 30,000
Secondary/ domestic	11kV to 400/230V	230,000	4 m x 5 m	50 to 500

Note: adapted from ENA technical report 138 (ENA, 2009)

The number of energy installations (power stations and major distribution substations) and energy generation capacity at significant likelihood of flooding in England and Wales are given in Appendix 8.

The results indicate that the number of power stations at significant likelihood of river and tidal flooding is projected to be in the range of 20 to 30 in the 2020s rising to about 30 to 40 by the 2080s. The projected generation capacity at significant likelihood of river and tidal flooding might be in the range of about 10GW to 16GW by the 2020s, rising to 19GW to 25GW by the 2080s assuming the same sites are used. The total generation capacity in England and Wales is about 70GW but this is projected to rise under current improvement plans.

Some power stations in floodplains have local flood protection which reduces their vulnerability to flooding. This local protection was not taken into account in this national analysis. It is therefore possible that the number of installations at significant likelihood of flooding in 2008 is overestimated.

The number of major substations (i.e. National Grid supply point substations as categorised in Table 5.7) at significant likelihood of river and tidal flooding is projected to be in the range of 45 to 60 in the 2020s rising to about 55 to 80 by the 2080s. This is out of a total number of 271 major substations in England and Wales.

The data are based upon regional growth curves which are used to uplift the present day flood probabilities, which in turn are based on modelled baseline flood probabilities.

The number of power stations and substations is based on points digitised by HR Wallingford from IPCC licences, the UK TOT Power Station Listing, National Grid 2009 data on substations and background mapping. Power station and substation numbers are based on a count of the number of points in grid cells where the annual flood probability exceeds 0.0133 (1:75 year). The National Grid dataset is for substations transmission site locations in 2009 in England and Wales. This includes 400-132kV substations. Each substation location may include one or more voltage level within that location; these locations are counted as one substation in the analysis as we consider just the major substations. Lower voltage level substations that are served by the major substations may be reconfigured to minimise disruption to supplies.

A separate analysis has been carried out for nuclear sites including proposed new nuclear power stations, radioactive waste stores and decommissioning sites. There are eight proposed new stations, twelve waste stores and sixteen nuclear power station decommissioning sites at a total of nineteen locations.

Because of the importance of these sites, flood and erosion protection is provided where required (regulations require flood protection to a 1 in 10,000 year standard). It is assumed that this protection will be enhanced as required, and this analysis is limited to assessment of the number of sites where enhanced protection will be required.

The analysis shows the following risks to nuclear sites in the UK by the 2080s:

- Of the total of nineteen sites with existing or future nuclear facilities, six would have a high risk of flooding if adequate protection is not provided. Four of these sites and one other site would also have a high risk of coastal erosion.
- Five of the eight sites for new nuclear power stations would have a high risk of flooding if adequate protection is not provided. Three of these sites would also have a high risk of coastal erosion.
- Five of the twelve sites used for radioactive waste storage would have a high risk of flooding if adequate protection is not provided. Four of these sites and one other site would also have a high risk of coastal erosion.
- Five of the sixteen decommissioning sites would have a high risk of flooding if adequate protection is not provided. Four of these sites and one other site would also have a high risk of coastal erosion.

All of the high risk sites are on the coast or estuaries. They may therefore be exposed to sea level rise and coastal erosion. The sites are generally well protected, but sea level rise may gradually reduce the standard of protection unless defences are raised. Similarly, coastal erosion protection may require upgrading over time depending on changes at each site.

The results for metric FL11 were used in the Energy sector in the assessment of metric EN1.

5.20 Hospitals and schools at significant likelihood of flooding (Metric FL12)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	L	c	u
FL12a	Number of hospitals at significant likelihood of flooding	M	2	3	3	3	3	3	3	3	3
FL12b	Number of schools at significant likelihood of flooding	M	2	3	3	3	3	3	3	3	3

The number of hospitals and schools at significant likelihood of flooding in England and Wales for different climate change scenarios are given in Appendix 8.

The results indicate that the number of hospitals at significant likelihood of river and tidal flooding is projected to be in the range of 50 to 70 by the 2020s rising to about 60 to 100 by the 2080s.

The number of primary and secondary schools at significant likelihood of river and tidal flooding is projected to be in the range of 1000 to 1300 by the 2020s rising to about 1200 to 1800 by the 2080s.

The data are based upon regional growth curves which are used to uplift the present day flood probabilities, which in turn are based on modelled baseline flood probabilities. The number of hospitals is based on the NRD property data, using MCM code 660. Hospital and school numbers are based on a count of the number of points in grid cells where the annual flood probability exceeds 0.0133 (1:75 year).

This metric does not cover health centres, GPs practices or flooding of access to hospitals. It therefore only provides an indication of flood risk to health services and community facilities.

5.21 Disruption of ICT due to flooding (Metric BU5)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	l	c	u
BU5	Disruption of ICT due to flooding	L	**Too uncertain**								

Disruption of ICT due to flooding was considered in the Business sector. The UK is heavily reliant on the effective functioning of the Information and Communication Technologies (ICT) sector. For example, 84% of UK businesses are estimated to be heavily dependent on their IT systems.

Weather has already disrupted the provision of services and the increasing dependence on ICT means that the consequences of these weather events could become more significant.

The main vulnerability to environmental conditions is the ICT enabling infrastructure. Elements of the infrastructure which are below ground are vulnerable to flooding, rising water tables, water ingress (particularly during times of snow melt or flooding), subsidence caused by drought or flooding, and consequential risks arising from damage to other elements of the infrastructure.

For example, a flood occurred at a BT exchange in Paddington in March 2010 affected broadband and telephone services across the UK for several hours.

ICT is dependent on electricity supplies, and therefore any failure of supplies arising from climate change will directly impact on ICT systems. Specific risks include the impact of flooding on electricity distribution, for example flooding of substations. Incidents such as the collapse of bridges during floods can also disrupt connections (for example, at Workington in 2009) as bridges are often used as a river crossing for cables and other services.

Whilst it has been acknowledged that weather already has the potential to interrupt or reduce the quality of ICT services, there is as yet very little prior work that specifically considers the potential impacts of flooding on ICT. However, the localised effects of weather-related disruption are projected to increase and could increasingly affect individual businesses and home workers in vulnerable locations.

It has therefore not been possible to provide an estimate of the number of days that might be lost due to disruption to ICT owing to a lack of suitable information. However, from the limited information available, the risk of major ICT disruption due to climate change is considered to be relatively low for large businesses, as they are often based in large urban centres and have flexibility in managing their ICT systems. Rural locations, those at the end of a network/telecommunication line, or served by only one or two networks are most vulnerable to disruption.

Perhaps the greatest risks are the currently unknown potential future impacts of climate change. For example, a major flood event covering a large geographical area could affect many elements of the system leading to widespread failures. These types of major disruptions to ICT could affect all businesses and may take considerable time to restore services.

5.22 No of residential properties at significant likelihood of flooding (to assess insurance impacts) (Metric FL13)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	C	u	l	c	u
FL13	No of residential properties at significant likelihood of flooding (to assess insurance impacts)	M	3	3	3	3	3	3	3	3	3

An assessment of the number of properties where flood insurance may become difficult or more expensive to obtain in the future has been carried out using Metric FL6a, the number of residential properties at significant likelihood of flooding.

The number of residential properties at significant likelihood of river and tidal flooding is projected be in the range of about 450,000 to 800,000 by the 2020s, rising to between 700,000 and 1.1 million by the 2080s for climate change only. The total number of people affected might be of the order of 1.6 million to 2.8 million by the 2080s.

These figures do not include flooding from other sources (particularly surface water and groundwater). The figures in Section 1.3.1 suggest that the total number of properties could double if surface water flooding is taken into account.

The figures given above are for existing properties (i.e. not new properties, which might include measures to reduce flood risk). The way in which the insurance industry will respond to the increase in flood risk is uncertain. For the purposes of this analysis, the figures provide an indication of the number of properties that either might not be able to obtain flood insurance cover or where premiums could increase to cover flood risk.

The results for metric FL13 were used in the Business sector in the assessment of metrics BU6 and BU7.

5.23 Number of homes where mortgage provision may be at risk (Metric BU6)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	l	c	u
BU6	Number of homes where mortgage provision may be at risk	L	2	2	2	2	2	2	2	2	3

The number of homes where mortgage provision may be at risk was assessed in the Business sector.

Climate change is projected to cause an increase in flood probability to properties throughout the UK, including flooding from tidal, fluvial and surface water sources. As the probability of flooding increases, insurance for properties that flood relatively frequently may be increasingly difficult to obtain. There are already cases in the UK where property insurance is either not obtainable or very expensive.

Within the UK, there is a long standing link between the insurability and mortgageability of a property. Mortgage lenders offer a loan against the value of a property, usually with up to a 25-30 year contract to the borrower. It is a standard condition of all mortgages for the property to be covered by standard buildings insurance, including flood cover, for the full term of the contract, in order to protect the borrower and the lender.

There is a risk that insurance may be more difficult or more expensive to obtain in areas of increasing flood risk. Consequences could include the following:

- Lenders and borrowers would be exposed to an increased risk of loss on properties where the cost of insurance becomes unaffordable for the borrower.
- House buyers may not be able to obtain new mortgages on properties where the risk of flooding is considered unacceptable by insurers or flood insurance is very expensive.
- The amount of mortgage lending could reduce as house buyers would not be able to obtain mortgages on properties where insurance is difficult to obtain.

This metric is concerned with the impact of increasing flood risk on mortgage lending revenues. There is an associated issue of asset devaluation if insurers consider the risk of flooding to be unacceptable or flood insurance is very expensive.

For the purposes of this analysis, the number of residential properties at significant likelihood of flooding (Metric FL6a) is used as an indicator of the impact of flooding on the availability of insurance, and consequently on the level of mortgage lending exposed. It is estimated that there are about 370,000 residential properties in the UK at significant likelihood of flooding out of a total of a 24.3 million residential properties. This is projected to rise to between 530,000 and 1.5 million by the 2050s and between 700,000 and 2.1 million by the 2080s. This provides an indication of the potential rate of increase of the number of residential properties with a high risk of flooding.

This risk is converted to mortgage lending risk by taking a proportion of the value of mortgages on properties at significant likelihood of flooding. The results are presented nationally for England and Wales.

The mortgage fund value at risk due to insurance becoming unaffordable or unavailable may be of the order of £1 to 8 billion by the 2050s and £2 to 9 billion by the 2080s, assuming the value at risk is 5% to 15% of the total value at significant likelihood of flooding, and that this does not spur cost-effective adaptation activity. The analysis and assumptions used for this metric are set out in the Business Sector Report (Baglee *et al.*, 2012).

5.24 Increase in payout costs by the insurance industry due to flooding (Metric BU7)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	l	C	u
BU7	Increase in payout costs by the insurance industry due to flooding	M	3	3	3	3	3	3	3	3	3

As a whole, the insurance industry has seen an increase in weather-related claims over recent decades, largely due to an increasing number of extreme events (Baglee *et al.*, 2012). Increase in payout costs by the insurance industry due to flooding was assessed in the Business sector.

The unusually widespread and severe flooding of summer 2007 is a good example where payout costs can exceed expectations, leading to a loss to the insurance industry. It has been estimated that about £3 billion of the summer 2007 loss was covered by insurance, with insurers receiving about 165,000 claims. The flooding of 2007 led to an estimated underwriting loss for the UK property insurance market of £1.5 billion (ABI, 2010).

Increases in flooding as a result of climate change could lead to increases in both the level of premiums charged and level of capital required by insurance companies. For example, for a 4 °C temperature rise, insured flood losses in the UK could lead to insurance rate increases of 21% and a further £1.9 billion could be added to the £5.9 billion capital requirement (ABI, 2009).

The baseline insurance claim data is taken to be the UK average from between 2001 and 2009 (for commercial and domestic property). Excluding data from 2007 (given the extreme level of this event), an estimated average annual claim for flooding in the domestic sector is calculated to be approximately £135m and for commercial property approximately £70m. If the 2007 event is included, these average figures (for the nine-year period) are about £180 million and £100 million respectively.

The number of properties at significant likelihood of flooding is used to provide an indication of how payout costs might change in the future (i.e. metrics FL6 and FL7). The projected change in the number of properties at risk for different climate change scenarios is used to scale the baseline value of insurance claims.

The outcome of the estimation process is that the combined domestic and commercial claims could increase by between 25% and 100% by the 2020s, rising to between 2 and 5 times by the 2080s. This equates to an estimate average annual total claim for flood related damage of the order of £500 million to £1bn a year by the 2080s (based on present day costs). This is about a third of the total weather-related insurance claims in the record year of 2007.

5.25 Area of SAM sites at significant likelihood of flooding (Metric FL15)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	l	c	u
FL15	Area of SAM sites at significant likelihood of flooding	H	1	2	2	2	3	3	2	3	3

The area of Scheduled Ancient Monuments (SAM) was selected as a metric to represent the impact of flooding on cultural heritage because information is readily available, although it is recognised that there are many aspects of cultural heritage that are not covered (for example, listed buildings).

The areas of SAM sites at significant likelihood of flooding are given in Appendix 8. The results show a gradual increase in the projected area of SAM sites at risk from about 7,000 to 9,000 hectares by the 2020s rising to about 7,500 to 10,000 hectares by the 2080s. The area is equally divided between river and tidal floodplains.

The data are based upon regional growth curves which are used to uplift the present day flood probabilities, which in turn are based on modelled baseline flood probabilities.

5.26 Change in CSO spill frequency (Metric WA10)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	l	c	u
WA10	Change in CSO spill frequency	L	1	1	1	2	2	2	3	3	3

Changes in CSO spill frequency was assessed in the Water sector. As mentioned in Section 4.7, analysis of UKCP09 Weather Generator outputs was required for this metric to estimate the frequency of heavy rainfall events that may cause CSO spills. This analysis was completed for London, Glasgow, Cardiff and Belfast, and simply counted the number of storms of different rainfall depths up to a total storm depth of 60 mm.

Figure 5.5 shows the number of heavy rainfall events in central London of different total depths and durations for the 1961-1990 period while Figure 5.6 shows the number of heavy rainfall events for the 2080s Medium Emissions scenario. The short duration events (>10 mm in 1 hour, >20 mm in 3 hours) are relevant for CSO spill frequency. The figures show that the frequency of short intense events does not markedly change, and may go up or down for this site.

Of greater concern for surface water flooding in general is the projected increase in larger and longer duration storms. For example, the number of 6 hour storms greater than 30 mm is projected to double by the 2080s.

A similar picture is evident for Glasgow, Cardiff and Belfast with little change in the one hour events and an increase in the longer duration heavy rainfall events. The potential impacts appear to be greater in London and Glasgow for the specific grid squares considered, as shown in Figure 5.7.

This information was used in the discussion of future increases in surface water flooding (Section 5.2), as the increases in the larger and longer duration events are likely to cause significant increases in potential future surface water flooding.

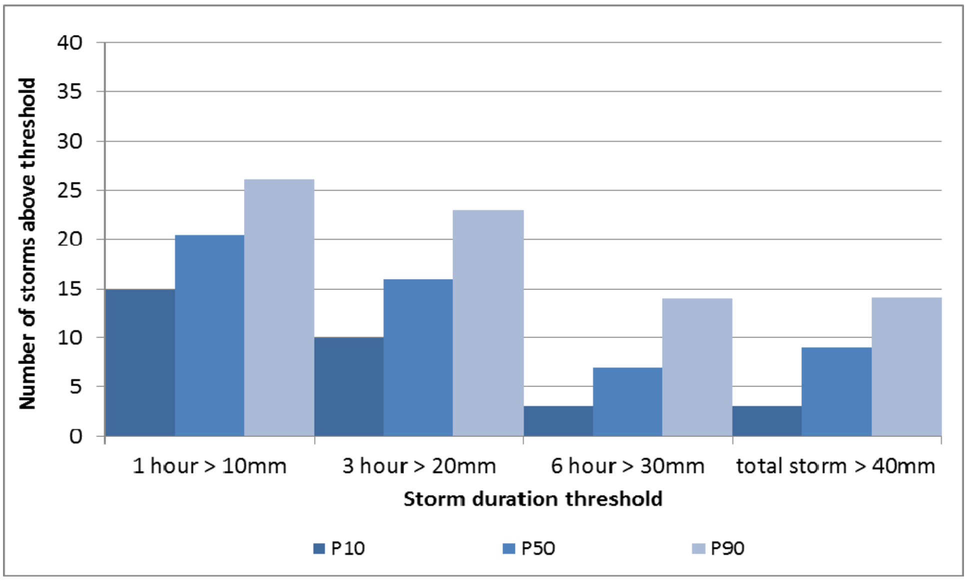


Figure 5.5 Analysis of the number of heavy rainfall events in London for 1961-1990

Medium Emissions scenario; single 25 km grid square; results from 100 WG runs

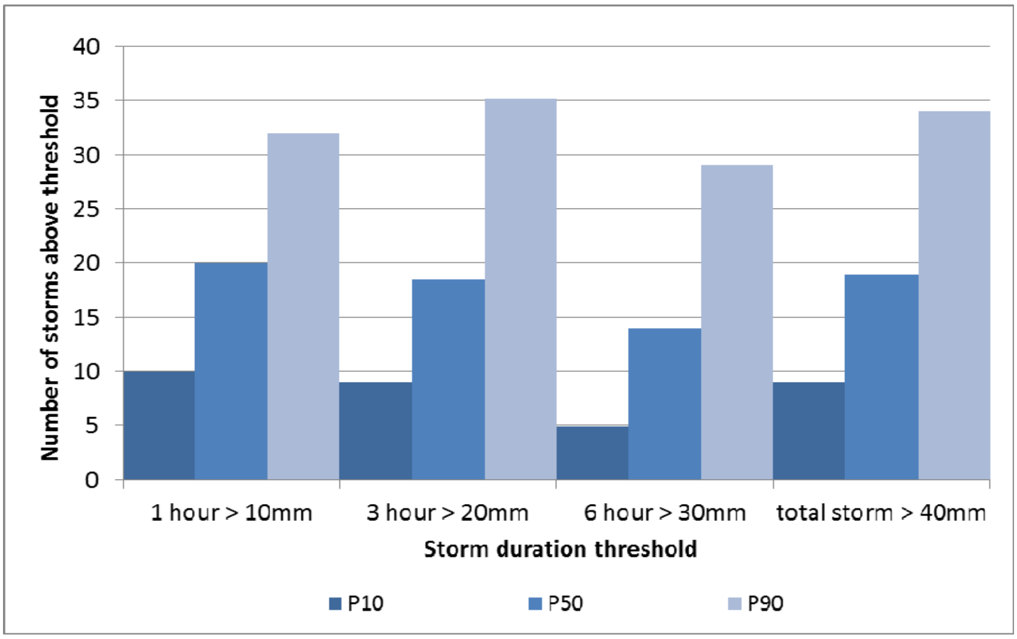


Figure 5.6 Analysis of the number of heavy rainfall events in London for the 2080s

Medium Emissions scenario; single 25 km grid square; results from 100 WG runs

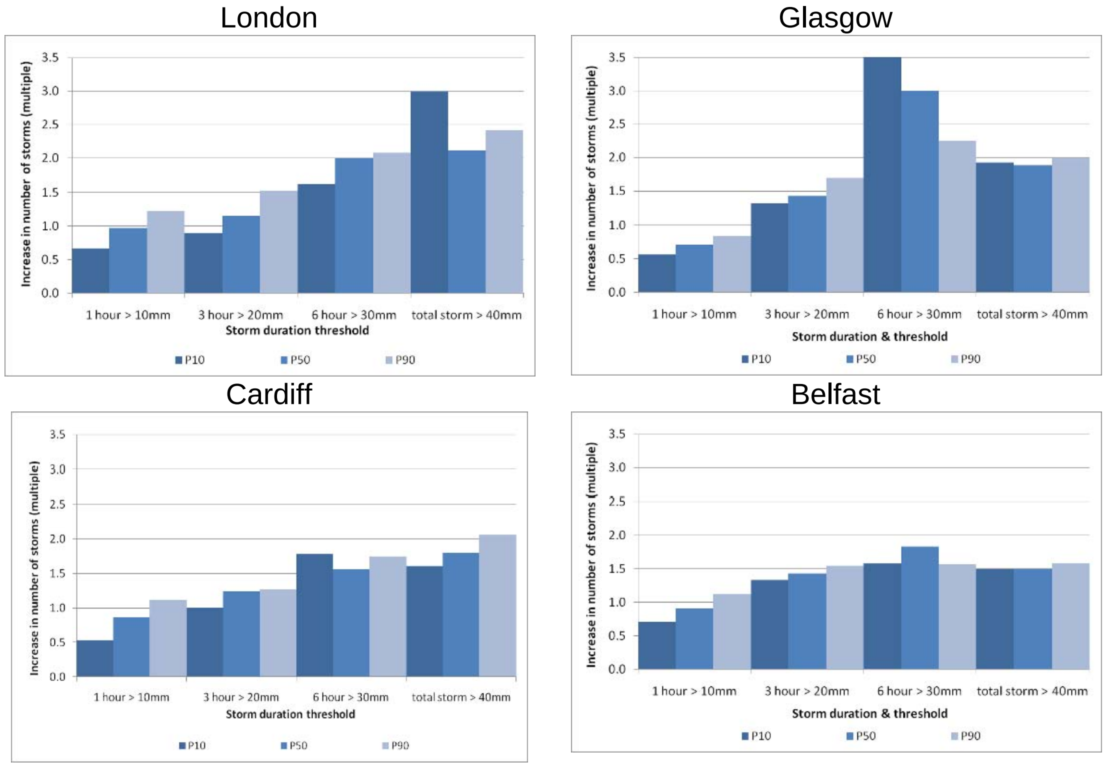


Figure 5.7 Change in frequency of heavy rainfall events for (a) London, (b) Glasgow, (c) Cardiff and (d) Belfast

5.27 Coastal erosion: Area of land lost (including agricultural land and BAP habitats) (Metric FL14)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	l	c	u
FL14a	Area of agricultural land lost due to coastal erosion	H	1	1	1	1	2	2	2	2	3
FL14b	Area of BAP habitat lost due to coastal erosion	H	1	1	1	2	2	2	2	2	3

The metric values calculated in this section are based on the assumptions in Section 4.5.6. In particular, it is assumed that existing defences will deteriorate for coastal erosion except in urban areas, where it is assumed that the present defence line will be maintained. No other adaptation measures are assumed in the analysis.

Coastal erosion will happen whether or not climate change occurs. Rates of erosion vary around the coast but the majority of values are in the range of 0.1 to 1 m per year. The rates are predicted to increase by factors of typically 2 to 5 depending on the scenarios considered (OST, 2003). Much of the projected increase is attributed to sea level rise and therefore to climate change, as discussed in Section 9.2.6.

The erosion projections are total areas of land lost using predicted future erosion rates, and are summarised in Table 5.8 for the range of climate scenarios used in the analysis. Data are given in Appendix 8 for agricultural land lost in England and Wales (Metric FL14a), and for BAP habitats lost in the England (Metric FL14b). It is recognised that the analysis does not cover all designated sites. This analysis therefore does not provide a complete assessment of the impacts of coastal erosion on all habitats.

Table 5.8 Land lost to coastal erosion (Metrics FL14a and FL14b)

Year	Agricultural land lost - England and Wales (ha) (Metric FL14a)	BAP habitat lost - England (ha) (Metric FL14b)
2008	-	-
2020s	1200 - 1500	30 - 50
2050s	3500 - 6000	140 - 280
2080s	6500 - 10000	280 - 540

The projected area of agricultural land lost by the 2080s represents about 0.06% to 0.09% of the total area of agricultural land (about 11,000,000 ha or 110,000km^2 (Defra, 2011b) in England and Wales. These estimates are tentative because they have been made using a simple analysis based on old data. Better data exists but was not made available for the CCRA project (Section 4.3.2).

The data used in this analysis are based on Defra's Futurecoast project but it was not possible to access detailed additional data, for example the data used to create the graphs of beach erosion. Thus the only data available for the assessments of the present rate of erosion was from Cliff Behaviour Units, which give no erosion rates where there are no cliffs. The analysis is limited to England and Wales and does not cover Scotland and Northern Ireland.

The analysis has involved re-scaling the Futurecoast rates using the Foresight future rates, Foresight future sea level rise and the CCRA sea level rise. This means that the analysis takes present rates and projects them everywhere regardless of any consideration of solid geology or defences that may be currently in place.

5.28 Coastal evolution impacts on coastal and estuary habitats (Metric BD2)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	l	c	u
BD2	Coastal evolution impacts on intertidal, grazing marsh etc.	M	1	2	2	2	2	2	2	3	3

Coastal evolution impacts on coastal and estuary habitats were assessed in the Biodiversity sector using the coastal erosion analysis presented in FL14b plus additional literature review.

A European-scale study of coastal erosion (Eurosion, 2004) found that over 17% of the coastline of the UK coast was experiencing erosion. Table 5.9 presents the breakdown of this for countries within the UK and also for regions of England. The table shows that about 3,000 km (17%) of the coast is currently eroding.

Table 5.9 Coastal erosion and coastal defences in the UK

[NB. Figures in the last 2 columns show that some eroding coasts can also have artificial defences]

Source: Eurosion (2004)

	Coast Length (km)	Length of Coast Eroding (km)	Length of Coast with Defences and Artificial Beaches (km)
Country			
England	4,273	1,275 (30%)	1,947 (46%)
Wales	1,498	346 (23%)	415 (28%)
Scotland	11,154	1,298 (12%)	733 (7%)
Northern Ireland	456	89 (20%)	90 (20%)
UK Total	**17,381**	**3,008 (17%)**	**3,185 (18%)**
England by Region			
North-East England	297	80 (27%)	111 (37%)
North-West England	659	122 (19%)	329 (50%)
Yorkshire and the Humber	361	203 (56%)	156 (43%)
East Midlands	234	21 (9%)	234 (100%)
East of England	555	168 (30%)	382 (69%)
South-East England	788	244 (31%)	429 (54%)
South-West England	1,379	437 (32%)	306 (22%)

The Foresight coastal flooding project, completed in 2004, found that 28% of the combined English and Welsh coast was experiencing erosion rates greater than 10 centimetres per year (Evans *et al*., 2004). However, some areas experience significantly greater erosion than this. For example, areas of Suffolk comprising boulder clay and sand cliffs are typically lost at a rate of between 1 and 4 metres per year.

Lee (2001) used a simple model to predict areas of habitat change over the next 50 years within three different environmental designations (SAC, SPA and Ramsar) in England and Wales. The predicted changes were based upon a review of available Shoreline Management Plans (SMPs) with regional workshops, and assumed that current and projected plans would be implemented over the long-term. The analysis adopted rates of sea level rise based on Defra guidance and broadly linked to the UKCIP02 projections. Habitat gains occurred from managed realignment and accretion, whilst losses occurred due to coastal squeeze, managed realignment and erosion. This showed that there would be a net loss of coastal dry land, wetland and open water habitat of approximately 4,000 hectares from protected sites in England and Wales over the next 50 years. He also noted that there could be a net gain of intertidal habitats (saltmarsh and mudflat/sandflat) of some 2,220 ha, although this is based on the assumption that much of the gains come from managed realignment programmes to offset the losses due to coastal squeeze and erosion of the unprotected coast.

The habitat datasets for coastal floodplain and grazing marsh, deciduous woodland, fen, purple moor grass and rush pasture, reedbed and saline lagoons from Defra project CR0422 have been used by the CCRA (as discussed in Section 5.27) to model the projected loss of habitat extent due to coastal erosion using the UKCP09 projections across three epochs (2020s, 2050s and 2080s). The results are summarised in Table 5.8 and are presented in more detail in Appendix 8.

This assessment only used a selection of priority BAP habitats and does not take account of marine-related habitats (e.g. salt marsh, coastal vegetated shingle) that may also be lost. In addition, other habitats not included in the CCRA analysis are dry lowland habitats, such as coastal sand dunes, eutrophic standing waters (ponds and lakes) and lowland heathland. Quantification of habitat losses for Wales, Scotland or Northern Ireland is not available at present. The total amount of BAP habitat loss due to coastal evolution is therefore very likely to be higher.

5.29 Major coastal flood / reconfiguration (Metric BD7)

Metric code	Metric name	Confidence	Summary Class								
			2020s			2050s			2080s		
			l	c	u	l	c	u	l	c	u
BD7	Major coastal flood / reconfiguration	M	1	2	3	2	2	3	2	3	3

Impacts of coastal flooding and reconfiguration on freshwater habitats were assessed in the Biodiversity sector. The joint Defra/Environment Agency NEOCOMER[11] project (Defra, 2006) predicted potential losses of habitats from Natura 2000/SSSI/Ramsar sites on the coast and estuaries in England that are vulnerable to flooding from the sea and which are protected by defences.

The study predicted that over 32,000 ha (320 km^2) of habitat within designated sites are vulnerable to coastal flooding (i.e. the extent of the habitat that could be flooded) and potentially needed to be recreated at alternative, more sustainable, locations not subject to coastal inundation. The predicted area comprised 7% inland water bodies and lagoons, 48% grassland and 45% bogs, marshes and swamps.

Defra project CR0422, incorporated analysis of the risk of irreversible damage to selected habitats within the 1:1000 year coastal floodplain of England due to coastal flooding under different scenarios of climate change and defences are either being maintained or degrading. The area at risk of loss increases from approximately 4,600ha by 13.5%[12] to 23%, a maximum average loss of approximately 5,600 (a range of 5,160-5,630 ha) or up to 5.3% of the total area (medium emissions with defences degraded)[13].

Over half of the national resource of coastal and floodplain grazing marsh, reedbed and saline lagoons, and over 30% of lowland raised bog in the derived alternative habitat inventories are situated in the coastal floodplain. This illustrates the importance of this coastal zone in maintaining the national resource of these habitats.

5.30 Consequences of a High++ scenario

No formal assessment has been made of the consequences of flooding for the High++ scenario referred to in Section 4.2.2. This scenario does not have an assigned probability and therefore it is not formally possible to calculate the associated risk.

[11] Neocomer: National Evaluation of the Costs of Meeting Coastal Environmental Requirements
[12] 2100 medium emissions with defences maintained
[13] Note that this is the average loss that could be experienced. This does not translate to the loss that will be experienced every year but rather the average loss that may be experienced at any point in time given the climate change scenario. Actual losses over a year or a decade may be higher or lower.

However, the response functions in Section 4.7 show a levelling off as the sea level rises because there are limited numbers of properties in the floodplains. It is reasonable to assume that the High++ scenario would overtop all tidal defences, and the number of properties in each region affected would be the asymptotic value for the response functions. This means that an estimate of the number of properties at risk from a High++ scenario can be estimated from the asymptotic values of the response functions shown in Figures 4.9 (residential) and 4.13 (non-residential).

The one exception is the Thames Estuary, where the flood defences provide a higher level of protection than elsewhere in the country. In this case the response function continues to rise. The High++ scenario could potentially inundate the entire floodplain on the Thames Estuary, as tidal water levels for an extreme event may overtop all of the defences.

This was demonstrated in the TE2100 study, where extreme sea level rise scenarios were used to predict the flood extent under extreme conditions. The values used for the High++ sea level rise scenario when this work was carried out in 2006 were higher than those projected in UKCP09 (TE2100, 2007).

Assuming that all properties on the Thames Estuary flood during a High++ event, the total number of properties in England and Wales that might flood during a High++ extreme surge tide event is estimated to be about 1.25 million. This is compared with projections from the CCRA analysis in Table 5.10. This very simple estimate has been carried out to provide an indication of the potential impact of a major tidal event that exceeds current projections.

Table 5.10 Properties at risk from tidal flooding: High++ scenario
Climate change only (i.e. no socio economic change)

Scenario	**Estimated number of properties at risk (thousands)** **Tidal flooding only**
Significant likelihood of flooding: Present day	170
Significant likelihood of flooding: 2080s Low p10	450
Significant likelihood of flooding: 2080s Medium p50	550
Significant likelihood of flooding: 2080s High p90	620
High ++	1250

6 Socio-economic Influence on the Projected Consequences

6.1 Socio economic scenarios

The main socio-economic changes used in the Floods and Coastal Erosion sector are increases in population and properties. The values of the assumed increases are given in Appendix 7, and the impacts on future projections of risk metric values discussed in Section 6.2. In addition, the effect of future change has been considered using six sets of socio-economic dimensions that could have an impact on sector risk. These are covered qualitatively in Section 6.3.

Changes in numbers of property and population are assumed to be evenly spread, so that the percentage increase on the floodplains is the same as elsewhere. However, current policies and planning guidance discourage development on the floodplains, and therefore the projections of people and property at risk of flooding taking account of socio economic scenarios are likely to be overestimates.

If no new development occurred on floodplains, future projections for people and property at risk would be the same as those for the climate change only scenarios. In practice the projected increases are likely to be between the climate change only and climate change with socio economic change scenarios, as some development on floodplains is inevitable.

6.2 Consequences of climate change taking account of socio economic change

The consequences of climate change and socio-economic change are tabulated in Appendix 8. This section provides a summary of results where the socio economic changes have been applied.

6.2.1 Number of people at significant likelihood of flooding (Metric FL1)

The projected number of people at significant likelihood of flooding is shown on Figure 6.1 for the P50 Medium Emissions scenario and the ‘Principal’ population growth assumption. The ranges of projections obtained from the analysis are also indicated.

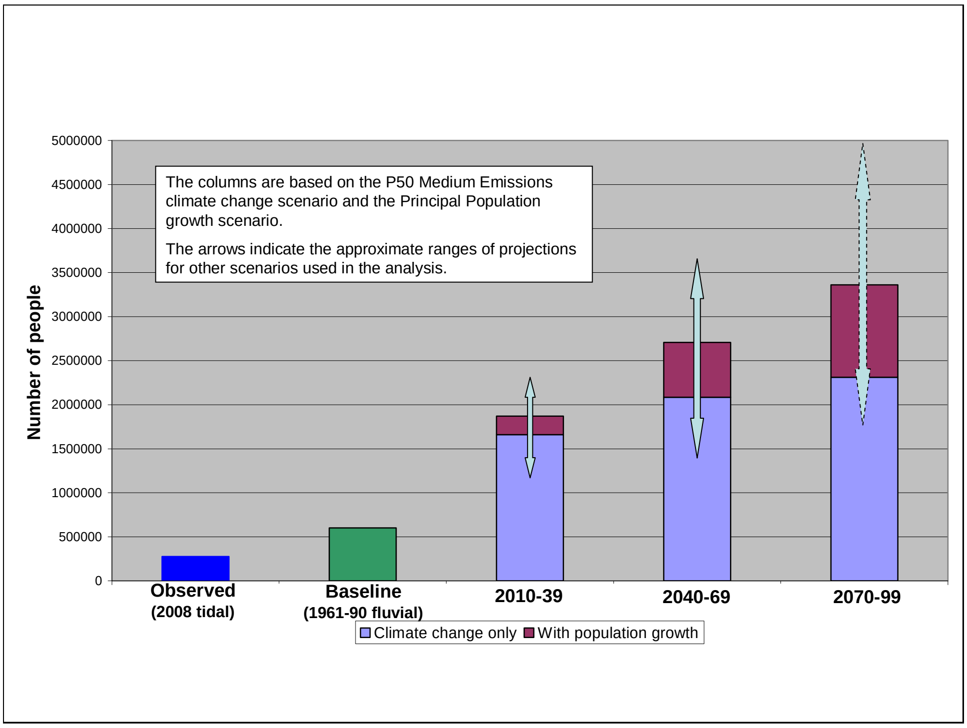


Figure 6.1 Number of people at significant likelihood of tidal and river flooding with population growth

The effect of the population growth scenario is to increase the number of people at significant likelihood of flooding by about 13% (2020s), 30% (2050s) and 45% (2080s). The projected totals are summarised in Table 6.1.

Table 6.1 People at significant likelihood of tidal or river flooding (thousands)

Epoch and climate change scenario	Fluvial	Tidal	Total	Change from 2020s Medium p50 scenario with no population increase (%)
No population increase				
1961-90	600			
2008		280		
2020s Medium p50	1100	580	1680	
2050s Medium p50	1220	860	2080	24
2080s Medium p50	1300	1000	2300	37
'Principal' population growth				
2020s Medium p50	1210	660	1870	11
2050s Medium p50	1580	1130	2710	61
2080s Medium p50	1880	1480	3360	100
2080s 'Low' population growth				
2080s Low p10	890	880	1770	5
2080s Medium p50	1370	1070	2440	45
2080s High p90	1570	1190	2760	64
2080s 'High' population growth				
2080s Low p10	1570	1610	3180	89
2080s Medium p50	2450	1960	4410	163
2080s High p90	2800	2200	5000	198

The results indicate that the projected number of people at significant likelihood of flooding may be in the range of 1.2 million to 2.4 million by the 2020s rising to between 1.7 million and 5 million by the 2080s.

6.2.2 Number of vulnerable people at significant likelihood of flooding (Metric FL2)

The numbers of residential properties in the highest 20% of deprived areas at significant likelihood of flooding show very similar trends to risk metric FL1. The projected number of properties at risk increases by about 45% by the 2080s with the Principal population growth scenario compared with the climate change only case.

The projected number of properties in the highest 20% of deprived areas at significant likelihood of flooding by the 2020s is in the range of 100,000 to 225,000, rising to between 170,000 and 560,000 by the 2080s.

6.2.3 Flood related deaths (Metric HE3)

Flood related deaths as a result of a changing climate are a function of several factors including age, topography or exposure of a site, deprivation levels etc. Flood related deaths are also more common among males as well as the elderly. However, the small number and inconsistent number of deaths reported as a result of extreme flood events means that it is unlikely that mortality rates could be based on anything other than exposure risk to the population as a whole.

For the different scenarios, time periods and probability bands considered as well as the different population projections, Table 6.2 gives the estimated number of additional deaths due to future extreme event flooding and storms. These figures assume that residency rates remain constant at 2.36 people per property as given by the 2001 census.

Table 6.2 Additional flood related deaths per year due to flooding

Population projection	**2020s**			**2050s**					**2080s**				
	Med	Med	Med	Low	Low	Med	High	High	Low	Low	Med	High	High
	p_{10}	p_{50}	p_{90}	p_{10}	p_{50}	p_{50}	p_{50}	p_{90}	p_{10}	p_{50}	p_{50}	p_{50}	p_{90}
Total													
No population growth	22	30	35	24	36	39	42	52	31	44	49	57	87
Low Population Growth (LPG)	23	31	37	26	38	41	44	55	32	46	51	58	89
Principal Population Growth (PPG)	24	32	38	29	43	46	50	61	40	57	62	70	102
High Population Growth (HPG)	25	33	39	32	48	52	55	67	49	69	75	83	116
Climate change and socio economic impact (baseline figure subtracted from total)													
LPG Climate change effect	5	13	19	8	20	23	26	37	14	28	33	40	71
PPG Climate change effect	6	14	20	11	25	28	32	43	22	39	44	52	84
HPG Climate change effect	7	15	21	14	30	34	37	49	31	51	57	65	98

6.2.4 Flood related injuries (Metric HE7)

Flood related injuries due to extreme event flooding are taken as being a function of flood related deaths. This ratio is assumed to remain constant under future socio-economic influences. Residency rates are also assumed to remain constant.

Table 6.3 therefore give the estimated number of injuries due to future extreme weather events (floods and storms) for the different scenarios, time periods and probability bands considered as well as the different population projections.

Table 6.3 Additional flood related injuries per year due to flooding

Population projection	**2020s**			**2050s**					**2080s**				
	Med	Med	Med	Low	Low	Med	High	High	Low	Low	Med	High	High
	p_{10}	p_{50}	p_{90}	p_{10}	p_{50}	p_{50}	p_{50}	p_{90}	p_{10}	p_{50}	p_{50}	p_{50}	p_{90}
Total													
No population growth	440	592	695	485	711	774	834	1043	627	884	984	1131	1742
Low Population Growth	461	623	734	517	760	825	888	1103	648	914	1016	1165	1779
Principal Population Growth	475	644	758	579	854	926	993	1220	808	1130	1240	1398	2033
High Population Growth	490	665	784	645	955	1033	1104	1344	989	1375	1495	1663	2323
Climate change and socio economic impact (baseline figure subtracted from total)													
LPG Climate change effect	101	263	374	157	400	465	528	743	288	554	656	805	1419
PPG Climate change effect	115	284	398	219	494	566	633	860	448	770	880	1038	1673
HPG Climate change effect	130	305	424	285	595	673	744	984	629	1015	1135	1303	1963

6.2.5 Mental stress caused by flooding (Metric HE10)

Flood / storm related effects on mental health are a function of a number of socio-economic factors related to the impacts of flooding on people. However, it is difficult to quantify any of these effects apart from the expected number of flood victims in any one year. This is a function of residency rate which is assumed to remain constant.

Table 6.4 therefore outlines the number of additional people expected to suffer a mental health effect, defined as going from a GHQ-12 of below 4 to 4 or above for the different time periods, emission scenarios and population growths considered in this report.

Table 6.4 Number of people suffering mental stress as a result of flooding (including socio-economic influence)

Annual Number of Additional Flood Victims who go from a GHQ-12 score of below 4 to 4 or above as a result of Climate Change (p_{50} estimates only)

Scenario	2020s	2050s			2080s		
	Medium	Low	Medium	High	Low	Medium	High
No population growth	3127 - 4169	4309 - 5745	4829 - 6439	5166 - 6887	5392 - 7189	5732 - 7642	6103 - 8138
Low Population Growth	3636 - 4849	5100 - 6801	5674 - 7566	6046 - 8062	5898 - 7865	6260 - 8346	6657 - 8876
Principal Population Growth	3969 - 5292	6648 - 8865	7322 - 9763	7760 - 10347	9436 - 12581	9936 - 13247	10483 - 13978
High Population Growth	4312 - 5750	8292 - 11055	9072 - 12095	9580 - 12773	13461 - 17948	14118 - 18824	14834 - 19778

6.2.6 Agricultural land at risk of flooding (Metric FL4)

Future socio economic scenarios have not been applied to the projections for agricultural land at risk of flooding. This is partly because the future scenarios are based on population and properties, but also partly because of uncertainties in the future of agriculture.

It is possible that agricultural production may have to increase to provide for a rising population and greater uncertainties with imported food. This might be achieved through higher yields and/or an increase in agricultural land. It is suggested in the Agricultural Sector that yields could be increased as temperatures rise providing that enough moisture and nutrients are available.

It is clear however that the effects of flooding on agriculture are likely to increase, and must be taken into account in future agricultural planning.

6.2.7 Properties at significant likelihood of flooding (Metrics FL6 and FL7)

The metrics for property show the same trends as population at significant likelihood of flooding, with a projected 45% increase in total numbers of properties at significant likelihood of flooding by the 2080s (under the ‘Principal’ population growth assumption) compared with the climate change only case.

The overall numbers are summarised in Tables 6.5 (properties) and 6.6 (EAD) for the P50 Medium Emissions scenario and the ‘principal’ population growth assumption. Ranges for combinations of climate and socio economic scenarios are also shown.

Table 6.5 Properties at significant likelihood of tidal or river flooding

Epoch	**Properties at risk (thousands)** P50 Medium Emissions climate change scenario Principal population projection		**Properties at risk (thousands)** Range of projections (combining climate and socio economic scenarios)	
	Climate change only	**With population growth**	**Low projection**	**High projection**
2020s	990	1110	760	1580
2050s	1220	1580	840	2100
2080s	1340	1950	1040	2850

Table 6.6 EAD for properties at risk of tidal or river flooding

Epoch	**Expected Annual damages (£ millions)** P50 Medium Emissions climate change scenario Principal population projection		**Expected Annual damages (£ millions)** Range of projections (combining climate and socio economic scenarios)	
	Climate change only	**With population growth**	**Low projection**	**High projection**
2020s	2100	2380	1550	3500
2050s	2960	3840	1770	6800
2080s	3750	5440	2130	11600

The 'Low' projections are based on the P10 Low or Medium Emissions scenario and low population growth. The 'High' projections are based on the P90 Medium or High Emissions scenario and high population growth. The baseline values are about 560,000 properties and an EAD of about £1.2 billion.

The projected number of properties at significant likelihood of flooding in the 2080s for the five climate change scenarios is from about 1 million to 3 million. The projected range of EAD for properties in the 2080s for the five climate change scenarios is from about £2 billion to £12 billion.

6.2.8 UK beaches and fixed tourist assets at risk from flooding (Metric BU2)

There is no simple direct link between projected socio-economic change and tourism assets at risk from flooding. Socio-economic projections have therefore not been applied. However, with an increasing population it is reasonable to assume that existing tourism assets may see increased visitor numbers, particularly if the opportunities for increased tourism as climate changes are realised. Where visitor numbers increase, revenue will rise but this also increases potential loss of income should an asset be flooded. Changes in tourism will affect financial performance of UK-based foreign operators.

6.2.9 Flood damage and interruption costs to business (Metric BU4)

There is no direct link between projected socio-economic change and the financial impact of industry assets at risk from flooding. Socio-economic projections have therefore not been applied. As the population increases there is likely to be increased employment and business activity, indicating that flooding impacts could increase. However the form of increases in business activity is difficult to predict.

For example, the major developments for the financial services sub-sector in London at Canary Wharf are to a large extent above flood level even though they are in a floodplain. However, even where new developments are not at direct risk of flooding, the work force may have limited access to a site during and after an event resulting in reduced productivity and loss.

6.2.10 Supply chain disruption (Metric BU9)

Climate change impacts on UK business supply chains depend on the rate and magnitude of climate change, but also on changes in technology, economics, lifestyles, policy and trade that will affect the capacity both for restricting and adapting to climate change.

This is particularly relevant to a discussion of supply chains, as climate risks on the other side of the globe can have significant repercussions for UK businesses. Analyses of climate risks depend heavily on assumptions about underlying socio-economic developments, which can be explored through the use of socio-economic scenarios describing possible future states of the world.

Within the UK, socio economic change including increasing population may lead to additional disruption, for example in terms of increased congestions on road networks.

6.2.11 Roads and railways at significant likelihood of flooding (Metric FL8)

Future socio economic scenarios have not been applied to the future projections for roads and railways at risk of flooding. This is because the future scenarios do not include assessment of the increases in transport links.

It may however be speculated that the number of links is likely to increase as the population increases and the need for mass transit systems in particular increases. Conversely, an increase in home working and community based economies could reduce the need for transport.

6.2.12 Disruption and delay caused by flooding of roads (Metric TR1)

Future socio economic scenarios have not been applied to future projections of delay and disruption caused to road transport. Whilst future increases in population and changes in economic conditions are likely to lead to changes in the amount of traffic on the roads, there are other factors that could also have a large effect on transport. These include societal changes and changes in modes of transport.

6.2.13 Scour of bridge foundations (Metric TR6)

As the effects of bridge scour generally apply to bridges that are already in existence, socio economic changes are unlikely to have a significant impact on this metric.

6.2.14 Water distribution and treatment installations at risk of flooding (Metric FL10)

It is likely that the number and capacity of water installations will increase under the socio economic scenarios which all show increasing population and property numbers.

However socio economic scenarios have not been applied in this case as it was not possible to produce projections for the climate change only case.

6.2.15 Power stations and electricity substations at significant likelihood of flooding (Metric FL11)

Future socio economic scenarios have not been applied to the future projections for energy generation and distribution. This is because the future scenarios do not include assessment of the increases in energy requirements, or the ways in which future energy will be provided.

It may be speculated that there are likely to be major changes in energy generation including more renewables and more large (nuclear) power stations. Much of the future renewable energy generation (including wind turbines, tidal and hydropower) is likely to be in flood risk areas. For example, some of the wind farms may be offshore and therefore subject to sea level rise and storminess. However renewable energy generation in flood risk areas is likely to be protected against present and future flood risk. The overall impact of future flood risk on energy generation is therefore difficult to predict.

6.2.16 Number of hospitals and schools at significant likelihood of flooding (Metric FL12)

Future socio economic scenarios have not been applied to the future projections for the number of hospitals or schools in flood risk areas. This is because of uncertainty in future hospital and school needs.

A simple assumption would be to assume that the number/cost of hospitals and schools in flood risk areas will increase in line with population projections. However, as hospitals are regarded as vulnerable development in planning terms, it is likely that new hospitals or schools may not be constructed in flood risk areas.

6.2.17 Disruption of ICT due to flooding (Metric BU5)

There is no direct link between projected socio economic change and loss of productivity due to ICT disruption. Socio-economic projections have therefore not been applied. Disruption may however increase as the population and dependence on ICT systems increases.

6.2.18 Insurance of residential properties (Metric FL13)

Projections for the number of residential properties exposed to a 1.3% (1:75) flood probability or greater (i.e. at significant likelihood of flooding) is covered by Metric 6a. The total numbers are given in Table 6.7 below. Further detail is provided in Appendix 8 for Metric 6a.

Table 6.7 Residential properties at significant likelihood of tidal and river flooding: median estimate

Epoch	Residential properties at risk (thousands) P50 Medium Emissions climate change scenario Principal population projection		Residential properties at risk (thousands) Range of projections (combining climate and socio economic scenarios)	
	Climate change only	With population growth	Low projection	High projection
2020s	690	780	510	970
2050s	870	1130	580	1510
2080s	960	1400	730	2080

The ‘Low’ projections are based on the P10 Low or Medium Emissions scenario and low population growth. The ‘High’ projections are based on the P90 Medium or High Emissions scenario and high population growth. The projected range of residential properties at significant likelihood of flooding is between about 700,000 and 2.1 million by the 2080s compared with a baseline of about 370,000.

6.2.19 Number of homes where mortgage provision may be at risk (Metric BU6)

The analysis assumes that the number of properties in flood risk areas will increase in proportion to the increases in population projected in the socio-economic scenarios. It may therefore be reasonably assumed that socio-economic scenarios should be applied to this metric. However new properties in the future are either likely to be built outside flood risk areas or, where development is permitted in flood risk areas, resilience measures are likely to be included to minimise the increase in flood risk (for example, raising floor levels above flood level).

The number of new homes where mortgage provision may be at risk in the future is therefore likely to be small, and socio-economic scenarios have therefore not been applied for this metric.

6.2.20 Increase in payout costs by the insurance industry (Metric BU7)

Given the resolution of the data available and the number of assumptions employed in exploring this risk, socio-economic projections have not been applied. However, as population increases then so will the number of households, increasing the insurance industry’s exposure to weather related claims.

An indication of the socio-economic impacts can be obtained from Table 6.5 which shows the number of properties at risk with and without population growth. The results show for the “Principal” socio-economic scenario an increase of about 30% compared with climate change only results by the 2050s, rising to about 50% by the 2080s.

6.2.21 Area of SAM sites at significant likelihood of flooding (Metric FL15)

Future socio economic scenarios have not been applied to the area of SAM sites as this is generally not linked to the future projections of population and number of properties.

6.2.22 Change in CSO spill frequency (Metric WA10)

The change in CSO spill frequency is influenced by population change as well as technological change. Population needs/demands have a strong effect on CSO spill frequencies both directly (as a greater population will increase sewer flows), and indirectly (as a greater urban area such as new developments will cause higher rates of runoff during storm events, at least at the local scale).

Current legislation would affect the impact that changing CSO spill frequencies would have on meeting WFD requirements, for example if there is a change in water quality objectives. In view of the number of factors to be considered, the impacts of socio-economic change have not been considered for this metric.

6.2.23 Coastal Erosion: Area of land lost (Metric FL14)

Future socio economic scenarios have not been applied to the areas of coastal erosion of agricultural land and BAP habitats as this is generally not linked to future projections of population and number of properties.

6.2.24 Coastal evolution impacts on coastal and estuary habitats (Metric BD2)

Future socio-economic scenarios have not been applied to coastal evolution. However future changes to the coastline will be directly affected by future approaches to managing the coast.

Habitat creation schemes have led to the creation of a range of new coastal habitats including saltmarsh, mudflat and saline lagoons. These schemes not only compensate for losses but also reduce the risk of coastal inundation in some areas.

6.2.25 Major coastal flood / reconfiguration (Metric BD7)

Future socio-economic scenarios have not been applied to coastal flooding. However, the effects of major floods will be affected by the way in which the coast and the associated defences are managed in the future.

Where flood defences are improved to take account of climate change, coastal flood impacts are unlikely to change significantly. However where defences are maintained at the present level or allowed to deteriorate, coastal freshwater habitats will be increasingly subject to inundation by saline water.

6.3 Socio-economic dimensions of climate change

Six sets of socio-economic dimensions have been devised to represent socio-economic factors that have the potential to have a significant impact on the sector risks identified, and also contain a high degree of uncertainty (which makes them unsuitable to model as a forecast). The dimensions are:

- Population needs/demands
- Global stability
- Distribution of wealth

- Consumer driven values and wealth
- Level of Government decision making
- Land use change/management.

6.3.1 Population needs/demands (high/low)

This dimension is intended to encapsulate drivers of population size and distribution (geographically and demographically) and the pressure the population forces onto the country in terms of housing, education etc. In the context of flooding, this dimension affects the increase in number of people exposed to flood risk.

One extreme is that there is a high degree of demand for development, where more people are exposed to flood risks. The other is that demand is low, and the number of additional people exposed to risk is small.

6.3.2 Global stability (high/low)

This dimension describes drivers based on world events that would increase or decrease global stability (e.g. war, natural disasters, economic instability). The extremes are higher global stability (with little pressure on Governments and people) compared to today, and lower global stability (with a high degree of pressure on Governments and people that outweigh other priorities) compared to today.

In the case of high global stability, Governments would be able to focus on domestic issues including flood risk management, and the ability to adapt and manage future risk would increase.

In the case of low global stability, Governments are likely to be more concerned with external affairs and the attention to flood risk management could reduce, resulting in higher future flood risks.

6.3.3 Distribution of wealth (even/uneven)

This dimension considers the distribution of wealth amongst the British population; the extremes being whether it is more even compared with today, or more uneven (with a strong gradient between the rich and poor) compared to today.

Where the distribution of wealth is more even, overall flood risk is likely to reduce. This is because more people would be able to implement risk management measures including suitable insurance and possibly flood proofing of properties. Where the distribution of wealth is more uneven, the number of people who are less able to implement risk management measures is likely to increase.

As the poorer communities would be less able to take such measures as adequate flood insurance and contingency planning, flooding would have a more severe impact leading to a widening of the gap between rich and poor (and increasing demands on Government to support the poor).

The housing market is sensitive to the distribution of wealth. If the provision of insurance in flood risk areas becomes more expensive or difficult to obtain, it would become more difficult to obtain mortgages in these areas. This in turn could lead to an increase in the number of poorer people living in flood risk areas without insurance, hence increasing vulnerability. Homeowners in flood risk areas may also have greater difficulty selling their properties.

6.3.4 Consumer driven values and wealth (sustainable/unsustainable)

Globalisation and consumerism are the primary drivers here, specifically movement towards or away from consumerism values. The extremes are:

a. that consumers prioritise their time for working and the generation of wealth, with a focus on the consumption of material market goods and services compared to today

b. consumers reduce the importance of work and wealth generation in favour of leisure and less materialism, with a focus on the consumption of non-market goods and services such as conservation and recreational activities in green spaces.

These two extremes could be considered as ‘unsustainable’ and ‘sustainable’ respectively. The unsustainable approach could lead to greater investment in flood risk management assets to protect the increasing wealth, but at the same time would lead to an overall increase in vulnerability as the number of assets in the floodplains increase.

In the long term this approach could leave a legacy of high flood risk and high asset maintenance requirements which could prove a burden for future generations.

The sustainable approach would concentrate on flood risk management solutions that reduce the burden on future generations, by minimising increases in flood risk and reducing risk wherever possible (as encapsulated in Defra’s ‘Making Space for Water’ policy).

6.3.5 Level of Government decision making (local/national)

This relates to how centralised policy making is on adaptation; the extremes being whether there is a completely centralised policy compared to today; or whether there is a very small central Government input and high degree of localism in decision making compared to today.

Flood risk management can be regional or local depending on the circumstances. Many flood problems (in local catchments for example) are local but others (for example, flooding from major rivers) are regional.

Centralised decision making would lead to a more strategic approach to flood management, where care is taken not to increase flood risk elsewhere. It also provides consistency of approach, and nationwide dissemination of guidance and good practice.

Localism could be very effective at dealing with specific local problems but would not be effective at dealing with problems related to larger river catchments or coastal cells.

The present approach of centralised direction and local or regional implementation appears to be a good compromise between these extremes.

6.3.6 Land use change/management (high/low Government input)

These dimensions relate to aspects of urbanisation versus rural development. The extremes are that looser planning restrictions might increase development in rural areas (building on the green belt, power stations, etc.) compared to today, versus tighter planning which might increase urban development (more brown field sites) compared to today.

Land use planning is directly related to flood risk. The more control there is in flood risk areas, the smaller the increase in flood risk will be. Looser planning restrictions could not only lead to more development in flood risk areas, but could also result in less consideration of the effects of development on flood risk elsewhere.

7 Economic Impacts

7.1 Summary

Climate change adaptation decisions that are designed to reduce climate change risks inevitably involved making trade-offs concerning the use of scarce economic resources. To the extent that economic efficiency is an important criterion in informing such decision-making, it is useful to express climate change risks in monetary terms, so that they can be:

- Assessed and compared directly (using £ as a common metric) and
- Compared against the costs of reducing such risks by adaptation.

For the CCRA, a monetisation exercise has been undertaken to allow an initial comparison of the relative importance of different risks within and between sectors. Since money is a metric with which people are familiar, it may also serve as an effective way of communicating the possible extent of climate change risks in the UK and help raise awareness.

Where possible, an attempt has been made to express the size of individual risks (as described in this report) in monetary terms (cost per year) however, due to a lack of available data it has sometimes been necessary to use alternative costs (repair or adaption) to provide an estimate. A summary of the results is provided in Table 7.1.

A variety of methods have been used to determine the costs. In broad terms, these methods can be categorised according to whether they are based on:

- Market prices (MP)
- Non-market values (NMV) or
- Informed judgement (IJ).

Informed judgement has been used where there is no quantitative evidence and was based on extrapolation and/or interpretation of existing data.

In general terms, these three categories of method have differing degrees of uncertainty attached to them, with market prices being the most certain and informed judgement being the least certain. It is important to stress that the confidence and uncertainty of consequences differs. Therefore, care must be taken in directly comparing the results. Whilst we attempt to use the best monetary valuation data available, the matching-up of physical and monetary data is to be understood as an approximation only.

Further, it is important to highlight that some results are presented for future climate change scenarios only, whilst others include climate change under assumptions of future socio-economic change.

Table 7.1 emphasises the high degree of uncertainty attached to the estimates of the order of magnitude of potential climate change risks. However, it is worth emphasising the metrics relating to domestic and commercial property flooding, which are High or Very High. These risks are well-known; what is interesting in this table is that both flooding to hospitals and agricultural land also have potentially high costs associated with them.

Table 7.1 Summary of results in £million per annum

(2010 prices, no uplift or discounting) – climate change signal only (current socio-economics) – relative change from baseline period. Medium p50 scenario

Risk metric	2020s	2050s	2080s	Estimation Method	Confidence ranking	Notes
FL1 People at significant likelihood of flooding.	-	-	-	-		Included in FL6
FL2 Vulnerable people at significant likelihood of flooding.	-	-	-	-		Included in FL6
HE3 Flood related deaths.	-M	-M	-M	Non-Market Value	L	
HE7 Flood related injuries.	-M	-M	-M	Non-Market Value/ Market Price	M	
HE10 Mental stress caused by flooding.	-L	-L	-L	Non-Market Value/ Market Price	L	
FL4 Agricultural land at risk of flooding.	-M	-M	-H	Market Price	M	Links to agriculture, and overlaps with AG2. Double-counting if summed.
FL6 Residential properties at significant likelihood of flooding and EAD.	-H	-H	-VH	Market Price	H	Property damage costs based on replacement costs and can be seen as adaptation costs.
FL7 Non-residential properties at significant likelihood of flooding and EAD.	-H	-H	-VH	Market Price	H	Property damage costs based on replacement costs and can be seen as adaptation costs.
BU2 UK beaches and fixed tourist assets at risk from flooding.	-L	-L	-M	Market Price	M	Maintenance costs used, equating to adaptation costs. Therefore likely to be lower bound of true welfare costs.
BU4 Flood damage and interruption costs to business.	-H	-H	-VH	Market Price	H	Double counting with FL7. Should not be interpreted as welfare impact.
BU9 Change in output for UK businesses due to an increase in supply chain disruption.	-M?	-M?	-H?	Informed Judgement	L	Qualitative risk assessment.
FL8 Road and rail at significant likelihood of flooding.	-L	-L	-L	Informed Judgement	L	Links with Transport and overlaps with TR1. Double-counting if summed.
TR1 Disruption and delay caused by flooding of roads.	-L	-L	-M	Informed Judgement MV	L	Climate change only (no future socio-economics).
TR6 Scour of bridge foundations.	-L?	-L?	-L?	Informed Judgement	L	Climate change only (no future socio-economics). Note: no data for assessment.
FL11 Power stations and electricity substations at significant likelihood of flooding.	-M	-M	-M/H	Informed Judgement	L	Included in Energy (EN1).
FL12 Hospitals and schools at significant likelihood of flooding.	-M	-H	-H	Market Price	L	Links with Health.
BU5 Disruption of ICT due to flooding.	-L	-L	-L	Informed Judgement	?	Qualitative risk assessment.

Risk metric	2020s	2050s	2080s	Estimation Method	Confidence ranking	Notes
FL13 No of residential properties at significant likelihood of flooding (to assess insurance impacts).	-	-	-	-	L	Included in FL6
BU6 Number of homes where mortgage provision may be at risk.	-	-	-		H	Double counting with FL6. Should not be interpreted as welfare impact.
BU7 Increase in payout costs by the insurance industry due to flooding.	-VH	-VH	-VH	Market Price	H	Double counting with FL6 and FL7. Should not be interpreted as welfare impact.
FL15 Area of SAM sites at significant likelihood of flooding.	-L	-L	-M	Informed Judgement/ Non-Market Value	L	Relies on crude quantitative assessment.
FL14 Coastal Erosion: Area of land lost.	-M	-M	-M	Market Price	M	Estimates based on market price for agricultural land, assumed to broadly equate with BAP restoration cost. Links with agriculture.
BD2 & BD7 Coastal evolution impacts and major coastal reconfiguration	-M	-M to -H	-M to -H	Impacts on ecosystem services[14]	M	Extrapolation from case studies and baseline valuation in UK NEA.

Note: - signifies a negative impact or loss; + signifies benefits or cost reductions.

Impact Cost Ranking: L = £1-9m/pa M = £10-99m, H = £100-999m, VH= £1000m+, ? = Not assessed

Monetisation Confidence Ranking:

Ranking	Description	Colour code
High	Indicates significant confidence in the data, models and assumptions used in monetisation and their applicability to the current assessment.	
Medium	Implies that there are some limitations regarding consistency and completeness of the data, models and assumptions used in monetisation.	
Low	Indicates that the knowledge base used for monetisation is extremely limited.	

7.2 Introduction to monetisation

The overall aim of the monetisation is to advance the knowledge of the costs of climate change in the UK, by generating initial estimates of the welfare effects.

The basic approach to the costing analysis is, for each impact category considered, to multiply relevant unit values (market prices or non-market prices) by the physical impacts identified in earlier sections of this sector report. The total value to society of any risk is taken to be the sum of the values of the different individuals affected. This distinguishes this system of values from one based on ‘expert’ preferences, or on the preferences of political leaders. However, due to the availability of data, it has sometimes been necessary to use alternative approaches (e.g. repair or adaptation costs) to provide indicative estimates.

[14] Note that it was necessary to use a slightly different methodology for monetisation in the Biodiversity Sector. See Biodiversity Sector Report (Brown *et al.* 2012) for more details.

There are a number of methodological issues that have to be addressed in making this conversion including the compatibility between physical units and monetary units and the selection of unit values that address market and non-market impacts. As far as possible, physical and monetary units have been reconciled. The selection of unit values is justified in the explanation of the method used to monetise each risk metric. The aim is to express the risk in terms of its effects on social welfare, as measured by the preferences of individuals in the affected population. Individual preferences are expressed in two, theoretically equivalent, ways. These are:

- The minimum payment an individual is willing to accept (WTA) for bearing the risk or
- The maximum amount an individual is willing to pay (WTP) to avoid the risk.

There are also other issues (beyond this scoping analysis) in terms of impacts that have non-marginal effects on the UK economy, the treatment of distributional variations in impacts, and the aggregation of impact cost estimates over sectors and time.

This sector differs from many in that a number of the risks assessed in this report are already quantified in monetary terms. This is a consequence of the fact that assessment of certain flood risks is undertaken within modelling frameworks that allow the flood risks to a number of receptors such as property and businesses to be monetised as a matter of course. This has been facilitated in part by the development of the Flood and Coastal erosion risk management appraisal guidance (FCERM-AG) within Defra and the Environment Agency[15]. The data on EADs of property is based on information used to develop long-term investment strategies (Environment Agency, 2009; Environment Agency Wales, 2010).

Adaptation

It is highlighted that costs used in FL6 and FL7 can be interpreted as adaptation costs since they are incurred in the repair and replacement of property following the occurrence of the flood risk. The assumptions regarding the baseline and adaptation are stated in Sections 4.5.5 and 4.5.6.

The following sub-sections review the monetary data available with respect to these risks and provide justifications for their adoption. Given the huge range of uncertainties, this is not a precise exercise. As a consequence, whilst it was attempted to use the best monetary valuation data available, the matching-up of physical and monetary data is to be understood as approximate.

Presentation of results, uplifts and discounting

Consistent with other sectors, the results below are presented in terms of constant 2010 prices) for the three time periods considered in the CCRA i.e. the 2020s, 2050s and 2080s. The results are presented in this way to facilitate direct comparison.

At this stage, the values are therefore not presented as a present value or equivalent annual cost. However, the use of the values in subsequent analysis, for example in assessment of the costs and benefits of adaptation options to reduce these impacts, would need to work with present values. For this, the values below would need to be adjusted and discounted. The HM Treasury Green Book recommends 3.5% discount rates. The results are reported on an annual basis.

[15] http://www.environment-agency.gov.uk/research/planning/116705.aspx

7.3 Monetisation of metrics

7.3.1 Number of people at significant likelihood of flooding (Metric FL1)

Outputs from the risk analysis

The total number of people at significant likelihood of flooding in England and Wales is estimated, given current levels of flood defences. These figures cover tidal and river flooding, but not surface water flooding. The welfare effects of flooding cannot be directly estimated on the basis of this risk metric. Rather, these effects are captured in the risk metrics FL6 and FL7. As a result, the monetised welfare effects are represented in the discussion of these metrics, below.

Methodology and unit values to be adopted

The indirect welfare impacts of this risk metric are discussed in FL6 and FL7 below.

Results and discussion

The indirect welfare impacts of this risk metric are discussed in FL6 and FL7 below.

7.3.2 Number of vulnerable people at significant likelihood of flooding (Metric FL2)

Outputs from the risk analysis

The number of properties in the top 20% of deprived areas in England and Wales at significant likelihood of flooding is estimated.

Methodology and unit values to be adopted

The welfare effects of flooding cannot be directly estimated on the basis of this risk metric. Rather, these effects are captured in the risk metrics FL6 and FL7. As a result, the monetised welfare effects are represented in the discussion of these metrics, below.

Results and discussion

The indirect welfare impacts of this risk metric are discussed in FL6 and FL7 below.

7.3.3 Flood related deaths (Metric HE3)

Outputs from the risk analysis

Flood related deaths as a result of a changing climate are assumed to be proportional to the number of people at risk due to fluvial or tidal flooding. For overtopping of seawalls, flood related deaths are assumed to increase exponentially in relation to changes in mean sea levels. A baseline rate for deaths due to flooding in the UK was given as 18 per year.

Methodology and unit values to be adopted

The metric to be valued is the number of fatalities resulting from floods. Thus, the Value of Prevention per Fatality (VPF) is the relevant monetary metric. The UK

Department of Transport uses a VPF in its economic appraisal of accident fatalities in the UK. As documented in unit 3.4.1 of webtag[16], this value is currently £1.79m (2010 prices).

It is assumed that the values are readily transferable to the floods context, which does involve a number of important contextual differences, not least the involuntary risk, as well as the size of the risk change. The value that is currently quoted in Defra guidance is £1.49m[17]. This latter value is therefore adopted in this analysis.

Results and discussion

The monetary totals for climate-induced flood related deaths are presented in Tables 7.2 and 7.3. Whilst Table 7.2 shows the results using current population (i.e. climate change only on current conditions), those in Table 7.3 are based on a range of population projections and include the effects of climate change together with socio-economic change.

In both tables, the number - and welfare cost - of fatalities increases into the future, and across the climate scenarios from low to high. As with metric HE1, the climate signal is more important than the population signal in determining the size of the additional cost. It is also notable that the range of uncertainty expressed by the results across the probability distribution function (p10 - p90) within a given emission scenario is substantial – the latter being a factor of four greater than the former in the 2020s.

Table 7.2 Monetary value of additional flood related deaths

Deaths per year due to extreme event flooding and storms; future climate change with current population (£m, 2010 prices)

2020s			2050s					2080s				
Med.	Med.	Med.	Low	Low	Med.	High	High	Low	Low	Med.	High	High
p_{10}	p_{50}	p_{90}	p_{10}	p_{50}	p_{50}	p_{50}	p_{90}	p_{10}	p_{50}	p_{50}	p_{50}	p_{90}
6	17	25	9	26	31	35	51	20	39	47	57	103

Table 7.3 Monetary value of annual additional flood related deaths with population growth

Deaths per year due to extreme event flooding and storms, future climate change with future socio-economic change (population projections) (£m, 2010 prices)

Population projection	2020s			2050s					2080s				
	Med.	Med.	Med.	Low	Low	Med.	High	High	Low	Low	Med.	High	High
	p_{10}	p_{50}	p_{90}	p_{10}	p_{50}	p_{50}	p_{50}	p_{90}	p_{10}	p_{50}	p_{50}	p_{50}	p_{90}
Low	8	20	28	12	30	35	39	55	21	41	49	60	106
Principal	9	21	30	16	37	42	47	64	33	57	66	77	125
High	10	23	32	21	44	50	55	73	47	76	85	97	146

[16] http://www.dft.gov.uk/webtag/

[17] Defra (2008) Defra Flood and Coastal Defence Appraisal Guidance: Social Appraisal Supplementary Note to Operating Authorities: Assessing and Valuing the Risk to Life from Flooding for Use in Appraisal of Risk Management Measures. May 2008

7.3.4 Flood related injuries (Metric HE7)

Outputs from the risk analysis

As stated in Section 4.7, flood related injuries as a result of a changing climate are assumed to be proportional to the number of deaths due to fluvial and coastal flooding, as well as for overtopping of seawalls, exponentially related to changes in mean sea levels. Baseline rates for injuries due to flooding in the UK are given as 360 per year.

Methodology and unit values to be adopted

The empirical evidence on the valuation of injuries is very sparse; valuation data relating to accidents are almost entirely derived for fatal accidents in the work-place. Commonly, the empirical evidence is expressed in terms of a ratio between a fatal and non-fatal injury. Values for injuries in the UK are utilized in the context of transport appraisal by the Department of Transport. The values are reported in webtag in unit 3.4.1. The disutility component of non-fatal injuries is valued using ratios between non-fatal (serious and slight) and fatal injuries of 13:100 and 1:100, respectively.

In Table 7.4 below, these ratios have been applied to the central VPF of £1.79m, also derived from webtag. The resource and opportunity cost components have been estimated directly. The average totals account for the relative frequency of serious and slight injuries. The values for road transport accidents are presented in Table 7.4, below. Values for rail accidents are very similar. These values have therefore been adopted in the CCRA analysis, specifically the total of £72,338, rounded to £72,000.

Table 7.4 Summary of non-fatal injury values per year by welfare component (£, 2010)

Derived from webtag[18].

Injury Severity	Opportunity Costs	Disutility	Resource costs	Total
Serious	23,658	232,700	14,333	270,691
Slight	2,504	17,900	1,061	21,465
Average	11,606	58,175	2,557	72,338

The numbers below use the projected future number of injuries from Table 6.3.

Results and discussion

Table 7.5 and Table 7.6 show the monetized results for non-fatal injuries relating to flooding and storms that result under future climate and population projections.

As with previous risks, those results generated using the population projections – in Table 7.6 - are higher than those using current population levels in Table 7.5. The tables show that the climate sensitivity changes the size of the results by up to a factor of 5 and is more important as a determinant of the overall range than population projections. It is also clear that there is significant uncertainty across a given climate scenario as well as between scenarios for a given time period – typically of a factor of 2 to 4.

[18] http://www.dft.gov.uk/webtag/

Table 7.5 Monetary valuation of additional flood related injuries

Injuries per year due to extreme event flooding and storms (current population) – (£m, annual, 2010 prices)

2020s			2050s					2080s				
Med	Med	Med	Low	Low	Med	High	High	Low	Low	Med	High	High
p_{10}	p_{50}	p_{90}	p_{10}	p_{50}	p_{50}	p_{50}	p_{90}	p_{10}	p_{50}	p_{50}	p_{50}	p_{90}
6	17	24	9	25	30	34	49	19	38	45	56	100

Table 7.6 Monetary valuation of additional flood related injuries per year with population growth

Injuries per year due to extreme event flooding and storms with socio-economic change (population projections) – (£m, annual, 2010 prices)

Population projection	2020s			2050s					2080s				
	Med	Med	Med	Low	Low	Med	High	High	Low	Low	Med	High	High
	p_{10}	p_{50}	p_{90}	p_{10}	p_{50}	p_{50}	p_{50}	p_{90}	p_{10}	p_{50}	p_{50}	p_{50}	p_{90}
Low	7	19	27	11	29	34	38	54	21	40	47	58	102
Principal	8	20	29	16	36	41	46	62	32	55	63	75	120
High	9	22	31	21	43	48	54	71	45	73	82	94	141

7.3.5 Mental stress caused by flooding (Metric HE10)

Outputs from the risk analysis

Similarly to flood related deaths, the effect of floods / storms on mental health as a result of a changing climate are assumed to be proportional to the number of people at risk due to fluvial or tidal flooding. This metric has been assessed as the number of people who go from a GHQ-12 score of below four to four or above as a result of a flood event, which is estimated as being between 30-40% of those flooded each year.

Methodology and unit values to be adopted

In order to express the impacts in monetary terms, unit values for psychological stress are derived. These are composed of the three welfare components: medical costs; the costs of lost productivity, and disutility. It is assumed that these component costs are independent of each other and so can be straightforwardly summed.

<u>Medical and productivity costs</u>

Since the psychological stress of flooding most frequently manifests itself in terms of mild depression (Reacher *et al.*, 2004), cost estimates associated with the treatment of this illness are estimated. It is assumed that this broadly equates with the health quality indicator GHQ-4 utilised in the quantification of mental health impacts.

The cost of treating depression has previously been studied in terms of comparing the cost-effectiveness of different drug treatments, and a wide range of studies have examined the cost-effectiveness of different drugs. Bower *et al.* (2000), the only identified study to cost mild depression, investigates the cost-effectiveness of three types of treatment, notably non-directive counselling, cognitive behaviour therapy and general practitioner care for patients with depression in the UK.

The results for a four month period of treatment from Bower *et al.* (2000) are reported in Table 7.7 and include direct and indirect costs. The direct costs include treatment costs whilst the indirect costs identified are the cost of production losses based on employment status, weeks worked, wage rate and time lost from work through illness. An assumption is made that the psychological stress lasts for eight months, the average length of a depression period (Klein and Wender, 1993), and that there is a four month treatment period.

Table 7.7 Per case mean costs of treating depression (£, 2010)

Resource use Costs at 4 months	GP care	Cognitive behaviour therapy	Non-directive counselling
Direct costs:			
Primary care	103	64	60
Drugs	21	8	11
Outpatient services	156	51	38
Inpatient services	104	3	63
Protocol therapy	0	212	228
Travel costs	4	5	11
Total direct costs	388	342	409
Total indirect costs	611	455	707
Total societal costs	1000	800	1115

Source: Bower *et al.* (2000)

The total per-case treatment and labour opportunity costs for cognitive behaviour therapy and non-directive therapy identified in Table 7.7 are rounded and define a range to be applied to the mild depression end-point, within which the GP care cost is found. A central value is derived by taking the simple mean of these three values. This equates to £970.

<u>Disutility</u>

The cost-based value neglects any valuation of the “pain and suffering” component of the total willingness-to-pay to avoid this illness. One study, Floyd *et al.* (2003), has addressed the valuation of this component. The study, using a contingent valuation survey, confirmed that flooding caused physical effects in the short-term and psychological effects in the short and longer-terms. Psychological effects included memory of the stress from flooding and damage, and the stress of recovering after an event, including that arising from settling claims with insurers and dealing with builders and repairers.

The study asked two groups of respondents for their willingness to pay (WTP) to avoid the stress impacts of flooding: those who had previously been flooded and those who had not been flooded but whose property was currently at flood risk. Unfortunately the unpublished study provides incomplete evidence of the WTP to avoid flood-incurred stress. A single value of £225 per household per year is presented, with no accompanying statistical information.

There appears to be no other study that has been undertaken and whose results could be used to test convergent validity. However, the value has been adopted in official Defra appraisal guidance (Defra, 2004). The single result from Floyd *et al.* (2003) is therefore transferred directly to the current context.

It is therefore assumed that the psychological effects valued in this study are equivalent, in welfare terms, to mild depression, whose treatment and productivity costs are estimated above. These are then converted from household totals to person-equivalents by dividing by 2.36, the average number of people per household as determined by the 2001 census. The unit value is therefore £94. The total rounded WTP over the three welfare components is £1,065.

Results and discussion

Table 7.8 shows the monetized results of the mental health risks associated with climate change-induced flooding and storms under alternative population and climate scenarios.

The table shows ranges for each climate/population combination, reflecting the uncertainty in the epidemiology relating to this risk. The data presented shows that the population projections have a similar-sized effect on the variation over time to the climate signal.

Table 7.8 Additional people who suffer mental stress as a result of flooding
People who go from a GHQ-12 questionnaire score of below 4 to 4 or above per year as a result of extreme event flooding; future climate change (current population) and socio-economic (population) projections (£m, annual, 2010 prices)

Population projection	2020s	2050s			2080s		
	Medium	Low	Medium	High	Low	Medium	High
Current	3 - 5	5 - 6	5 - 7	6 - 8	6 - 8	6 - 8	7 - 9
Low	4 - 5	6 - 7	6 - 8	7 - 9	6 - 9	7 - 9	7 - 10
Principal	4 - 6	7 - 10	8 - 11	8 - 11	10 - 14	11 - 15	11 - 15
High	5 - 6	9 - 12	10 - 13	10 - 14	15 - 20	15 - 21	16 - 22

7.3.6 Agricultural land at risk of flooding (Metric FL4)

Outputs from the risk analysis

Section 5.8 above identifies the projected increases in area of agricultural land affected by frequent flooding (annual probability 10% or greater) for river and tidal flooding. The affected area is disaggregated by its agricultural class, in broad terms crops and livestock. This metric has been applied in the Agriculture sector metric AG2 using data provided from the Floods sector and the description below is repeated from that sector report.

Methodology and unit values to be adopted

To estimate the impact on agricultural production, a study on the crop impacts of the summer 2007 floods on agriculture has been used. The estimates given by Chatterton *et al.* (2009) are perhaps most useful as they divide the damage by type of land. These estimates of costs per hectare are, themselves, derived on the basis of the Defra/Environment Agency FCERM-AG guidance. These estimates have been used as a proxy for flood damage arising from all floods. This does not take account of the fact that damage from river and tidal water are likely to be different, and that depths of water and different contamination issues may affect the true values.

An expected value approach has been applied, using the mid-point of the annual return period to reflect the probability. The average annual damage costs under the different scenarios are then estimated, using 2010 damage as the base year. The results are reported for the Medium Emissions scenario.

Results and discussion

The Expected Annual Damage is reported in Table 7.9. The total costs for the p50 Medium Emissions scenario range from about £30 to £140 million for the 2020s and 2080s respectively.

Table 7.9 Expected Annual Damage to agricultural land

Damage due to climate change induced flooding (£m, 2010 prices, no uplift or discounting). Net climate impact for the p50 Medium Emissions scenario; no socio-economic change.

Epoch	Grades 1, 2, 3			Grades 4,5			Total
	<3	3 to 5	5 to 10	<3	3 to 5	5 to 10	
2020s	3.0	10.2	5.2	1.5	4.4	7.5	31.2
2050s	28.4	16.4	7.0	7.7	6.2	-5.1	78.1
2080s	62.4	20.7	13.8	16.8	5.7	-2.1	138.4

The assumption that costs for the summer 2007 flood are similar to that of all floods is questionable, particularly as winter floods may have different impacts to summer floods. The assumption that tidal flooding has similar impacts is also questionable. However, the results give an indication of the overall order of magnitude.

7.3.7 Properties at significant likelihood of flooding (Metrics FL6 and FL7)

Outputs from the risk analysis

The number of residential and non-residential properties at significant likelihood of flooding for the climate scenarios is estimated and the EAD, primarily in terms of property repair costs, are calculated.

Methodology and unit values to be adopted

The monetary estimates are made within the flood modelling referred to in Section 4.5.1. The values used are consistent with those recommended for use in the Defra/ Environment Agency FCERM-AG guidance. Flood defence levels are assumed to be kept constant in absolute terms. Thus under climate change scenarios the relative risk levels may increase. No additional autonomous adaptation, e.g. by household, and in household design, is assumed.

Results and discussion

The EAD results are outlined and discussed in Sections 5.6 (climate change only) and 6.2.7 (with socio economic scenarios) and is not repeated here. However, in order to facilitate results in other sectors, Table 7.10 utilises the results in Section 5.11 to derive the EAD attributable to climate change alone (i.e. total value minus baseline), for the p50 Medium Emissions climate scenario. These results do not include socio-economic change.

The residential totals are further disaggregated to indicate that whilst approximately 75% of the cost will be borne by household insurance companies, one quarter of the total is attributed to provision of emergency and hospital services (see e.g. Chatterton *et al.*, 2009). These costs do not include other losses such as time off work, uninsured losses, etc.

Table 7.10 Property flooding: Climate attributable EADs
England and Wales; £m, 2010 prices, no uplift or discounting; p50 Medium emissions climate scenario; No socio-economic change.

	Residential		Non-residential	Total
	Insurance	National		
2020s	345	115	440	900
2050s	795	265	840	1900
2080s	1095	365	1090	2550

7.3.8 UK beaches and fixed tourist assets at risk from flooding (Metric BU2)

Outputs from the risk analysis

The Business sector report made an estimate of the potential value of the risk to a range of assets related to tourism and wider recreational activities. Preventative expenditures in the form of the cost of flood bunds around each of the building were used.

Risks to tourist assets and activities that may be at risk from coastal flooding were also identified and qualitatively assessed.

Methodology and unit values to be adopted

It is recognised that the costs to tourist activity that may be impacted by coastal and river flooding are likely to be significant. The methodology in the Business sector report related to the valuation of this risk relies on the application of the cost of flood bunds. These can be seen as adaptation costs and can best be interpreted as lower bound estimates of willingness to pay (WTP), assuming that they are implemented. However, whilst there are likely to be important impacts on local areas, it is not certain that the welfare loss will be significant in aggregate since tourists are likely to change their destination.

Results and discussion

Mid-point estimates for 312 buildings generated annual climate change attributable costs of £0.1 million by the 2050s and £0.2 million by the 2080s. In order to derive an indicative estimate of the potential aggregate size of this risk, this was scaled up over the 28,659 listed buildings and churches of national or international importance located in England in Flood Risk Zone 3, and listed in the Business sector report. This produces annual climate change attributable costs of £9 million by the 2050s and £18 million by the 2080s. These can therefore be categorised as a Low cost in the 2020s and 2050s and a Medium cost in the 2080s.

7.3.9 Flood damage and interruption costs to business (Metric BU4)

Outputs from the risk analysis

This metric focuses upon the financial impact on industry arising from business interruption, including damage to assets.

Methodology and unit values to be adopted

The EAD values for non-residential property in England and Wales were used in the analysis. In addition to damage costs, some businesses claim compensation from insurance for disruption to businesses where flooding involves extra costs and lost income. It is assumed that business interruption costs increase at the same rate as EAD, so the costs may increase by about 75% by the 2020s, 140% by the 2050s and 200% by the 2080s (based on the p50 Medium Emissions climate change scenario). These figures do not include socio-economic change.

Results and discussion

The damage costs from flooding to non-residential properties reported in Table 7.11 are shown to increase across the time periods so that the p50 Medium Emissions climate scenario in the 2080s shows an increase in cost by a factor of three compared to the current (2008) annual damage.

Table 7.11 Marginal Increase in non-residential properties at significant likelihood of fluvial and tidal flooding

EAD; England & Wales; Current population; £million/year, no uplift or discounting; Climate change only (no socio-economic change)

	2020s			2050s					2080s				
	Med p10	Med p50	Med p90	Low P10	Low p50	Med p50	High p50	High p90	Low p10	Low p50	Med p50	High p50	High p90
Climate multiplier	1.17	1.75	2.46	1.32	2.1	2.41	2.67	3.61	1.71	2.7	2.98	3.43	4.79
EAD including Baseline (£560m)	650	1000	1350	750	1200	1350	1500	2000	950	1500	1650	1950	2700
Climate attributable (£m)	90	440	790	190	640	790	940	1440	390	940	1090	1390	2140

Additional business interruption cost were estimated to be £15m, £28m and £40m for the 2020s, 2050s and 2080s, respectively under that the p50 Medium Emissions climate scenario.

7.3.10 Supply chain disruption (Metric BU9)

Outputs from the risk analysis

Supply chain disruptions can cause significant harm to business operations. They can raise costs, trigger inventory accumulations, and reduce a business' market share. A broken or damaged chain puts production and distribution in jeopardy, reducing revenue when goods cannot be manufactured or delivered. Disruptions can also affect credibility with customers, investors and other stakeholders.

Retail supply chains are complex and dependent on a network of interconnected, yet independent, elements. As a consequence, the risk assessment judged that it is not possible to develop a clear and direct causal link between climate change and supply chain disruption. It states that many climatic factors (e.g. heat, precipitation, melting, flooding) can disrupt supply chains, making a single response function too simplistic.

Methodology and unit values to be adopted

The risk assessment provides no quantitative assessment of the potential supply side disruption possible from extreme events attributable to climate change. As a consequence it is difficult to attach an economic estimate to such events. An informed judgement was therefore used to indicate the magnitude of this impact.

Results and discussion

Whilst quantitative estimates are not available from the risk assessment described above, there are studies that derive estimates of the economic impacts of extreme events on UK business. A principal direct effect is that resulting from flooding.

For instance, the summer 2007 floods in England were estimated to result in £740 million of damage in terms of property damage or disruption (Environment Agency, 2010). The evidence also indicates that individual events globally, as well as in the UK, may result in significant effects to UK businesses.

In order to assess the risks to the UK Food and Drink sector from climate change it is useful to explore the extent to which raw materials and foodstuffs used in the sector may be impacted upon in their source country or region. It is suggested (see e.g. Parry, (ed.) 2000), that such impacts may affect agricultural yields and their subsequent supply price. This possibility is explored in Hunt *et al.* (2009) which suggests that the most vulnerable sub-sectors (including production and preservation of meat including poultry, operation of dairies and cheese making, and manufacture of prepared feeds for farm animals) may suffer profitability losses of 10-20% by the 2020s and 20-40% by the 2080s.

On the basis of this and similar evidence, an informed judgement is that this impact may justify an indicative Medium or High cost ranking, though with a high degree of uncertainty.

7.3.11 Roads and railways at significant likelihood of flooding (Metric FL8)

Outputs from the risk analysis

The metric used in the risk assessment is kilometres at significant likelihood of flooding. This metric closely relates to the Transport sector risk metric, TR1, which assesses transport disruption caused by flooding.

Methodology and unit values to be adopted

The TE2100 flood risk analysis (TE2100, 2009) makes some initial estimates of the welfare cost of the disruption that might result from such flood risks. Specifically, it generates the following unit values:

- Motorway disruption - £200,000/day/km
- “A” Class Road disruption - £77,000/day/km
- Rail disruption - £115,000/day/km.

It is assumed that a flood disrupts each kilometre impacted by one day once in 75 years. The unit values are then multiplied through to give total damage costs.

Results and discussion

The annualised results, attributable to climate change alone, for the p50 Medium Emissions climate change scenario and current transport socio-economics, are presented in Table 7.12 for the three transport modes considered. As can be seen, the costs are negligible compared to those for property in Table 7.11. It is also emphasised that these totals may be higher if more frequent flood events are included in the analysis.

The results overall are below the levels estimated by TR1 since the analysis considers a 1 in 75 year flood risk only whereas the TR1 considers all flood frequencies. Moreover, it is comforting to see the consistency in scale of the estimates given the different methods utilised to generate the estimates.

Table 7.12 Flood costs to transport

EAD, £m/year, no uplift or discounting; Climate change only (p50 Medium Emissions scenario); no socio-economic change.

	2020s		2050s		2080s	
	River	Tidal	River	Tidal	River	Tidal
Rail	0.37	0.09	0.54	0.21	0.69	0.32
Motorway	0.13	0.04	0.20	0.10	0.26	0.14
A Road	0.43	0.09	0.60	0.23	0.75	0.35
Total	0.93	0.22	1.34	0.54	1.7	0.81

7.3.12 Disruption and delay caused by flooding of roads (Metric TR1)

Outputs from the risk analysis

This metric looks at the disruption and delay associated with flooding on the road network. These economic costs can be significant. The costs of the autumn 2000 floods including delays were estimated at £13 million (economic) and £73 million (financial) for the road sector (Penning-Rowsell *et al.*, 2002). The estimated total costs relating to delays and disruption to road users during the 2007 floods were approximately £100 million (Environment Agency, 2010) and also led to an estimated £25 million in rail user delays and a further £10 million for rail infrastructure costs.

The analysis uses a qualitative response function that links the projected increase in winter precipitation (as an indicator of the likely increase in flood risks) to published figures for the cost of disruption/delay from the 2007 flooding events in England.

Methodology and unit values to be adopted

Ideally this analysis would use the traditional transport appraisal guidance (in the DfT Transport Appraisal Guidance and webtag) to look at the costs of time delays (using the Value Of Time, VOT), and combine this with estimated impacts of future flood risk and levels of disruption to road users.

Consistent with the guidance, the analysis should also include higher Vehicle Operating Costs (VOC) where there are diversions, i.e. extended trips. It should also include the additional repair and restoration costs where these were additional to the costs of time delays. However, this detailed work was beyond the scope of the analysis and the current level of evidence.

Therefore, a simplified version of such an approach has been adopted using previous estimates of the value of lost time from the 2007 floods to build up a semi-quantitative analysis. The Environment Agency (2010) estimates for the 2007 floods are used of £98 million (with a range from £22 to £174 million depending on assumptions) from the extra time and distances travelled due to blockage at given ‘nodes‘ on the road network, plus an additional £85 million cost of damage to roads and related infrastructure such as bridges and culverts.

The underlying work on VOT/VOC for these estimates was undertaken by the Highways Agency and used the DfT appraisal approach. These estimates are used here although they represent current values and that there are no adjustments for future time periods.

Results and discussion

For England, the outcome of the assessment shows that cost of disruption from flood is expected to remain relatively low in economic terms in the 2020s (£1 – £9 million per year) for the p50 and p90 projections (but effectively zero for the low p10 scenario).

It also remains low in economic terms in the 2050s (£1 – £9 million per year) for the p50 Medium Emission projection in the 2050s, but increases to a medium cost (£10 – 99 million/year) for the p90 Medium and p90 High Emissions projections (although again zero for the p10 projections).

Finally, the costs are estimated to rise to a medium level (£10 – £99 million/year) for the p50 Medium Emissions projection in the 2080s, and are estimated to rise to a high level (£100 – £1,000 million/year) under the p90 Medium Emissions and p90 High Emission projections.

It is highlighted that these estimates are indicative only. They are presented in current prices, with no adjustments or discounting. They would also rise further with future projections in transport demand (consistent with future projections). They would also rise if other transport modes, such as rail, were included, and if other flood hazards, such as coastal and intra-urban flooding, were included. Note that the estimates do not include any planned adaptation, including on-going future maintenance.

7.3.13 Scour of bridge foundations (Metric TR6)

Outputs from the risk analysis

This metric considers the potential for road and rail bridge failures due to scour.

Section 4.7 discusses the a response function for scour depth against river flow, but as reported in Section 5.17 it was not possible to estimate the potential number of bridge failures and a qualitative discussion is presented on this risk.

Methodology and unit values to be adopted

Ideally this analysis would follow the approach for road and rail transport disruption and delays (the value of time) above, along with the additional costs of repair. However, no estimates are currently available of the number of bridges affected or the associated consequences.

Results and discussion

In the absence of quantitative or qualitative information, it is very difficult to provide even an indicative estimate for this risk.

The information in Section 5.17 indicates historical failures over the past decade, but it has not been possible to translate these into estimates of future risks. Assuming a relatively modest increase in relative risks from climate change, it is possible that future risks will be low in monetary terms (£1 – £10 million/year) but this can only be considered an extremely approximate estimate.

7.3.14 Water distribution and treatment installations at risk of flooding (Metric FL10)

Whilst the importance of this metric is potentially high, there is currently no information available to prepare an estimate of the magnitude. Monetisation of this metric has therefore not been carried out, and it is not included in Table 7.1.

7.3.15 Power stations and electricity substations at significant likelihood of flooding (Metric FL11)

Outputs from the risk analysis

The number of energy installations (power stations and distribution substations) at significant likelihood of flooding under climate change scenarios is summarised in Section 5.19. The generation capacity at significant likelihood of flooding is also presented. These results are used in the EN1 risk metric analysis in the Energy sector report.

Methodology and unit values to be adopted

Since the lost load resulting from flooding of energy infrastructure (substations and power stations) is not known it is not possible to undertake a detailed quantitative analysis. An informed estimate as to the possible order of magnitude has therefore been made.

Results and discussion

Assuming a mix of major and minor substations, the average costs of outages and a very indicative estimate of the likely equivalent annual rate of flooding (based on risk levels), it is concluded that the potential impacts could be medium in the 2050s (£10 – £100 million/year) and possibly medium to high (>£100 million) by the 2080s.

The analysis of power stations needs to consider that the system already runs with reserve margin in place, thus it is not easy to identify whether, or how much, lost load results. Whilst the number of potential stations at risk rises sharply in the future, the siting and design of future plants would be expected to build in resilience and so reduce risks for the 2050s and 2080s.

For example, placing new plant outside flood risk areas would reduce the risk although the number of large flat sites is limited. Most of the proposed next generation of nuclear power stations are in flood risk areas but a high level of protection against flooding would be expected. As a consequence, the order of magnitude is judged to be ranked as low. Thus, for risk metric FL11 in total the suggested cost ranking is medium in the 2020s and 2050s, and medium/high in the 2080s, although this is highly uncertain.

7.3.16 Number of hospitals at significant likelihood of flooding (Metric FL12)

Outputs from the risk analysis

The metric used in the risk assessment is numbers of hospitals at significant likelihood of flooding. Metric FL12b (the number of schools at significant likelihood of flooding) has not been assessed here.

Methodology and unit values to be adopted

As with the treatment of transport, unit values derived from the TE2100 study could be applied in this case. This study estimates the disruption costs associated with a two month hospital closure following a flood event.

In order to derive these costs, it is assumed that 257 patients per day on average visit the Accident and Emergency Department in any one London hospital, implying potentially 15,420 patients affected, of which 3,084 are emergency cases. Assuming each patient has to travel 10 miles at 10 mph, damage are estimated to be £695 million for a two month flood event per hospital.

This unit value is adopted as an indicative value only. It is then multiplied by the number of hospitals at risk. This is then multiplied by the probability of a flood event occurring in a given year (1 in 75 is assumed) to give an EAD.

Results and discussion

The annualised results attributable to climate change alone for the p50 Medium Emissions climate scenario and current socio-economics are presented in Table 7.13. Again, compared with the other property costs reported above, these estimates are relatively small. It should be remembered that for individual hospitals at risk significant adaptation expenditure may be justified, thereby reducing subsequent risks and these estimates. However, it is also emphasised that these totals may be higher if more frequent flood events are included in the analysis rather than just the 1 in 75 year flood.

Table 7.13 Flood costs to hospitals – England & Wales

EAD, £m/year, 2010 prices, no uplift or discounting; Climate change only (p50 Medium Emissions scenario); no socio-economic change.

2020s			2050s					2080s				
1 Medium p10	2 Medium p50	3 Medium p90	4 Low p10	5 Low p50	6 Medium p50	7 High p50	8 High p90	9 Low p10	10 Low p50	11 Medium p50	12 High p50	13 High p90
0	56	120	28	83	120	167	232	74	158	167	204	278

7.3.17 Disruption of ICT due to flooding (Metric BU5)

Outputs from the risk analysis

Whilst it has been acknowledged that weather already has the potential to interrupt or reduce the quality of ICT services, there is as yet very little prior work that specifically considers the potential impacts of climate change on ICT and its knock-on effects to business.

Methodology and unit values to be adopted

The potential impacts of weather disruption to ICT systems are discussed in qualitative terms in Section 5.21. However, as no information is available on the magnitude of the problem, no assessment of costs has been carried out.

Results and discussion

An indicative judgement is made that this risk has a low cost ranking across the future epochs to 2100.

7.3.18 Insurance of residential properties (Metric FL13)

Outputs from the risk analysis

An assessment of the number of residential properties where flood insurance may become difficult or expensive to obtain in the future has been carried out using Metric FL6a, the number of residential properties exposed to significant likelihood of flooding.

Methodology and unit values to be adopted

There is no additional welfare impact to metric FL6 and so the risk has not been monetised.

Results and discussion

The indirect welfare impacts of this risk metric are discussed under metrics FL6 and FL7.

7.3.19 Number of homes where mortgage provision may be at risk (Metric BU6)

Outputs from the risk analysis

This metric is concerned with the impact of increasing flood risk on mortgage lending revenues as a function of market changes and the important issue of asset devaluation in the event of the loss of insurance cover.

For the purposes of this analysis, the number of properties at significant likelihood of flooding (coastal and river) is used as an indicator of the impact of flooding on the availability of insurance, and consequently on the level of mortgage lending exposed. Here, the baseline (current) sea level and river flow peak data are used to derive the existing level of risk to properties (by numbers of properties).

This risk is converted to mortgage lending risk using average house prices in each region. Climate change scenarios can then be used to scale this risk according to the change in number of properties that are likely to be flooded.

Methodology and unit values to be adopted

This risk metric is not concerned with a welfare impact. It is concerned with the scale of the mortgage fund value for residential property at risk, relative to the 2008 baseline. The results are therefore simply those given in Section 5.23 above. It should be highlighted that the values given are related to total asset values and are therefore not comparable to results presented elsewhere in the risk assessment in annual terms.

7.3.20 Increase in payout costs by the insurance industry due to flooding (Metric BU7)

Outputs from the risk analysis

The baseline insurance claim data is taken to be the UK average from between 2001 and 2009 (for commercial and domestic property). The baseline number of properties deemed at significant likelihood of flooding is also calculated. The change in the number of properties at risk is then determined according to the climate change scenario and the insurance claims are scaled accordingly.

Methodology and unit values to be adopted

As with the previous risk metric (BU6) this risk metric is not concerned with a welfare impact. Rather it is concerned with the scale of the pay-out costs associated with flooding. The results are therefore simply reproduced from Section 5.11 above.

Results and discussion

Preceding analysis, reported in Section 5.24, estimates that the combined domestic and commercial claims could double by the 2020s (p50 Medium Emissions climate scenario), increase by almost three-fold in the 2050s and increase between three and four times by the 2080s. This equates to an additional average annual total claim for flood related damage of the order of £250m, £450m and £600 million in the 2020s, 2050s and 2080s, respectively.

However, the overall impact to the industry is unclear, being determined by the balance of pay-out following an event versus the cost of products to consumers (i.e. cost of premiums). The risk is thus fundamentally one of how well the industry understands weather risk (and how this may vary as climate changes). The evidence suggests that the insurance industry is adapting to the challenges arising from climate change.

7.3.21 Area of SAM sites at significant likelihood of flooding (Metric FL15)

Outputs from the risk analysis

The area of Scheduled Ancient Monuments (SAM) was selected as a metric to represent the impact of flooding on cultural heritage because information is readily available, although it is recognised that there are many aspects of cultural heritage that are not covered (for example, listed buildings).

Methodology and unit values to be adopted

There is little evidence on which to base monetary valuation of the impacts of flooding on cultural heritage, and SAMs specifically. No values are suggested by Environment Agency guidance. However, the TE2100 project documentation summarises the findings of a small number of studies that have produced values related to cultural heritage generally.

On this basis, an indicative value of £12/household/year is utilised in the TE2100 analysis. This value is adopted in order to generate indicative values. The estimates of area at risk of flooding given in Appendix 8 have been used to identify the percentage changes from the current, 2008, area at risk. It is assumed that the Willingness to Pay (WTP) value is reduced by this amount. This unit value is then multiplied by the number of households in the UK (about 24 million) and converted to an annual expected value by multiplying by a 1 in 75 annual probability.

Results and discussion

The above method gives annual damage costs of £0.5m to £0.9m over the period to the end of the century. On the basis of this extremely crude analysis it is judged that this risk metric is likely to attract a Low cost ranking in each of the three time periods.

7.3.22 Change in CSO spill frequency (metric WA10)

Outputs from the risk analysis

The change in spill frequency is likely to have implications on the quality of the receiving waters. This may be of particular concern when uncontrolled discharges of CSOs occur due to episodic high flows following intense summer rainfall. Thus, water quality is then expected to deteriorate as a result of these incidents.

The monetisation was therefore undertaken in the Water Sector report for water quality but not flood risk. The monetisation estimates are therefore not presented in this document.

7.3.23 Coastal Erosion: Area of land lost (Metric FL14)

Outputs from the risk analysis

The metric values calculated in Section 5.27 assume that existing defences will deteriorate for coastal erosion except in urban areas, where it is assumed that the present defence line will be maintained. This means that urban areas will not be affected by coastal erosion, and reflects the 'hold the line' policies generally adopted for urban areas. No other adaptation measures are assumed in the analysis.

The metric estimates the area lost to coastal erosion for agricultural and BAP habitat land using predicted future erosion rates. The analysis is limited to England and Wales and does not cover Scotland and Northern Ireland.

The analysis has involved re-scaling the Futurecoast rates using the Foresight future rates, Foresight future sea level rise and the CCRA sea level rise. This means that the analysis takes present rates and projects them everywhere regardless of any consideration of solid geology that may be currently in place.

Methodology and unit values to be adopted

In order to make indicative estimates a value of £4,000 per hectare has been used. This is based on current valuation of Agricultural (arable) land, consistent with HMT Green Book guidance, and a typical replacement cost of BAP habitats which broadly coincide with this value level. Clearly this is a crude estimate that could be refined further. However, for current purposes it serves to give a first estimate of the possible scale of this risk.

Results and discussion

Table 7.14 monetises the physical risk results for England and Wales given in Table 5.9. This is understood to be a cumulative, rather than annual total of land loss and so the costs are also cumulative, although not discounted. An annual total could crudely be made by dividing the 2080s results by 75. This gives a total of £0.4m and constitutes a low cost ranking.

Table 7.14 Costs of coastal erosion – England and Wales

Cumulative total; £m, 2010 prices, no uplift or discounting; Climate change only (p50 Medium Emissions scenario); no socio-economic change.

	Agriculture	BAP Habitat
2020s	5.44	0.16
2050s	18.76	0.76
2080s	30.88	1.52

7.3.24 Coastal evolution and flooding / reconfiguration impacts (metrics BD2 and BD7)

These metrics cover coastal evolution impacts on coastal and estuary habitats (metric BD2) and impacts of coastal flooding and reconfiguration (Metric BD7) on lowland wetland coastal habitats.

Outputs from the risk analysis

The physical risk estimation undertaken in the preceding sections provides estimates of losses in a range of coastal habitats. The estimates made combine modelling of coastal evolution with the impacts of major events. As a result, BD2 and BD7 are considered in totality here.

Methodology and unit values to be adopted

A tentative summary of the evidence for economic impacts from the risks covered in the Biodiversity Sector Report are mainly based upon a qualitative assessment of the evidence at UK level and extrapolation from limited quantitative case studies carried out to-date. The UK National Ecosystem Assessment (UK NEA, 2011) has demonstrated that even baseline knowledge of the relationship between ecosystem services and biodiversity is often rather uncertain, highlighting the need for caution in interpreting this information.

Many people recognise that biodiversity has intrinsic value (i.e. a non-humanistic right to exist) rather than just a utilitarian value to humans but this judgement is typically personal and highly subjective. Ecosystem services are directly paid for if the benefit is a tangible material product, such as food or timber, which are traded as 'goods' on markets. However, most benefits from ecosystem services are an improvement in the condition or location of things of value to human wellbeing (public good benefits), rather than directly traded products with an explicit market value. Failure to take account of public good aspects of biodiversity and other externalities (i.e. those beyond the direct market value) may lead to biodiversity being undervalued in a market-orientated world. The consequence of this is that appropriate action is not taken to conserve biodiversity for the benefit of society as a whole.

Coastal habitats provide a broad range of benefits in addition to their intrinsic biodiversity value, including protection against flooding and erosion, regulation of water quality, high diversity of wild species, and amenity value. The average value that each of these ecosystem services provides has been estimated by the UK NEA (Table 7.15) together with the marginal values for benefits gained or foregone through habitat gain or loss. These values will vary significantly depending on the location of the site, particularly the relative geographic position with respect to people and settlements that would obtain that benefit (Bateman *et al.*, 2011b). In general, measures to maintain habitat at existing locations (where this is possible) tend to provide a more cost-effective response than seeking to develop replacement habitat elsewhere. This is particularly demonstrated by saltmarsh and mudflat habitats: recent re-evaluation of schemes by the Environment Agency indicates that replacement costs for these habitats are ca. £50,000 per ha, which is significantly higher than for other habitats (Brown *et al.* 2012). However, at some locations the maintenance of habitat in situ may be considered unviable and the only alternative is to seek compensatory habitat elsewhere under the terms of the EU Habitats Directive.

Results and discussion

Based upon the analysis undertaken by the UK NEA, the estimated gross value of coastal wetlands for buffering the effects of storms and in controlling flooding has been assigned a notional value of £1.5 billion annually (Bateman *et al.*, 2011a). However, to-date there has been no national-level assessment of the relative benefits of natural against man-made defences. Instead, evidence is provided by case studies of local schemes that have estimated the avoided costs from man-made defences when natural schemes are present, although these appraisals have tended not to quantify the full range of ecosystem benefits. For example, it has been estimated that an 80m width zone of inter-tidal habitat fronting sea walls can save £2600-4600 per metre in sea defence costs (King and Lester, 1995). At some locations, investing in habitat restoration can therefore provide a cost-effective alternative to the maintenance or upgrade of hard engineered defences as a response to sea-level rise.

Table 7.15 Ecosystem service valuations for coastal wetlands (Bateman *et al.*, 2011a)

	Average additional value of service where present(£/ha/yr)	**Marginal value of service per new unit area (£/ha/yr)**
Flood control and storm buffering	3730	2498
Wild species diversity	2786	1866
Water quality	2676	1793
Water supply	16	12
Amenity and aesthetics	2080	1394

Default value where no services are present is £1856ha/yr.

Coastal ecosystems can also store and sequester carbon, particularly in saltmarsh habitats through the interaction of vegetation with fine sediment particles. It has been estimated that this could provide an additional value of £60–600/ha/yr (Beaumont *et al.*, 2010). Furthermore, this sequestration role also acts to store other pollutants that would otherwise reduce water quality, particularly in estuarine environments. The value of coastal habitats in providing food is another service where data is currently lacking: often these ecosystem goods have a high-value or premium price based upon quality and diversity.

Specific local data is available through economic appraisal of managed realignment schemes. These appraisals have shown that such schemes can be cost-effective, particularly when based upon a long-term analysis period, but again that spatial location is critically important in determining the ecosystem services generated, the human beneficiaries, and the relative benefits against costs (e.g. Humber estuary and Blackwater estuary - Turner *et al*. 2007; Luisetti *et al.* 2011). It has been also suggested that larger schemes may provide less benefits in marginal economic terms (Bateman *et al.*, 2011a); however, this assertion needs to be reconciled with minimum interventions required from a biophysical perspective to meet the primary goals of flood risk reduction and creation of habitat for priority species.

8 Adaptive Capacity

8.1 Overview

Adaptive capacity considers the ability of a system to design or implement effective adaptation strategies to adjust to information about potential climate change, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (Ballard, 2009, after IPCC, 2007). This can be considered as having two components; the inherent biological and ecological adaptive capacity of ecosystems and the socio-economic factors determining the ability to implement planned adaptation measures (Lindner *et al.*, 2010). Considering adaptive capacity is essential for adaptation planning and the CCRA project has included work in this area that will contribute to the ongoing Economics of Climate Resilience study and the National Adaptation Programme. The CCRA work on adaptive capacity focuses on structural and organisational adaptive capacity and this chapter provides an overview of the assessment approach.

The climate change risks for any sector can only be fully understood by taking into account that sector's level of adaptive capacity. Climate change risks can be reduced or worsened depending on how well we recognise and prepare for them. The consequences of climate change are not limited to its direct impacts. Social and physical infrastructure, the backdrop against which climate change occurs, must also be considered. If such infrastructure is maladapted, the economic, social or environmental cost of climate impacts may be much greater; other consequences could also be considerably more detrimental than they otherwise might have been. Avoiding maladaptation is one outcome of high adaptive capacity; high adaptive capacity lowers the negative consequence of climate impacts. Conversely, low adaptive capacity increases the negative consequences.

8.2 Assessing structural and organisational adaptive capacity

The methods used for assessing structural and organisational adaptive capacity in the CCRA are based on the PACT framework[19]. The work included a preliminary literature- and expert interview-based assessment of all eleven sectors in the CCRA. This was followed by more detailed analysis for the following sectors:

- **Business, Industry and Services** (focusing on the finance sector)
- **Transport** (focusing on road and rail)
- **Built Environment** (focusing on house building)
- **Health**
- **Biodiversity and Ecosystem Services**
- **Water**

[19] PACT was developed in the UK as one of the outcomes of the ESPACE Project (European Spatial Planning: Adapting to Climate Events) http://www.pact.co/home.

Structural adaptive capacity

The extent to which a system is free of structural barriers to change that makes it hard to devise and implement effective adaptation strategies to prepare for future impacts. This covers issues such as:

> ***Decision timescales***: This considers the lifetimes of decisions, from their conception to the point when their effects are no longer felt. The longer this period is, the greater the uncertainty as to the effects of climate change impacts. Cost-effective adaptation becomes harder. Potential climate impacts also become more extreme over longer timescales. This means that a greater scale of adaptation may need to be considered, and that the barriers to adaptation resulting from 'lock-in' to maladapted processes become more pronounced (Stafford-Smith *et al.*, 2011). Adaptive capacity is therefore lower, and maladaptation more likely, when long-lasting decisions are taken.
>
> ***Activity levels***: This considers what opportunities are there for adaptation, and on what scale. The frequency with which assets are replaced or created determines how many opportunities there will be to take action which increases adaptive capacity.[20] In addition, when a lot of asset replacement and/or new investment is expected, there will be more chances to learn from experience, which increases adaptive capacity.
>
> ***Maladaptation***: This evaluates the effect of decisions already made on adaptive capacity. Long-term previous decisions which have reduced adaptive capacity are often difficult or expensive to reverse. Such decisions were made either before climate change was recognised as an issue, or more recently as a result of poor organisational capacity. Such maladaptation makes implementing effective strategies much harder.
>
> ***Sector (or industry) complexity***: This refers to the level of interaction between stakeholders within an industry, or with outside industries and groups, that is required to facilitate effective decision-making. Complexity is higher (and adaptive capacity lower) when many stakeholders are involved in decision-making and when their agendas (e.g. their financial interests) differ substantially.

Organisational adaptive capacity

Organisational adaptive capacity is the extent to which human capacity has developed to enable organisations to devise and implement effective adaptation strategies. Effective adaptation requires decision-making that takes account of an uncertain future and avoids locking-out future options that might be more cost-effective if climate impacts become more severe, or arrive more rapidly, than expected. The PACT framework used to assess this recognises different levels of adaptation. This framework is arranged in a hierarchy of ‘Response Levels’ (‘RLs’), as set out below, of increasing capacity[21]. These levels do not supersede one another; instead, each one builds on the experiences and practices built up in the previous response level. Organisations may need to be active on all levels for an effective adaptation programme. An RL4 organisation focused on breakthrough projects still needs to be stakeholder-responsive, for example.

> ***RL1: Core Business Focused:*** At this level, organisations see no benefit from adapting; if change is required of them, it should both be very

[20] This differs from ‘Decision timescales’ because investment in a sector is not continuous but varies over time, with periods of high investment being followed by periods of little or no investment.

[21] The PACT framework contains six response levels: those cited are the most relevant to the adaptation field.

straightforward to implement and also incentivised, e.g. through ‘carrots’ and ‘sticks’.

RL2: Stakeholder Responsive: At early stages of adaptation, organisations lack basic skills, information, processes and also skilled people; they need very clear advice and information plus regulations that are straightforward enough to help them get started.

RL3: Efficient Management: As organisations begin to professionalise adaptation, they become more self-directing, able to handle short term impacts up to 10 years (Stafford-Smith *et al.*, 2011). They need professional networks, best practice guidelines, management standards, etc.

RL4: Breakthrough projects: When impacts beyond 10 years need to be considered, organisations may need to consider more radical adaptation options. As well as high quality support from scientists, they may need support with the costs of innovation.

RL5: Strategic Resilience: Adapting a whole region or industry for long-term climate impacts of 30 years or more requires lead organisations to develop very advanced capacity that is able to co-ordinate and support action by a wide range of actors over programmes that are likely to last for many years.

8.3 Adaptive capacity of the floods sector

There is considerable ongoing work on developing adaptive capacity in the floods sector. The main difficulty regarding adaptation in this sector is that flood risk (in terms of assets and people at risk) is already present on the floodplains, and adaptation to substantially reduce risk would be expensive and have limited effectiveness. In addition, the costs of adapting the many kilometres of existing flood defences and other assets could be very high.

The features of structural adaptive capacity are:

- Decision timescales vary; for the planning and construction of wide scale flood defences and other physical measures, there are long timescales. For non-structural measures such as provision of flood warning, decision timescales are shorter.
- Activity levels also vary; the Environment Agency has a continual programme of asset management and maintenance; flood defence replacement or improvement, however, does not occur frequently.
- Maladaptation: Few recent major decisions are likely to require reversal and it is likely that adaptation of existing measures should be possible in most cases. However adaptation could be expensive and involve significant resources, particularly if existing structures are not designed for future adaptation. For example, the flood defences on the Thames Estuary required major engineering works when they were raised in the 1970s.
- Sector complexity is characterised by a small number of organisations that are involved in developing strategies and plans and a large number of stakeholders that are involved in influencing decisions.

Organisational adaptive capacity is being enhanced through a number of sector characteristics, activities and initiatives:

- Awareness of climate change impacts is generally high, particularly within the regulatory bodies and amongst the consultants who advise them.
- Strategic planning and the design of new works include allowances for climate change.
- Government guidance on development and flood risk is well established within planning authorities. This takes account of climate change, and aims to prevent an increase in flood risk associated with new developments.
- The spatial planning process requires Strategic Flood Risk Assessments (SFRA) to plan new development that would not cause an increase in flood risk. Flood Risk Assessments (FRA) are required for individual developments to identify any potential flood risks and associated mitigation measures. Both SFRAs and FRAs take account of climate change.
- An in-depth review of flooding risk was completed by Sir Michael Pitt in 2008 and proposed a programme of activity over 25 years. Lessons from this report were incorporated into legislation on flood risk management enacted in 2010. This included, for instance, regulations for developers and water companies requiring Sustainable Urban Drainage Systems (SUDs) in new developments.
- There is a vigorous community of practice, with great expertise and with many committed agents of change.
- There has been a commendable level of experimentation (for instance in the Thames Estuary 2100 Project). Many lessons on advanced adaptation practice have been drawn from this project, for instance on Decision Pipelines and on Real Options Appraisal, that have the potential significantly to contribute to practice in other sectors.

Adaptive capacity is therefore primarily limited by structural challenges, for instance by the availability of resources to adapt existing infrastructure. Adaptation to flooding is likely to be a gradual process where defences are improved, resilience is increased and new developments take account of the increase in flood risk.

9 Discussion

9.1 Consequences of climate change

This report provides a summary of the main impacts and consequences of climate change in the Floods and Coastal Erosion sector. Impacts are defined as effects of climate change on the socio-biophysical system whereas consequences are the effects on society, the economy or the environment.

The analysis has concentrated on the main consequences of climate change. The consequences of flooding and coastal erosion affect all sectors to a greater or lesser degree. The consequences for which analysis has been carried out therefore include those that have been analysed in this sector plus others that have been analysed in other sectors.

Whilst most of the consequences that have been analysed are direct consequences of flooding, some are indirect consequences (for example, mental health). A degree of systematic mapping has been undertaken to identify cross sectoral and indirect impacts of flooding and coastal erosion but there is scope to further develop this work, for example to assess in more detail the impacts of flooding on vulnerable groups.

9.2 Results of the analysis

The analysis shows that there could be a large increase in the consequences of flooding during the 21st Century as a result of climate change. The projected increases in sea level rise, winter rainfall and storm rainfall intensity would increase both the frequency and extent of flooding.

9.2.1 Rate of increase in risk

One of the most important findings of the analysis is the relatively large increase in flood risk for relatively small increases in river flows and sea level (see, for example, the response functions in Section 4.7). Many of the people and properties at risk are in areas protected by flood defences. Relatively small increases in sea levels or river flows are likely to have a large impact on the frequency of flooding in these areas.

This is because the chosen threshold of ‘significant likelihood of flooding’ (1.3% annual probability of flooding) is just below the standards of protection provided by the defences (typically 1% annual probability for river defences and 0.5% annual probability for tidal defences). Thus a relatively small increase in river flow or sea level may cause overtopping of defences and an increase in flood risk.

The floodplains are typically U, V or W shaped. Much of the land area and, as a consequence, the receptors are located on the lower level regions rather than the sloping sides of the floodplain. Furthermore, it is assumed that the 0.1% annual probability (1:1000) floodplain is the maximum floodplain extent for all epochs. Thus the floodplain does not grow as the water levels increase once the present day 0.1% level is exceeded. This is considered to be a reasonable assumption, as discussed in Section 4.5.3.

Since the land area and receptors are being counted when the probability of inundation exceeds a certain value, it does not take very much increase in flood frequency or water level to add many more receptors to the count. Thus small increases in defence overtopping lead to a large increase in the number of receptors at risk.

As the flood frequencies continue to increase there are fewer receptors to add to the counts as the flood extent reaches the sloping edges of the floodplains. Thus the rate of increase in the number of receptors reduces.

For receptors such as agricultural land, where a number of flood probabilities are quoted, the results show some area being lost from the lower probability counts to the higher probability counts as well as some land being added to the lower probability counts from land nearer the edge of the floodplain. Thus the same trend exists in the highest probability band since the area in this band can only increase. The area in other probability bands varies as some land is gained but other land is lost.

The shape of the response function for London differs compared with other parts of the UK. This reflects the fact that the tidal flood defences for London and the Thames Estuary provide a higher standard of protection than elsewhere in the UK (annual probability of flooding of 0.1%, or 1 in 1000 years). As the sea level rises and river flows increase, the area at significant likelihood of flooding increases but more gradually than in other areas and a smaller proportion of defences are overtopped. As a result, flooding does not cover the full extent of the floodplain by the 2080s, and flood risk continues to rise (rather than levelling off).

9.2.2 Impact of climate change scenarios

The climate change scenarios cover a wide range of projected changes to climate drivers. For example, projected increases in peak river flows range from less than 10% to over 50% for the five scenarios applied in the 2080s. Similarly, sea level rise ranges from less than 0.2 m to more than 0.5 m by the 2080s.

As a result there is a wide range of projected values of change. Table 9.1 shows projections due to climate change only for three metrics: property numbers; property EAD and number of major electricity substations. The latter is one of the metrics calculated using frequency data.

The results show the wide range of projections. Whilst the results give an indication of the potential direction and magnitude of change, there is clearly a wide range of uncertainty that reflects the range of projections in the climate scenarios.

One reason why the range reduces for the later scenarios (2050s and 2080s) as a percentage of the median value is the fact that the number of receptors in the floodplains is limited as shown on the response functions. In extreme climate events where the whole floodplain is inundated, the uncertainty in the number of receptors affected would be small.

Table 9.1 Projected increases in flood risk for different climate change scenarios

Epoch	Metric	Baseline	Increase from baseline (climate change only)			Range as a % of the median value
			Lowest	Median	Highest	
2020s	Properties at significant likelihood of river or tidal flooding (thousands)	560	140	430	600	107
2050s			210	660	820	92
2080s			420	770	940	67
2020s	EAD for properties at risk of river or tidal flooding (£ million)	1,200	200	900	1750	172
2050s			450	1750	3250	160
2080s			900	2550	4950	158
2020s	Major electricity substations at significant likelihood of river or tidal flooding (no.)	58	3	10	18	150
2050s			5	22	34	132
2080s			13	28	41	100

9.2.3 Impact of socio-economic scenarios

The socio-economic scenarios indicate increases in population and property numbers of about 12% by the 2020s, 30% by the 2050s and 45% by the 2080s. These increases have a significant impact on overall flood risk if, as has been assumed in this analysis, the growth is evenly spread across all areas including floodplains.

The proportion of the increase in risk that is attributable to climate change only is summarised in Table 9.2 based on the results presented in Tables 6.5 and 6.6.

Table 9.2 Projected increases in flood risk due to climate and socio-economic change

p50 Medium Emissions climate change scenario; river and tidal flooding; England and Wales

Epoch	Metric	Increase from baseline		Proportion of total due to climate change only (%)
		Climate change only	Total (climate change and socio-economic change)	
2020s	Properties at significant likelihood of river or tidal flooding (thousands)	430	550	78
2050s		660	1020	65
2080s		780	1390	56
2020s	EAD for properties at risk of river or tidal flooding (£ million)	900	1180	76
2050s		1760	2640	67
2080s		2550	4240	60

The results show that the proportion of total increase in risk due to climate change alone decreases from about 76% in the 2020s to 60% in the 2080s. However the proportion due to socio-economic scenarios depends on where new developments take place in the future. Policies are already in place in all four UK countries to prevent an increase in flood risk as a result of new development. Information on flood risk areas is improving with the development of flood maps for surface water groundwater flooding.

If it is possible to avoid any increase in risk due to socio-economic development, the increases shown in the projections for the socio-economic scenarios would not occur. In practice it is likely that some will occur, partly as a result of uncertainty in the extent of flood risk areas and partly as a result of new development in flood risk areas.

Development in flood risk areas is likely to occur in existing urban areas that are protected by defences or in cases where there is a strong case for development, for example a new power station on the coast. However, where new development takes place in flood risk areas, there are opportunities to minimise or eliminate any increase in flood risk by taking flooding into account in development design. Measures that are already adopted include raising building floor levels and providing high level access that can be used in flood events.

9.2.4 Regional results

The results were derived using regional response functions (Section 4.7) and regional projections of climate and socio-economic change (Appendix 7). The regional results were then added together to provide the national results.

The regional results are not presented in this report but an indication of regional variations in the magnitude of consequences is given on the maps in Appendix 10. These show broad bands of change in a number of metrics, and indicate the regions where the greatest consequences are likely to occur.

9.2.5 Higher sea level rise

The UKCP09 sea level rise projections that have been used for this analysis show values of sea level rise up to about 0.6 m. There is a concern that the sea level could rise faster than this, and a High++ scenario is included in the UKCP09 outputs where the mean sea level rise is between 0.93 and 1.9 m, and the increase in tidal surge is between 0.2 and 0.95 m.

It is roughly estimated that the additional number of properties at risk of flooding would more than double if the High++ scenario occurred in the 2080s. There is clearly an important need to monitor the causes of sea level rise and update projections on a regular basis.

There have been a number of papers that have commented on the sea level rise projections from the IPCC fourth assessment report and some have tried to derive a better estimate of rise through the century, e.g. Nicholls, R.J. *et al.* (2011).

In the Netherlands, expert judgement was used to derive sea level rise scenarios for coastal management. This concluded that plausible global sea level rise scenarios were 0.55 m to 1.1 m in 2100.

This suggests that there is a need for coastal managers to keep open a range of adaptation options and to be able to change approach as confidence in the predictions become more robust.

9.2.6 Climate change and natural variability on the coast

The estimates of land lost due to coastal erosion do not take account of erosion that would occur without climate change, as they are changes compared with present day. There is therefore a need to attribute the projected change between the erosion that would occur without climate change, and the contribution of climate change.

The causes of coastal change on a morphological time scale (decades to centuries) are tectonic land movements, sea level and sediment supply. Fluvial sediment inputs are relatively small in the UK and cliff and shoreface erosion is largely (at a regional scale) determined by rate of sea level rise. On shorter time-scales, changes in storm patterns may cause local changes to the coastal geomorphology and the associated evolution of spits, beaches, etc. This might be a consideration in projecting future coastal erosion, if the UKCP09 projections predicted a change in the frequency duration or tracking of storms but this is not the case, and these are not projected to change significantly.

Rates of sea level are relatively low in a geomorphological context. This is then moderated by tectonic changes, with higher rates of relative sea level rise in Southern England and negative values in Scotland. There is some evidence that the eustatic changes have accelerated over the last century to around 3mm/yr and the projections suggest that this acceleration will continue. However attribution of the rate of change is difficult. Some recent work has suggested that even Scotland is now experiencing relative sea level rise (although this is based on rather short data sets). Long term erosion would continue in the absence of sea level rise, as sea level is only one of several factors in determining erosion rates.

If one considers the baseline as 2010, then a large proportion of the ongoing change is probably due to climate driven sea level rise (perhaps two thirds for locations with no tectonic change). However, this will then be influenced at a local scale by efforts to control the coast, particularly along urban frontages. This is where the more detailed work from the National Coastal Erosion Risk Map (NCERM) will help by providing local detail that can be scaled to give more representative short term changes (of the order of 10-20 years). Although it is worth noting the work of Clayton, who showed that the long-term rates of erosion on the Norfolk coast were unaffected by protection works over time scales that are longer than the design life of the structures (Clayton, 1989).

9.3 Social vulnerability

Flooding can have a profound effect on the lives of people who are affected. The people who are likely to suffer most include those who live in poorer communities and those who are vulnerable for other reasons, for example the elderly and disabled.

The analysis includes an assessment of the number of properties in deprived areas and (by implication) the number of people. It also provides an estimate of the number of people who might suffer mental stress as a result of flooding. In addition, a social vulnerability checklist has been completed (in Appendix 6).

The purpose of this section is to consider the wider impacts of flooding on vulnerable people including those who live in deprived areas and those who are vulnerable for other reasons.

People who live in deprived areas where incomes may be low, crime rates high and community cohesion may be poor can be particularly vulnerable to flooding. One reason for this is that poorer communities are often in more vulnerable locations where the flood risk is relatively high. Poorer communities may also contain poorer quality buildings which could be damaged beyond repair by flooding leaving the occupants with nowhere to live, or be costly and difficult to repair.

People who cannot afford property and contents insurance are particularly vulnerable to flooding because they would have great difficulty recovering following a flood. They may also have problems finding temporary accommodation if their home becomes uninhabitable as a result of flooding.

More generally poorer communities may not be able to rehabilitate themselves as well as more affluent communities. There is also a risk that a high proportion of residents affected by flooding could suffer mental stress and health problems. Injuries and poor health problems may continue for extended periods (months or years) after the flooding has receded.

The overall impact of increases in flooding on poor communities could lead to an increasing number of people who are unable to manage and require support.

Another category of vulnerable people are those in all communities who are less able to cope with floods. These include the elderly and those who are sick or disabled. Particular problems include inability to evacuate, which could result in a higher likelihood of injury or fatality. Vulnerable people are also likely to suffer more than most in the case of service shutdown (for example power or water).

The elderly and disabled often live in bungalows or ground floor flats to avoid the need to use stairs. However, these are particularly vulnerable to flooding as there is no upper storey to escape from floodwater, and nowhere dry to store belongings.

Flooding is a situation where isolated people are likely to suffer most as they often lack social networks and they may be unaware of the flood risk and the flood warning arrangements.

Communities in erosion zones are very vulnerable, particularly those who live in houses that are likely to be destroyed by erosion within the lifetime of the occupant. These houses tend to be cheaper if they are in known erosion zones because of their limited life, and therefore will attract people with less money. Once a house is destroyed, the occupants may not be able to afford to relocate and may have nowhere to live.

9.4 Limitations

9.4.1 Limitations of the current methodology

There are a number of important limitations and assumptions in the analysis, which are discussed in these sections.

Most of the analysis is based on information for England and Wales, which is supported by quantified models. More limited information exists in Scotland and Northern Ireland, which together represent about 6% of the flood risk to the UK as a whole.

The modelling approach used for the analysis is not available for Scotland and Northern Ireland. Work is in progress to develop flood risk models for Scotland, but all the work carried out to date is based on an annual probability of flooding of 0.5% (rather than 1.3% used in this analysis). The England and Wales model results include results for an annual probability of 0.5%, but it may be necessary to revise the approach for the next CCRA to ensure that results from Northern Ireland and Scotland can be used.

The analysis is generally based on tidal and river flooding. There is much less information available for surface water flooding. In particular, no information was available on future projections of the consequences of surface water flooding.

The study is concerned with assessing the underlying change in flood risk due to climate change, so that comparisons can be made with other types of climate change risk. The analysis does not consider adaptation to manage the increase in flood risk and assumes that the existing defence system will be maintained at its current extent and condition. The analysis does not take account of investment to reduce the risk or deterioration in the condition of the existing flood risk management system.

It is important to understand the scope of the analysis to ensure that the results are not used incorrectly. The projections should be interpreted as the increase in flood risk that would occur if no new flood risk management measures were to be implemented other than operating and maintaining the existing system.

The analysis is based on the results of national modelling. The models are complex and great care was needed to ensure that the interpretation of the results was suitable for the CCRA analysis.

There are also concerns regarding the projections for increases in flood risk by the 2020s. This is partly because of the relatively large short-term increase in risk and uncertainty over the baseline date for river flooding.

It is advised that the short-term projections (for the 2020s) are treated with extreme caution and not used for planning purposes.

The baseline used for coastal erosion includes the assumption that urban areas will be protected. In practice, whilst large urban areas on the coast would be protected wherever possible, it is likely that erosion will occur in some communities. It is recommended that more detailed work is undertaken on this aspect in the next CCRA.

It is assumed in the application of the socio-economic scenarios that population growth occurs evenly including the floodplains. This is potentially an unrealistic assumption because policies are in place to avoid an increase in flood risk due to development wherever possible, as discussed in Section 9.2.3.

9.4.2 Gaps in evidence

There are a number of important limitations in the available data for the analysis including the following:

- Most of the analysis is based on information for England and Wales, which is supported by quantified models. Suitable information for analysis was not available for Scotland and Northern Ireland.
- The analysis is generally based on tidal and river flooding. There is much less information available for surface water flooding which meant that it could not be covered by the analysis. In particular, no information was available on future projections of the consequences of surface water flooding.

- Information on water pumping stations and treatment works was not available for the analysis.

- The quality of coastal erosion data used in the analysis was relatively poor and better information should become available from the National Coastal Erosion Risk Map (NCERM).

The quality of information for the analysis is summarised in Table 9.3, including an assessment of the main gaps in information. It is apparent from the table that the main gaps where further information is required are projections for future surface water flooding, projections for future flood risk in Scotland and Northern Ireland, information on the locations of critical infrastructure in the water sector, and improvements in the coastal erosion analysis. A particular gap is the combined effects of sea level rise and coastal erosion on communities on coasts and estuaries.

Table 9.3 Information quality and data/information gaps

Quality of information:	Good	Medium	Poor

Consequences	Risk metrics	Quality of information	Gaps in information and data
People affected by flooding	**FL1** No. of people		Scotland and NI Surface water flooding
Vulnerable people affected by flooding	**FL2** No. vulnerable people		Scotland and NI Surface water flooding
Extreme flood event mortality	**HE3** Flood related deaths		
Extreme flood event morbidity	**HE7** Flood related injuries		Knowledge of flood related injuries
Effect of floods on mental health	**HE10** Mental stress caused by flooding		
Impact of flooding on agriculture	**FL4** Area of agricultural land at 10% and 33% or greater annual probability of flooding		Scotland and NI Surface water flooding Waterlogging
Flooding of residential properties	**FL6a** No. residential properties **FL6b** EAD to residential property		Scotland and NI Surface water flooding
Flooding of non-residential properties	**FL7a** No. commercial properties **FL7b** EAD to commercial property		Scotland and NI Surface water flooding
Coastal flooding of natural and tourist assets	**BU2** UK beaches and fixed tourist assets at risk from flooding		Data on risk to tourist assets
Flooding of business and industry assets	**BU4** Flood damage and interruption costs to business		
Supply chain disruption caused by flooding	**BU9** Change in output for UK businesses due to an increase in supply chain disruption.		No relevant information currently available.
Flooding of roads and rail	**FL8a** Roads exposed to flooding (km) **FL8b** Rail exposed to flooding (km)		Scotland and NI Surface water flooding
Disruption and delay to road transport	**TR1** Disruption and delay caused by flooding of roads		
Scour at bridges	**TR6** Scour of bridge foundations		Information on bridge foundations
Flooding of water installations	**FL10** Water distribution and treatment installations at risk of flooding.		Location of water installations. Data should become available in 2011.

Consequences	Risk metrics	Quality of information	Gaps in information and data
Flooding of energy installations	**FL11a** Power stations (number and capacity) **FL11b** Electricity substations **FL11c** Nuclear sites		Scotland and NI Surface water flooding
Flooding of health and education facilities	**FL12a** Hospitals and hospital beds at significant likelihood **FL12b** Schools and school pupils		Scotland and NI Surface water flooding
Flood disruption to ICT systems	**BU5** Disruption of ICT due to flooding		No relevant information currently available
Effects of flooding on insurance of residential properties	**FL13** No of **residential** properties at significant likelihood of flooding (to assess insurance impacts)		Scotland and NI Surface water flooding
Flood impacts on property mortgages	**BU6** Value of mortgages at risk		Scotland and NI Surface water flooding
Larger insurance and reinsurance payouts	**BU7** Increase in payout costs by the insurance industry		
Flooding of cultural heritage sites	**FL15** Area of SAM sites at significant likelihood of flooding		Scotland and NI Surface water flooding Locations of cultural heritage sites
Sewer flooding and CSO spills	**WA10** Change in CSO spill frequency		
Land lost due to coastal erosion	**FL14a** Agricultural land **FL14b** BAP habitat		Scotland and NI Improved coastal erosion data including towns on coasts and estuaries
Coastal evolution impacts on habitats	**BD2** Coastal evolution impacts on coastal and estuary habitats		Improved information on coastal impacts
Flood impacts on coastal habitats	**BD7** Major coastal flood / reconfiguration		

The gaps in evidence outlined above do not cover impacts on the Tier 1 list that were not taken forward to Tier 2. It is recommended that this list is reviewed and further work undertaken on those impacts that may be underestimated at present.

For example the possibility of flooding as a result of joint extremes (including high sea levels combined with high fluvial flows, or high sea levels combined with extreme wave conditions) is relatively poorly understood at present.

Another potential gap is the need for additional monitoring and interpretation of data so that it can be used in future cycles of the CCRA.

10 Conclusions

It is estimated that about 6 million people in the UK (about 10% of the population) are at risk of flooding from rivers or the sea. A similar number are at risk from surface water flooding. In addition, about 3,000 km of the coastline (17% of the total length) is eroding. Thus floods and coastal erosion are already serious risks in the UK, and they are projected to increase as a result of climate change.

This report provides estimates of the potential change in flood and coastal erosion risk due to climate change, so that comparisons can be made with other types of climate change risk. The results are to be used in the preparation of the CCRA report required by the Climate Change Act, which will provide an overview of the potential risks from climate change to the economy, the environment and society.

This report has no other purpose. In particular, it is not intended to provide information on how to adapt to future change or what the effects of measures to reduce flood risk are likely to be.

Projections of the change in risk have been calculated for a number of consequences of flooding and coastal erosion. These were selected from a long list of consequences by a process of scoring and consultation, and are considered to be the most important consequences. The results are given in terms of the number of receptors in most cases (people, property, etc) and information on the spatial scale that this would cover is only provided in a small number of cases, for example area of agricultural land at risk of flooding.

The climate change projections indicate that the sea level is highly likely to continue to rise and that the rate of rise is projected to increase. This would lead to an increase in flood risk on the coast and in estuaries through overtopping, increasing rates of erosion and defence asset deterioration if there were no interventions to reduce the risk.

Considering UKCP09 projections of future rainfall, it is considered likely that winters will become significantly wetter and that extreme winter precipitation will increase across the UK in all regions.

In summer, less overall rainfall is considered likely but future summers are projected to be characterised by intense heavy downpours interspersed with longer relatively drier periods. These winter and summer changes would lead to an increase in fluvial and surface water flooding.

Based on these projections, the analysis indicates that the risk from tidal and river flooding could increase. For example, the annual flood damages to properties is projected to increase by between 70% and 400% by the 2080s compared with the baseline as a result of climate change assuming no change in population or property numbers, and assuming no change in existing flood risk management measures.

These increases could be exacerbated by socio-economic change as the population and property numbers are projected to rise. However, the additional increase that might occur as a result of socio-economic change will depend on the success of current and future polices on preventing development in flood risk areas. Depending on scenario, the effect of socio-economic change could be to increase the additional risk due to climate change by between 0% and 90% by the 2080s.

Whilst the projected increases in flood risk for the 2050s and 2080s are consistent with projections produced in other projects, there is concern that the near-term results (for the 2020s) appear high compared with the baseline data. Whilst this reflects uncertainty in the date of the baseline data rather that the projections for the 2020s, it is advised that results presented for the 2020s in this report should be treated with caution, and not be used for planning purposes.

The overall numbers of people and property at risk from surface water flooding are comparable with those for river and tidal flooding. However, future projections of flood risk were not available for this type of flooding and it is not included in the analysis. Information on projected future surface water flood risk should be developed for the next CCRA.

The analysis indicates that the number of people at risk of tidal and river flooding could increase by between 100% and 400% by the 2080s. The potential consequences include an increase in cases of mental stress due to flooding amongst those affected, and a greater need for temporary accommodation while properties are being repaired. Flood risks to people include vulnerable individuals in all communities (for example, the elderly and disabled) and those who live in deprived communities.

An increase in flooding is also likely to affect agriculture, roads, railways and other infrastructure (including power stations, electricity substations, water and sewage treatment works, communications, hospitals, etc). Projections have been made of the potential increases in risk where data were available. Indirect consequences including the effects of the temporary disruption of essential services due to flooding have been identified but not quantified.

The effects of increases in flooding on business that have been assessed include damage to premises, disruption to supply chains, effects on property insurance and the potential consequences for mortgage lenders. The potential effects on business have been assessed as High or Very High.

The effect of climate change on the coastal erosion and evolution is difficult to assess because of the complexity of the processes and the fact that the coast will continue to evolve whether or not climate change occurs. However it is projected that climate change would cause an increase in the rate of loss of land due to erosion and an increase in flood risk to coastal freshwater habitats.

There are a large number of indirect consequences of flooding and coastal erosion on society, the economy and the environment. These include, for example, the disruption caused when services fail as a result of flooding of critical infrastructure, or the overall impacts on vulnerable people. Some of these wider impacts have been assessed in the analysis but in other cases there is a need to gather suitable information to inform an analysis of the consequences.

Whilst the analysis contains some broad assumptions it is clear that the increase in flood risk based on the UKCP09 projections could be large and have widespread consequences.

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Appendices

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1. Sector Scoping Report

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Comments were also provided on the report by a large number of Government and other consultees. These comments are gratefully acknowledged and have been taken into account in this release.

Appendix 2 The 'Tier 1' list of impacts

The following points should be considered when using the data:

- In addition to the impacts identified in the sector report, impacts were extracted from the CCRA scoping study (Watkiss *et al.*, 2009)[22], a regional report (HR Wallingford, 2010c)[23], and additional grey and research literature.
- Where the same or similar impacts have been identified, attempts have been made to remove duplicates. However, where there are subtle differences between impacts, similar impacts have been retained as separate impacts in the spreadsheet. Additional and sometimes novel impacts raised at the CCRA Forum event (21st January 2010) have also been recorded.
- There are many potentially adverse impacts but also a number of opportunities have been identified. A preliminary assessment has been made of threats (adverse impacts) and opportunities in the tables using the following colour code:
- T= threat (red), O = opportunity (green); N = neutral impact (amber).
- However it is recognised that there may be both positive and negative aspects of the same impact.

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Flooding and Coastal Erosion Sector: Climate Change Impacts

Climate effects	Impacts	T/O/N	Consequences	Comments
Main climate driver: Changes in annual, seasonal or daily precipitation				
1. Increased winter rainfall	Increased risk of inland river flooding		**Population affected** - loss of life; health impacts. Loss and damage to **properties**; Damage to **agriculture**; Cost for emergency response; B**usiness** interruption/loss; **Social/community** disruption; Degradation of water quality, as potential **pollutants** are transported into water courses.	River flooding covers a wide range of impacts. High score. Metrics taken forward include: People: FL1, FL2, HE3, HE7, HE10 Agriculture: FL4 Property: FL6, FL7 Business: BU2, BU4, BU9
2. Increase in rainfall intensity and volume - increase in frequency of heavy winter rainfall events	Increase in surface water flooding		Impact on health, higher repair costs (economic costs) and longer periods of disruption; pollution	Surface water flooding covers a wide range of impacts. High score. Metrics taken forward same as item 1 above plus WA10 (CSO spills)
3. Decrease in summer rainfall	Dry weather drainage blockage		Flooding and Infrastructure Damage	Clustered with item 2 above.
4. Increased winter rainfall; increase storm intensity	Intra-urban flooding		Social disruption, Economic Costs and Pollution; Population affected, damage; possible withdrawal of insurance.	Clustered with item 2 above.
5. Seasonal changes in rainfall	Groundwater flooding		Flooding and Infrastructure Damage	Not taken forward (low score)
6. Increases in rainfall intensity and volume	Sewer flooding		**Increase in flooding and associated pollution** (where there are combined sewers). Impacts on health; higher repair costs.	Clustered with item 2 above. Metric WA10 is particularly relevant
7. Increase in intense multi-day rainfall events	A slight increase in the number of mine water outbreak events		Damage to infrastructure; significant pollution of watercourses	Not taken forward (low score)
8. Increase in intense rainfall events combined with high tide or river levels	Restriction or tide-locking of drainage outfalls		Flows backing-up and flooding	Clustered with items 1, 2 and 17
9. Drier summers (decrease in summer rainfall)	May delay onset of flood season		Benefits in terms of flood risk	Not taken forward (low score)
10. Increase in winter rainfall; intense rainfall events; sea level rise	Flooding of contaminated sites and waste management sites		Water quality and water quality objectives; detrimental impact on ecosystems and habitats	Not taken forward (low score)
11. Increased winter rainfall; increase storm intensity	Damage to critical infrastructure		Disruption of: **Transport** **Energy** generation and distribution **Water** supply and treatment **Health** other emergency services. **Communications** including ICT	High score. Metrics taken forward include: FL8, TR1, TR6 (transport) FL11 (energy) FL12 (health and schools) BU5 (ICT)
12. Increase in winter rainfall; increase in frequency of intense rainfall events	Resettlement		Social/community disruption	Not taken forward (low score)
13. Intense rainfall events	Slippage risk to soil dams		Flooding and Infrastructure Damage	Not taken forward (low score)
14. Increased winter rainfall; increase storm intensity	Change in recreational activities or amenities		Social deterioration	Not taken forward (low score)
15. Increased winter	Potential gains and		Environmental loss	Not taken forward.

Climate effects	Impacts	T/O/N	Consequences	Comments
rainfall; increase storm intensity	losses of ecosystems			Primarily a biodiversity issue.
16. Increased winter rainfall; increase storm intensity	Potential gains and losses of ecosystem services		Environmental reduction	Not taken forward. Primarily a biodiversity issue.
Main climate driver: Sea level rise				
17. Sea level rise and storm surge	Increased tidal flooding - population flooded		**Population affected** - loss of life; health impacts. Loss and damage to **properties**; Damage to **agriculture**; Cost for emergency response; **Business** interruption/loss; **Social/community** disruption;	Tidal flooding covers a wide range of impacts. High score. Metrics taken forward include: People: FL1, FL2, HE3, HE7, HE10 Agriculture: FL4 Property: FL6, FL7 Business: BU2, BU4, BU9
18. Sea level rise and storm surge	Land lost (area flooded or submerged)		Social inequalities if no compensation for loss of coastal land; less land for agriculture, potential crop failures; increase in demand for housing; pressures on land use and planning (many sectors). Social, economic and environmental costs	Clustered with item 17 above.
19. Sea level rise and storm surge	Increased coastal erosion		Loss of land; increase in expected annual damage; changes to coastal processes. Economic costs	High score. Metric FL14 taken forward
20. Sea level rise and storm surge	Forced movement of population		Social and community disruption	Not taken forward (low score)
21. Sea level rise and storm surge	Coastal squeeze		**Loss of habitats**; impact on planning; managed retreat with consequences for wildlife, infrastructure and cultural resources: Environmental, Economic and Social issues	High score. Metric BD2 from Biodiversity Sector taken forward
22. Sea level rise and storm surge	Salinity intrusion		Security of supply: Pollution of groundwater; salinisation of productive farmland	This was not regarded as an important flooding issue. It is however of interest to agriculture and water.
23. Sea level rise and storm surge	Loss of natural assets (beach/dune)		**Environmental loss** of species and change in recreational activities (social consequences)	High score in Business Sector. Metric BU2 taken forward. Environmental aspects covered by metric BD2.
24. Sea level rise and storm surge	Loss of wetland		**Environmental loss** of species and change in recreational activities (social consequences)	High score in Biodiversity Sector. Metric BD7 taken forward.
25. Sea level rise and storm surge	Loss of ecosystems		Environmental loss	Covered by metrics BD2 and BD7
26. Sea level rise	Changes to coastal processes		Potential for increased flooding and effects on coastal habitats - environment	Covered by metrics BD2 and BD7
27. Sea-level rise	Tidal flooding threatening the stability of estuaries shores			Not taken forward (low score)
28. Sea level rise	Permanent sea breaches		More frequent and severe flooding	Clustered with item 17 above.
29. Sea level rise and storm surge	Damage or risk to infrastructure		Disruption of: **Transport** **Energy** generation and distribution **Water** supply and treatment **Health** other emergency services **Communications** including ICT. Some installations, such as oil refineries, could be relocated at the end of their operational life.	High score. Metrics taken forward include: FL8, TR1 (transport) FL11 (energy) FL12 (health and schools) BU5 (ICT)
30. Sea level rise and storm surge	Reduction in ecosystem services		Environmental loss	Clustered with item 26 above.
31. Sea level rise and storm surge	Major sea level rise, > 1 metre		Severe tidal flooding, with resultant economic and social disruption. Lack of adaptation.	Clustered with item 17 above.
32. Sea level rise	City inundation		Smaller agglomerations sacrificed to save larger ones : Social / Community disruption	Clustered with item 17 above.
33. Sea level rise	Loss of		Damage to **historic sites**	Low score but considered

Climate effects	Impacts	T/O/N	Consequences	Comments
and storm surge	archaeological or cultural importance		**Social/community** disruption	potentially important by consultees. Metric FL15 taken forward (which also covers freshwater flooding)
34. Sea level rise and storm surge	Increased pumping costs (land drainage)		Economic costs; pressure on drainage systems	Not taken forward (low score)
35. Sea level rise and storm surge	Change in recreational activities or amenities		Local economic costs	Not taken forward (low score)
36. Sea level rise	Harbours can take in larger ships		Social and economic opportunities tourism / trade	Not considered important as benefit small
Main climate driver: Changes in annual, seasonal or extreme temperature				
37. Warmer winters (increase in average winter temperature)	Reduction in snow-related flood events		Benefits to those floodplain areas which traditionally suffer from these events	Clustered with items 1, 40 and 45
38. Hotter summers (increase in average summer temperature)	More summer convective storms and flooding		Urban infrastructure damage	Clustered with item 2 above.
39. Change in wave climate; sea-level rise	Increased overtopping of coastal defences by waves		Increased flooding	Clustered with item 17 above.
40. Increase storm intensity	Increased risk of inland river flooding		As consequences for increased winter rainfall	Clustered with item 1 above.
41. Increases in rainfall intensity and volume - increase in frequency of storm events	Increase in surface water flooding		Impact on health, higher repair costs (economic costs) and longer periods of disruption; pollution; evacuation and closure of transport links	Clustered with item 2 above.
42. Changes to predominant wind directions	Increased exposure for certain coastlines		Recreational Opportunities : increase in recreational activities (e.g. surfing), decreases in some recreation activities; enhanced/accelerated erosion, more frequent tidal flooding in estuaries, deltas and embayments	Not taken forward (low score)
43. Increase in storms; heavy rainfall	Damage to reservoirs		Flooding and breach risk; stability concerns; area may need to be evacuated; closure of roads, impact on energy infrastructure	Not taken forward (low score)
Additions from workshop and review comments				
44. Flooding	Failure of the insurance industry		Loss of **insurance** for properties. Link with **mortgage provision**	High score. Metrics taken forward include: FL13 (insurance availability) BU6 (mortgage impact) BU7 (insurance payouts)
45. Sea level rise; flow increase; bigger waves. Also dryer summer conditions	More overtopping of defences leading to more defence failures. Drying of flood banks in summer leading to increased chance of failure		Increased flooding	Clustered with items 1 and 17 above.
46. Sea level rise	More frequent operation of flood barriers, leading to reduction in reliability and increased chance of failure.		Increased flooding	Clustered with items 1 and 17 above.

Climate effects	Impacts	T/O/N	Consequences	Comments
47. Increase in precipitation leading to increase in sediment yield and higher river flows.	Inland erosion and accretion, leading to loss of river banks, blockages and consequent flooding.		Damage to assets and infrastructure. Increased flooding caused by blockages.	Not taken forward (low score)
48. Changes in temperature and precipitation.	Increase in vegetation in river channels		Increase in flood risk. Need for more maintenance activities.	Clustered with item 1 above.

Appendix 3 The policy landscape

A3.1 Introduction

The UK Climate Change Risk Assessment (CCRA) method is designed to identify key climate risks or opportunities for the UK and where possible quantify the potential impact of climate change across a number of sectors. In order to consider present and future adaptation, an understanding is needed of where policy is already in place (or in development) that will minimise these risks. It is for this reason that a review of the policy landscape has been undertaken as an element of the CCRA.

A3.2 Background

Climate change has been taken into account in flood and coastal erosion risk management policy and practice for many years. Sea level rise was taken into account in the design of the Thames Barrier in the 1970s and sea level rise allowances have been included in UK Government guidance for flood and coastal defence projects for many years (see, for example, MAFF, 1999).

A strategic approach to flood and coastal erosion risk management has also developed which has led to the adoption of Catchment Flood Management Plans (CFMPs) and Shoreline Management Plans (SMPs). Whilst England and Wales were advanced in this type of approach, a plan-led approach has been adopted in all four UK countries to ensure that the specific requirements of the EU Floods Directive (Directive 2007/60/EC) are met. The Directive requires climate change to be taken into account in the development of flood risk management plans.

A requirement of sustainable development is that planning policy should take account of flood and coastal erosion risk at all stages in the planning process to avoid inappropriate development in areas at risk of flooding. The requirement to take flood risk into account in spatial planning is well established and supported by guidance in all four UK countries. The impacts of climate change on flood risk are also taken into account by planning authorities in local planning decisions. At the time of writing, planning policy within England was being reviewed by Government to provide a more streamlined planning system.

The adoption of more sustainable approaches to flood and coastal erosion risk management has led to changes in policy and legislation. Recent flood events have highlighted particular issues that are now being addressed such as the importance of reducing flood risk to critical infrastructure and increasing the flood resilience of properties, particularly where community flood defences or other alternative measures are not viable. This includes Sector Resilience Plans that set out the current level of resilience of critical infrastructure to natural hazards.

A3.3 Main Stakeholders

The main stakeholders in flood and coastal erosion risk management are:

<u>Government</u>

- The Department for Environment Food and Rural Affairs (Defra) in England
- Scottish Government
- Welsh Government
- Northern Ireland Executive

- Other government departments for example with policy responsibility for spatial planning, emergency planning, transport and critical infrastructure.

<u>Government agencies</u>

- Environment Agency
- Environment Agency Wales
- Scottish Environmental Protection Agency (SEPA)
- Rivers Agency, Northern Ireland.

<u>Other</u>

- Local authorities
- Internal Drainage Boards (IDB) (England & Wales)
- Groups representing communities at risk from flooding and/or coastal erosion
- Water companies
- Organisations involved with emergency planning and response, coastal management, insurance, conservation, heritage, transport, other infrastructure and services.

A3.4 Policy Landscape: England

The Flood and Water Management Act (2010) has set a new framework for flood and coastal erosion risk management in England. The Act builds on previous legislation but includes changes in responsibilities and requirements, and is in the process of implementation. One of the requirements of the Act is the production of a national flood and coastal erosion risk management strategy for England, which has been developed to provide the overarching framework within which risk management authorities and communities can develop local solutions to tackle the flooding and coastal erosion risks that they face (Environment Agency, 2011). Lead local flood risk authorities are responsible for developing, maintaining and applying a local flood risk management strategy which specifies how risks are to be managed within its area consistent with the National Strategy.

The Act implements Sir Michael Pitt's recommendations requiring urgent legislation, following his review of the 2007 floods. Current legislation and policy aims to provide better, more sustainable management of flood risk for people, homes and businesses taking account of climate and other future change.

The Flood Risk Regulations (2009) transpose the EU Floods Directive into law in England and Wales. This will lead to new flood hazard mapping and flood risk management plans which will build on existing flood mapping and flood risk management planning. The existing Catchment Flood Management Plans (CFMPs), Shoreline Management Plans (SMPs) and associated strategies all consider the impact of climate change when identifying the preferred approaches to flood and coastal management.

The Government has published the draft National Planning Policy Framework (NPPF) for consultation. The draft NPPF aims to make the planning system less complex and more accessible and will replace individual planning policy statements for example on development and flood risk. The NPPF retains the key elements of the policy endorsed by the Pitt Review into the 2007 floods, to avoid and manage flood risk to development. It seeks to ensure that: development is located away from flood risk whenever possible; development that is needed in flood risk areas is safe and resilient; flood risk is assessed so it can be avoided and managed; opportunities offered by new development are used to reduce causes and impacts of flooding. The NPPF also seeks to reduce the risk from coastal change by avoiding inappropriate development in vulnerable areas.

Strategic Flood Risk Assessments are required to ensure that flood risk is taken into account in strategic planning of new development, and Flood Risk Assessments are required for individual new developments. These approaches require consideration of climate change.

Departmental Adaptation Plans (DAPs) have been developed which set out how each Government department will respond to climate change. They include current adaptation responses and future adaptation priorities and actions. Those for Defra and DCLG reflect current flood and coastal erosion risk management policies.

A3.5 Policy Landscape: Scotland

Responsibility for managing flooding in Scotland is shared between SEPA, local authorities and Scottish Water. Local authorities are responsible for delivering the majority of flood protection work in Scotland and Scottish Water have responsibilties for surface water and sewer flooding. SEPA has a strategic role including co-ordination and facilitating the delivery of information.

The Flood Risk Management (Scotland) Act 2009 sets out a sustainable approach to flood management that is responsive to the implications of climate change. The Act also incorporates the requirements of the EU Floods Directive including flood hazard mapping and flood risk management plans, to be implemented by SEPA. The concept of sustainable flood management was introduced in the Water Environment and water Services Act 2002.

The main aim of the Act is to deliver timely and sustainable approaches to reducing the impact of flooding to Scotland's communities, environment, cultural heritage and economy. Managing flooding sustainably means moving away from reactive management of flooding towards a proactive and catchment focused approach. The Act requires consideration of the implications of climate change and adaptation actions. The document *Sustainable Flood Risk Management* sets out statutory guidance to SEPA, local authorities and Scottish Water on their responsibilities under the Act.

Policy on development and flood risk is set out in Scottish Planning Policy (SPP), where one of the key aims is to prevent further development which would have a significant probability of being affected by flooding or which would increase the probability of flooding elsewhere (SPP7, Planning and Flooding). Planning Advice Note (PAN) 69 contains advice on planning and building standards in areas where there is a risk of flooding.

A3.6 Policy Landscape: Wales

Legislation for flood and coastal erosion in Wales is the same as that in England. In particular, the Flood and Water Management Act (2010) sets a new framework for flood management in Wales and the Flood Risk Regulations (2009) cover the requirements of the EU Floods Directive.

The Flood and Water Management Act requires the development of a strategy for flood and coastal erosion risk management for Wales. Consultation on the strategy was undertaken in 2010 and the strategy is due to be published by the Welsh Government in 2011. The need to adapt to climate change is recognised both in the legislation and the Consultation Document.

Specific policy on development and flood risk is set out in Technical Advice Note (TAN) 15 – Development and Flood Risk, which provides supplementary guidance to Planning Policy Wales. The guidance aims to direct new development away from those areas which are at high risk of flooding, and requires climate change to be taken into account in the planning process. Guidance on planning in the coastal zone is covered by TAN 14 – Coastal Planning.

A3.7 Policy Landscape: Northern Ireland

The Rivers Agency within the Department of Agriculture and Rural Development (DARD) is the statutory drainage and flood defence authority. Flood risk management policy is set out in Living with Rivers and the Sea (DARD, 2008) which includes the transition from flood defence to flood risk management in Northern Ireland.

The Rivers Agency is responsible for delivery of the requirements of the EU Floods Directive under the requirements of the Water Environment (Floods Directive) Regulations (Northern Ireland) 2009. This includes flood hazard mapping and flood risk management plans that take account of climate change.

Policy on development and flood risk is set out in Planning Policy Statement (PPS) 15: Planning and Flood Risk (June 2006). The primary aim is to prevent future development that may be at risk from flooding or that may increase the risk of flooding elsewhere, taking account of the potential impacts of climate change.

A3.8 Summary

Policy in relation to flood and coastal erosion is relatively mature in that there has been significant work undertaken to understand the risks associated with flooding and the areas that are most at risk.

Current policy and legislation in all four UK countries takes climate change into account, and aims to achieve sustainable flood risk management. The requirements of the EU Floods Directive are being implemented in the UK countries, including flood risk management plans that take account of climate change.

Whilst guidance on development and flood risk differs between countries, the overall aim is to prevent or minimise any increase in flood risk as a result of new development.

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Appendix 4 Selection of the 'Tier 2' impacts

FLOODS AND COASTAL EROSION SECTOR

	Magnitude			*Note 2*			*Note 1*		*For info.*		
Name of clustered consequences (incl. individual impact reference numbers from sectors summary report)	**Economic**	**Environmental**	**Social**	**Vuln. Groups Y/N**	**Likelihood**	**Urgency**	**Total Score**	**Ranking**	**Average Pedigree**	**Tier 2 impact?**	**Comments on selection**
Coastal flooding (17, 18, 20, 28, 31, 32, 39, 42, 45)	3	2	3	Y	3	2	59	1	3	**Yes**	Score >30. Includes people and property. Agriculture and transport routes in 'Possible' category
Tidal flooding (8, 20, 22, 46)	3	1	3	Y	3	2	52	2	2	**Yes**	Linked to coastal flooding
Coastal squeeze - Loss of inter-tidal areas (21)	1	3	1	N	3	2	37	3	3	Yes	Score >30. Covered in Biodiversity Sector
River flooding (1, 9, 12, 37, 40, 45)	3	1	3	Y	2	2	35	4	3	**Yes**	Score >30. Includes people and property. Agriculture and transport routes in 'Possible' category
Damage to critical infrastructure (11,29)	3	1	3	Y	2	2	35	4	2	**Yes**	Score >30. Includes water and energy. Health buildings in 'Possible' category.
Insurance collapse (44)	3	1	3	Y	2	2	35	4		**Yes**	Score >30.
Pluvial and sewer flooding (2, 3, 4, 6, 9, 12, 37, 38, 41)	2	2	2	Y	2	2	30	7	2	**Possible**	Score 30. Sewer flooding covered by surface water data. CSO spills covered in the Water Sector.
Loss of natural resilience and ecosystem function (15, 16, 23, 24, 25, 26, 30)	2	2	2	N	2	2	30	7	2		Score 30. Covered in Biodiversity Sector but under different headings
Coastal erosion (12, 19, 20, 42)	2	1	2	N	2	2	25	9	4	**Yes**	Low score but important for other sectors (including Marine and Transport). Includes people and property. Heritage and transport routes in 'Possible' category
Inland erosion and accretion (47)	2	2	1	N	2	2	25	9	3		Added following workshop
Flood season for agriculture (9)	3	1	1	N	2	2	25	9	2		Regarded as improtant as workshop
Opportunities (9, 36, 42)	1	2	1	N	2	2	20	12			
Increase in vegetation in river channels (48)	2	1	1	N	2	2	20	12	2		
Release of pollutants (7, 10)	1	3	2	N	2	1	15	14	2		
Resettlement (12, 20)	2	1	3	Y	2	1	15	14	3		
Groundwater flooding (5)	1	2	2	N	2	1	12	16	2		
Reservoir flooding (13, 43)	1	1	3	Y	1	2	12	16	1		
Land drainage (34)	2	1	1	N	2	1	10	18	1		
Estuary stability (27)	2	2	2	N	1	1	7	19	3		
Loss of archaeological or cultural importance (33)	1	1	1	N	2	1	7	19	1		
Change in recreational activities (14, 35)	1	1	2	N	1	1	5	21	1		
Note 1	The threshold for the Tier 2 list is a score of 30, based on a review of all sectors.										
Note 2	Y/N used as an indication of whether vulnerable groups have been identified (via the social vulnerability checklist) as being particularly affected by this impact										
Score											
High	3										
Medium	2										
Low	1										

Appendix 5 Indirect consequences of flooding

A method for assessing the indirect consequences of flooding is presented in this Appendix. The method involves linking the drivers of climate change with direct impacts of flooding and the indirect consequences.

Figure A5.1 shows some the linkages related to flooding in four levels, as follows:

- Level 1: Direct biophysical effects of climate change
- Level 2: Direct impacts of flooding
- Level 3: Indirect consequences of flooding (layer 1)
- Level 4: Indirect consequences of flooding (layer 2), leading to consequences for the economy, society and the environment.

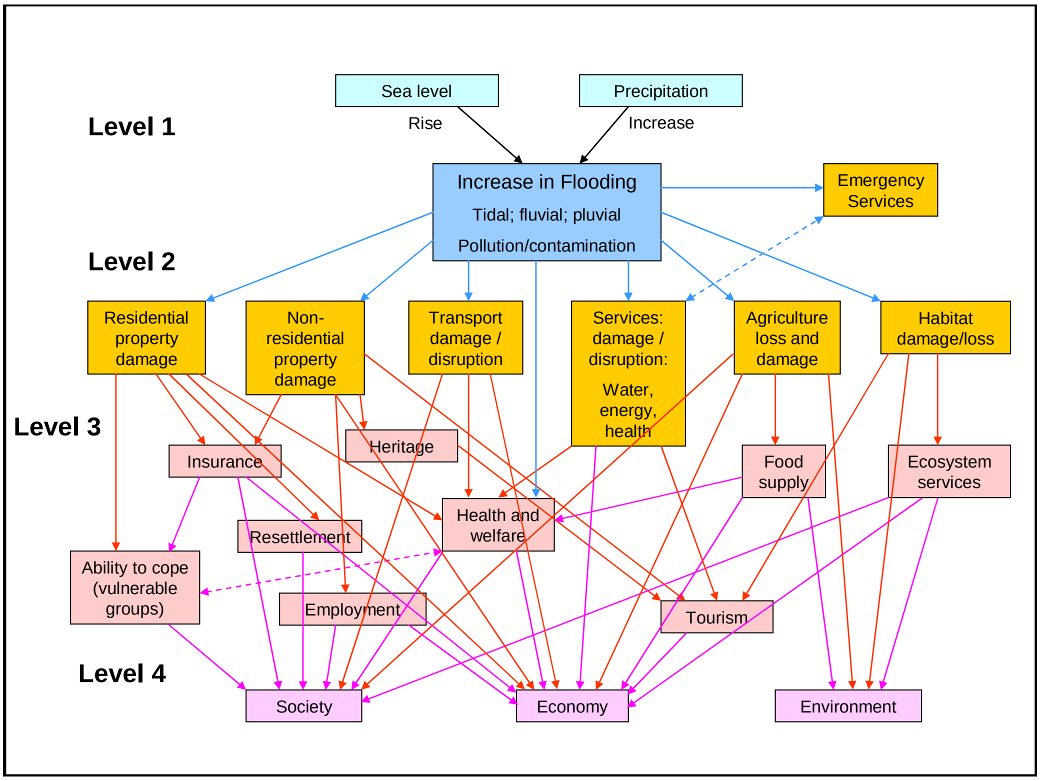


Figure A5.1 Linkages related to flooding

Figure A5.2 shows the indirect consequences of residential property damage arising from sea level rise. The links for levels 1, 2 and 3 are shown by the thick arrows. The main indirect consequences shown are:

- Health and welfare of those affected
- Impacts of repair work on the economy
- Impacts on the insurance industry
- The need for resettlement
- The ability to cope, particularly for vulnerable groups.

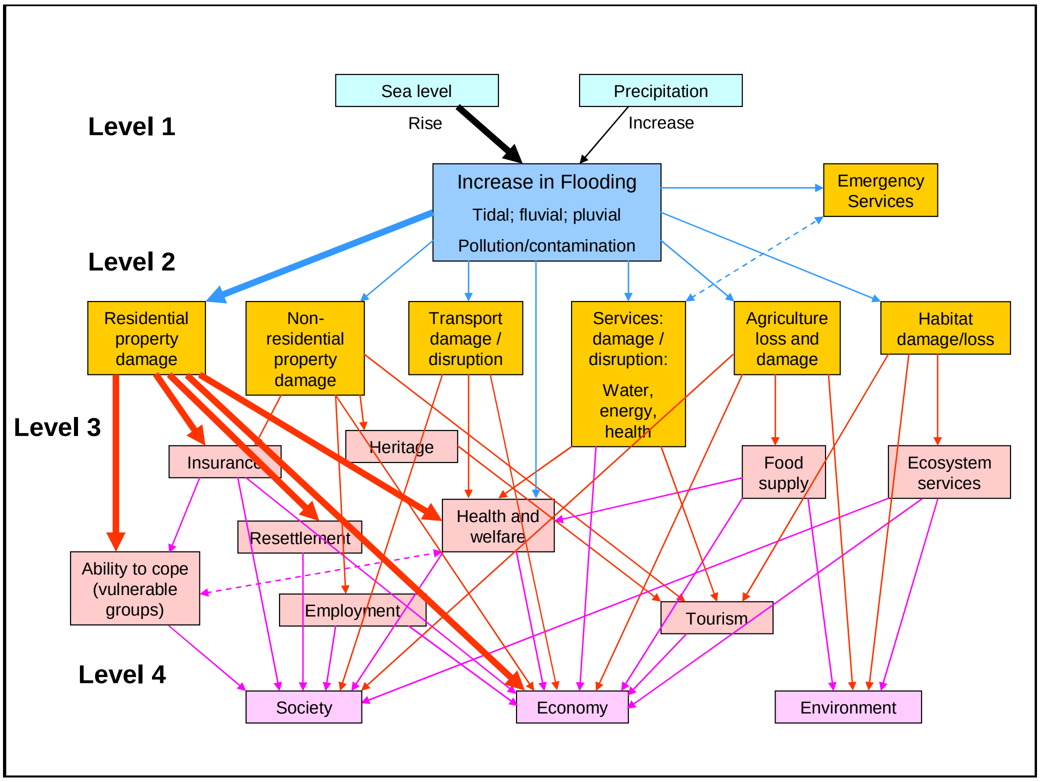


Figure A5.2 Linkages related to flooding of residential properties (levels 1 to 3)

Figure A5.3 shows layer 2 of the indirect consequences of flooding and, in particular, the effects on community and the economy.

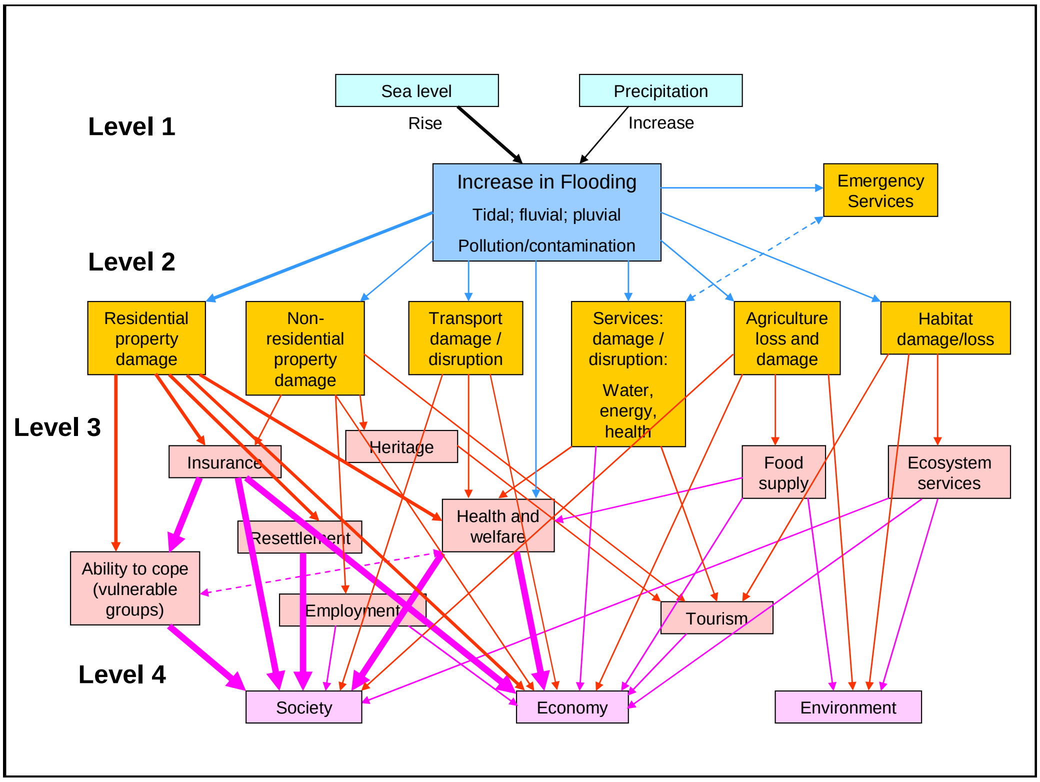


Figure A5.3 Linkages related to flooding of residential properties (level 4)

The diagram shows that society is affected by the following consequences arising from the flooding of residential properties:

- Health and welfare of those affected.
- The effect on vulnerable groups, particularly those who are unable to cope.
- Resettlement of those who have to move out of their homes. This is normally temporary, but can last many months.
- Consequences for the insurance industry, for example lack of availability of insurance.

This analysis shows a possible way of linking climate change impacts with social, economic and environmental consequences.

This analysis also leads to a more holistic understanding of the impacts. In the example given above, there are clear links between the health and welfare of those affected by flooding, the need for resettlement and the availability of insurance.

Appendix 6 Social vulnerability checklist

CCRA - Social Vulnerability Checklist
Flooding and Coastal Erosion Sector

Sector	**Flooding and Coastal Erosion**		
Cluster/Theme	**Tidal Flooding**		
Category of social vulnerability factor	Questions to ask	Comment (general answer)	Evidence (opinion, reports, research)
Place	Which locations are affected by these impacts? Is it spread evenly across regions or not?	Lowland coastal communities within the floodplain. Lowland areas around coast including estuaries and tidal rivers. Some very extensive urban areas including part of London, Hull and other coastal cities. Significant variation in both hazard and consequence. Flooding can be rapid and deep near the coast. Overtopping of coastal defences can place individuals in direct danger. Economic impacts may reach far and wide as there are many nationally important infrastructure and distribution installations, particularly on estuaries.	Numerous regional and local flood studies. NaFRA Tyndall Centre – coastal simulator TE2100 Strategy outputs
Social deprivation	How will people with poor health (physical or mental) be affected by these impacts?	Inability to evacuate may result in higher likelihood of injury or fatality. Risk of mental stress and health problems may be high. Mental health impacts are covered in the Health Sector report.	Experience from tidal floods (e.g. Towyn in N. Wales) and associated reports. SFVI research.
	How will people with fewer financial resources be affected?	Poorer communities often in more vulnerable locations. Inability to afford home and contents insurance will affect poorer communities badly. Poorer communities may not be able to rehabilitate themselves as well as more affluent communities. Problems with temporary accommodation when homes are being repaired.	Experience from historic floods. Social research.

Sector	Flooding and Coastal Erosion		
Cluster/Theme	Tidal Flooding		
Category of social vulnerability factor	Questions to ask	Comment (general answer)	Evidence (opinion, reports, research)
	How will people living or working in poor quality homes or workplaces be affected?	Poor quality buildings may be overwhelmed and collapse, increasing the risk of injury or fatality to their occupants. Poor quality buildings are less cost effective to repair.	Experience from historic floods.
	How will people who have limited access to public and private transport be affected?	Depending on width of the coastal floodplain, it may be difficult to evacuate on foot – therefore those people without access to private transport may require assisted rescue. They also have less chance of safe evacuation.	Evacuation and rescue research (e.g. Floodsite Task 17).
Disempowerment	How will people with lack of awareness of the risks be affected?	The threat is likely to be significantly underestimated with higher risk of injury or fatality.	East coast flood scenario. Social flood risk research.
	How will people without social networks be affected?	There may be delay or lack of communication of the hazard, resulting in delay or lack of evacuation. Evacuation may be difficult without any assistance from members of the community.	
	How will people with little access to systems and support services (e.g. health care) be affected?	Injuries and poor health problems may continue for extended periods (months or years) after the flooding has receded. These will be exacerbated by lack of access to services.	
Other	Are any other social vulnerability issues relevant?	Particular communities are at increased risk (e.g. the elderly; those living in bungalows; communities close to large flood defences). If resettlement is necessary, vulnerable communities may be worst affected.	Nafra – identification of significant flood areas

Sector	Flooding and Coastal Erosion		
Cluster/Theme	River, Surface water and Sewer Flooding		
Category of social vulnerability factor	Questions to ask	Comment (general answer)	Evidence (opinion, reports, research)
Place	Which locations are affected by these impacts? Is it spread evenly across regions or not?	Flooding from rivers and other watercourses affects fluvial floodplains. Surface water and sewer flooding may occur at many locations throughout the country – including coastal and river floodplains and other areas. Surface water flooding can occur in urban and rural areas. Sewer flooding is generally in urban areas. Significant variation in both hazard and consequence, ranging from deep floods on the floodplains of large rivers to flash floods on steep catchments. Effects can be widespread or localised and affects transport as well as properties.	NaFRA LTIS Environment Agency Flood Map National surface water mapping (Agency)
Social deprivation	How will people with poor health (physical or mental) be affected by these impacts?	Inability to evacuate may result in higher likelihood of injury or fatality. Risk of mental stress and health problems likely to be high. Flooding can be long duration on big rivers. Pollution within the flood water is likely to exacerbate health problems and increase damage to property.	Evidence from historic floods and associated research.
	How will people with fewer financial resources be affected?	Inability to afford home and contents insurance will affect poorer communities badly. Poorer communities may not be able to rehabilitate themselves as well as more affluent communities. Poor quality temporary accommodation during property repair.	Many properties in flood risk areas do not have insurance. Health impacts of recent floods (e.g. Hull).
	How will people living or working in poor quality homes or workplaces be affected?	Poor quality buildings may be overwhelmed and collapse increasing the risk of injury or fatality to their occupants, although flow velocities from river floods lower than on the coast. Poor quality buildings are less cost effective to repair.	Existing communities where properties in flood risk areas are of poor quality.

Sector	Flooding and Coastal Erosion		
Cluster/Theme	River, Surface water and Sewer Flooding		
Category of social vulnerability factor	Questions to ask	Comment (general answer)	Evidence (opinion, reports, research)
	How will people who have limited access to public and private transport be affected?	Depending on width of the floodplain, it may be difficult to evacuate on foot, therefore those people without access to private transport may require assisted rescue. Effect is less than on the coast, as floodplains are often narrow and 'shelter in place' is often possible.	
Disempowerment	How will people with lack of awareness of the risks be affected?	The threat is likely to be significantly underestimated with higher risk of injury or fatality. They will also be less prepared for floods, resulting in greater damage to properties and possessions.	Social research into flood risk awareness.
	How will people without social networks be affected?	There may be delay or lack of communication of the hazard, resulting in delayed evacuation or lack of evacuation. Evacuation may be difficult without any assistance from members of the community. Flooding is a situation where isolated people are likely to suffer most.	Experience from historic floods.
	How will people with little access to systems and support services (e.g. health care) be affected?	Injuries and poor health problems may continue for extended periods (months or years) after the flooding has receded. Little access to services would exacerbate the problems.	
Other	Are any other social vulnerability issues relevant?	Particular communities are at increased risk (e.g. the elderly and those living in bungalows or caravans). If resettlement is necessary, vulnerable communities may be worst affected.	

Sector	Flooding and Coastal Erosion		
Cluster/Theme	Groundwater Flooding		
Category of social vulnerability factor	Questions to ask	Comment (general answer)	Evidence (opinion, reports, research)
Place	Which locations are affected by these impacts? Is it spread evenly across regions or not?	Nationwide risk but the dominant locations are where the water table is particularly close to the ground surface or there are particular types of geology (e.g. chalk aquifers). Some types of groundwater flooding can last for many weeks. Other types (e.g. linked to river water levels) have a much shorter duration.	National groundwater mapping (BGS and Jacobs for Defra)
Social deprivation	How will people with poor health (physical or mental) be affected by these impacts?	Less able to respond and adapt. Groundwater flooding can last for a long time (although the water is generally clean). Would require assistance to move until the flooding is over (and property repaired.	Opinion
	How will people with fewer financial resources be affected?	Inability to afford home and contents insurance could affect poorer communities badly (although g/w flood areas are not well defined at present). Poorer communities may not be able to rehabilitate themselves as well as more affluent communities. Poor quality temporary accommodation during flooding and property repair.	Opinion
	How will people living or working in poor quality homes or workplaces be affected?	Poor quality buildings are less cost effective to repair. Social housing may be required.	Opinion
	How will people who have limited access to public and private transport be affected?	Probably not a serious issue as groundwater areas tend to be small.	Experience from recent floods
Disempowerment	How will people with lack of awareness of the risks be affected?	Lack of preparedness, leading to higher damage to possessions and mental stress. Risk of buying or renting properties away from obvious flood risk areas, that turn out to be at flood risk.	Experience from recent floods

Sector	Flooding and Coastal Erosion		
Cluster/Theme	Groundwater Flooding		
Category of social vulnerability factor	Questions to ask	Comment (general answer)	Evidence (opinion, reports, research)
	How will people without social networks be affected?	They will suffer from a lack of help with temporary accommodation, dealing with the problem, etc. This will lead to increased stress.	Opinion
	How will people with little access to systems and support services (e.g. health care) be affected?	Whilst groundwater flooding is unlikely to cause injury, it can last for a long time with no obvious solution. Health (stress) impacts will be exacerbated.	Experience from recent floods
Other	Are any other social vulnerability issues relevant?	Long periods of inundation can make living impossible. Those affected will require resettlement for an extended period.	Opinion

Sector	Flooding and Coastal Erosion		
Cluster/Theme	**Reservoir Flooding**		
Category of social vulnerability factor	**Questions to ask**	**Comment (general answer)**	**Evidence (opinion, reports, research)**
Place	Which locations are affected by these impacts? Is it spread evenly across regions or not?	Impact limited to locations in the vicinity of and of downstream of reservoirs. Whilst localised, flooding can occur quickly, have high depths and velocities, and have little warning.	RIM mapping
Social deprivation	How will people with poor health (physical or mental) be affected by these impacts?	Inability to respond to warnings. They will require special help and should be included in emergency planning.	Opinion
	How will people with fewer financial resources be affected?	Inability to afford home and contents insurance could affect poorer communities badly. However the liability could lie with the reservoir owner. Poorer communities may not be able to rehabilitate themselves as well as more affluent communities.	Opinion
	How will people living or working in poor quality homes or workplaces be affected?	More prone to structural collapse and loss of life. Houses can be completely destroyed (beyond repair).	Opinion
	How will people who have limited access to public and private transport be affected?	This could have a serious impact if the distance to safety is large, because of the need to evacuate rather than ‘shelter in place’.	Opinion
Disempowerment	How will people with lack of awareness of the risks be affected?	Less able to respond in times of emergency. They may be slower to respond to a warning, reducing their chances of safe escape.	Opinion
	How will people without social networks be affected?	More likely to be isolated and not know what to do, hence higher chance of injury or death.	Opinion
	How will people with little access to systems and support services (e.g. health care) be affected?	Injuries and poor health problems may continue for extended periods (months or years) after the flooding has receded. Little access to services would exacerbate the problems.	Opinion

Sector	Flooding and Coastal Erosion		
Cluster/Theme	**Reservoir Flooding**		
Category of social vulnerability factor	**Questions to ask**	**Comment (general answer)**	**Evidence (opinion, reports, research)**
Other	Are any other social vulnerability issues relevant?	The risk is small but the consequences would be catastrophic. Vulnerable people are less able to move, and may also have less influence on improving dam safety.	Opinion

Sector	Flooding and Coastal Erosion		
Cluster/Theme	Damage to Critical Infrastructure		
Category of social vulnerability factor	Questions to ask	Comment (general answer)	Evidence (opinion, reports, research)
Place	Which locations are affected by these impacts? Is it spread evenly across regions or not?	Nationwide, where households receive services via critical infrastructure installations that are located near the coastal zone or in coastal, tidal or fluvial floodplains. Services include water, electricity and gas supply, health services, etc.	NRD
Social deprivation	How will people with poor health (physical or mental) be affected by these impacts?	Vulnerable people are likely to suffer more than most in the case of service shutdown. Particularly the elderly and disabled. Loss of water may require the use of water tankers, distribution points, etc.	Experience from recent floods
	How will people with fewer financial resources be affected?	Poorer communities may not be able to buy alternative services or afford more costly transport options.	Experience from recent floods
	How will people living or working in poor quality homes or workplaces be affected?	No impact.	Opinion
	How will people who have limited access to public and private transport be affected?	Unable to access alternative health services or alternative water/energy supplies.	Experience from recent floods
Disempowerment	How will people with lack of awareness of the risks be affected?	May be caught out by unexpected loss of services or transport. People are generally unaware of this potential impact.	Experience from recent floods
	How will people without social networks be affected?	People with poor social network will suffer most due to lack of support (e.g. sharing transport, food, problems, etc).	Opinion
	How will people with little access to systems and support services (e.g. health care) be affected?	There is a higher risk of fatality and long term health problems in communities with that may be cut off or which have service shut downs.	Opinion
Other	Are any other social vulnerability issues relevant?		

Sector	Flooding and Coastal Erosion		
Cluster/Theme	Coastal Erosion		
Category of social vulnerability factor	Questions to ask	Comment (general answer)	Evidence (opinion, reports, research)
Place	Which locations are affected by these impacts? Is it spread evenly across regions or not?	Impact occurs in coastal locations where erosion takes place, particularly those with soft cliff frontages. The extents are very limited but very serious for those in erosion zones. The overall number of people affected is small.	NCERM – Mapping by Agency (need this data set and model)
Social deprivation	How will people with poor health (physical or mental) be affected by these impacts?	Increased stress reflecting the lack of empowerment to do anything about the risk and the over hanging threat. Mental and physical stress is likely to be a problem.	Opinion
	How will people with fewer financial resources be affected?	Houses tend to be cheaper in known erosion zones (because of limited life). Once a house is destroyed, the occupants may not be able to afford to relocate and have nowhere to live.	Experience from some coastal communities
	How will people living or working in poor quality homes or workplaces be affected?	Progressive loss of the community as either services are lost to erosion or companies/people withdraw due to the threat of erosion – a slow community death.	Experience from some coastal communities
	How will people who have limited access to public and private transport be affected?	Difficulty evacuating and relocating.	Opinion
Disempowerment	How will people with lack of awareness of the risks be affected?	Warning of danger of access will be ignored and lives placed at risk. Poor purchase decisions – buying or renting properties at risk.	Opinion
	How will people without social networks be affected?	Facing a serious problem without support will lead to stress and health problems.	Opinion

Sector	Flooding and Coastal Erosion		
Cluster/Theme	Coastal Erosion		
Category of social vulnerability factor	Questions to ask	Comment (general answer)	Evidence (opinion, reports, research)
	How will people with little access to systems and support services (e.g. health care) be affected?	Such people will be worse off due to lack of community support.	Opinion
Other	Are any other social vulnerability issues relevant?	Where to relocate to? Placing pressure on the surrounding towns/villages. Connectivity of coastal infrastructure (gas pipelines, sewerage, roads etc) may be lost with a wider impact.	Underground and overground infrastructure networks show locations at risk.

Sector	Flooding and Coastal Erosion		
Cluster/Theme	Release of pollutants		
Category of social vulnerability factor	Questions to ask	Comment (general answer)	Evidence (opinion, reports, research)
Place	Which locations are affected by these impacts? Is it spread evenly across regions or not?	Impact limited to locations near industrial sites (e.g. mines and sites containing hazardous substances). Also includes release of sewerage pollution into flood waters.	NRD COHAM sites (HSE) if not in NRD Experience from recent floods
Social deprivation	How will people with poor health (physical or mental) be affected by these impacts?	Pathogens and chemical hazards are likely to affect the vulnerable most severely.	Opinion
	How will people with fewer financial resources be affected?	May not be able to afford clean up costs and therefore may live in poorer conditions following an incident.	Opinion
	How will people living or working in poor quality homes or workplaces be affected?	Properties more difficult and less cost-effective to clean and restore after an event.	Opinion
	How will people who have limited access to public and private transport be affected?	Pollution often means that properties cannot be safely lived in after a flood. This may affect the ability to relocate while properties are being repaired.	Opinion
Disempowerment	How will people with lack of awareness of the risks be affected?	Damage and loss of possessions likely to be greater.	Opinion
	How will people without social networks be affected?	No additional impact.	Opinion
	How will people with little access to systems and support services (e.g. health care) be affected?	Poor health problems may continue for extended periods (months or years) after the flooding has receded. Little access to services would exacerbate the problems.	Opinion
Other	Are any other social vulnerability issues relevant?	Pollutants can cause illness, and the most vulnerable will be more susceptible.	Opinion

Sector	Flooding and Coastal Erosion		
Cluster/Theme	**Insurance cost and/or availability (i.e. withdrawal for the statement of principles and loss of insurance provision to some)**		
Category of social vulnerability factor	**Questions to ask**	**Comment (general answer)**	**Evidence (opinion, reports, research)**
Place	Which locations are affected by these impacts? Is it spread evenly across regions or not?	Localised to areas of higher risk.	ABI Statement of principles
Social deprivation	How will people with poor health (physical or mental) be affected by these impacts?	Stress related consequences will increase.	Opinion
	How will people with fewer financial resources be affected?	Most likely group to be unable to pay increased premium or self insure. Such people will suffer more due to inability to repair property and replace contents.	Opinion
	How will people living or working in poor quality homes or workplaces be affected?	Most likely group to be unable to pay increased premium or self insure. Cost for repair and damage incurred likely to be higher due to poorer resilience of property.	Opinion
	How will people who have limited access to public and private transport be affected?	No Impact.	Opinion
Disempowerment	How will people with lack of awareness of the risks be affected?	Could result in cheaper houses in the floodplain. The unaware could make poor purchase decisions.	Opinion
	How will people without social networks be affected?	Such people will be worse off due to lack of community support.	Opinion
	How will people with little access to systems and support services (e.g. health care) be affected?	Less able to cope with stress and other health impacts.	Opinion
Other	Are any other social vulnerability issues relevant?	Flood damage and loss of insurance could lead to complete household breakdown.	Opinion. Many poorer households do not currently have insurance.

Appendix 7 Future scenarios

A7.1 Effects of climate change

The two main climate drivers for increased flooding are increases in river flow (arising from increased precipitation) and sea level rise.

Table A7.1 shows the increases in river flow that have been used for the analysis by UKCP09 Region (Kay *et al.*, 2010). Table A7.2 shows the sea level rise data that have been used based on UKCP09 data.

The data in Tables A7.1 and A7.2 have been used to develop tables showing increases in flood frequency for river and tidal floods. These are presented in Tables A7.3 and A7.4 respectively. These data can be used to estimate the increase in frequency of flooding for a range of different receptors. The highest return period of 1 in 100 years for river flooding was limited by the data used, but the tables were extrapolated to cover the required range of return periods.

Table A7.1 Increases in river flows

		Percentage increase in peak flow from 1961-90 baseline												
	Projection	2020s			2050s					2080s				
Nation	UKCP09 Region	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England	East Midlands (48% Anglain, 47% Humber, 2% Severn, 2% North West, 1% Thames)	0.1%	8.6%	22.1%	0.0%	12.0%	15.2%	17.3%	34.3%	1.7%	17.7%	21.7%	27.4%	54.8%
England	East of England (87% Anglian, 13% Thames)	0.0%	7.0%	22.1%	0.0%	10.7%	14.0%	16.0%	36.4%	0.0%	17.0%	21.1%	28.3%	60.0%
England	London (100% Thames)	0.0%	7.0%	23.0%	0.0%	9.0%	14.0%	16.0%	39.0%	0.0%	17.0%	22.0%	30.0%	60.0%
England	North East (91% Northumbria, 8% Tweed, 1% Solway)	0.3%	10.2%	22.1%	0.0%	12.9%	16.3%	18.8%	36.5%	6.1%	18.3%	21.2%	27.4%	52.2%
England	North West (75% North West, 21% Solway, 2% Dee, 2% Northumbria)	5.0%	14.8%	23.9%	0.0%	13.2%	21.8%	30.5%	41.8%	10.0%	22.8%	26.7%	37.5%	59.5%
England	South East (53% Thames, 42% South East, 4% Anglian, 1% South West)	0.0%	7.1%	23.4%	0.0%	11.7%	15.8%	18.2%	45.2%	0.9%	19.6%	24.6%	33.4%	60.0%
England	South West (73% South West, 19% Severn, 8% Thames)	0.0%	12.0%	24.5%	0.0%	14.5%	19.9%	20.6%	41.2%	5.7%	23.1%	27.7%	36.6%	60.0%
England	West Midlands (71% Severn, 26% Humber, 2% North West,1% Dee)	0.1%	10.1%	22.7%	0.0%	14.4%	17.5%	20.4%	37.2%	3.2%	20.9%	24.2%	31.9%	57.0%
England	Yorkshire and The Humber (95% Humber, 3% North West, 2% Northumbria)	0.2%	10.2%	22.1%	0.0%	13.0%	16.2%	18.4%	32.4%	3.3%	18.2%	22.1%	26.4%	49.4%
Wales	Wales (59% Western Wales, 33% Severn, 8% Dee)	3.0%	13.0%	23.4%	0.0%	14.6%	20.8%	26.8%	39.9%	8.4%	23.5%	27.6%	36.8%	58.7%

Table A7.2 Sea level rise

		Relative sea level rise from 2008 baseline in metres												
	Projection	2020s			2050s					2080s				
Nation	**UKCP09 Region**	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England	East Midlands (Skegness)	0.051	0.082	0.113	0.113	0.172	0.202	0.239	0.339	0.187	0.293	0.346	0.411	0.587
England	East of England (Happisburgh)	0.053	0.084	0.115	0.116	0.176	0.206	0.243	0.344	0.194	0.3	0.353	0.418	0.594
England	London (Thamesmead)	0.048	0.079	0.11	0.106	0.166	0.196	0.233	0.334	0.178	0.284	0.337	0.402	0.579
England	North East (Newcastle)	0.035	0.066	0.097	0.078	0.138	0.168	0.205	0.305	0.135	0.241	0.294	0.359	0.535
England	North West (Walney Island)	0.03	0.061	0.092	0.065	0.125	0.156	0.192	0.293	0.115	0.221	0.274	0.339	0.516
England	South East (Shoreham)	0.048	0.079	0.11	0.105	0.166	0.196	0.233	0.333	0.178	0.284	0.337	0.402	0.578
England	South West (Lands End)	0.06	0.091	0.122	0.131	0.192	0.222	0.259	0.359	0.218	0.324	0.377	0.442	0.6118
England	Yorkshire and The Humber (Flamborough)	0.049	0.08	0.111	0.109	0.169	0.199	0.236	0.336	0.182	0.288	0.341	0.406	0.583
Wales	Wales (Cardigan)	0.044	0.075	0.106	0.096	0.156	0.186	0.223	0.323	0.163	0.269	0.322	0.387	0.563

Table A7.3 Change in river flood frequency

Data are shown as annual probabilities of flooding for present day events with annual probabilities of 0.1 (1:10), 0.04 (1:25), 0.02 (1:50) and 0.01 (1:100).

	P10 Return Period				P50 Return Period				P90 Return Period			
Northumbria	10	25	50	100	10	25	50	100	10	25	50	100
1961-90	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010
2020s Med	0.100	0.040	0.020	0.010	0.159	0.071	0.036	0.021	0.244	0.122	0.068	0.039
2050s Med	0.100	0.040	0.020	0.010	0.200	0.095	0.050	0.029	0.321	0.176	0.104	0.063
2080s Med	0.134	0.057	0.029	0.016	0.236	0.117	0.065	0.037	0.378	0.218	0.134	0.085
2080s High	0.159	0.071	0.036	0.021	0.282	0.148	0.085	0.050	0.481	0.303	0.200	0.133
2080s Low	0.134	0.057	0.029	0.016	0.214	0.103	0.056	0.032	0.329	0.182	0.108	0.066
2050s Low	0.100	0.040	0.020	0.010	0.179	0.082	0.043	0.025	0.287	0.151	0.087	0.052
2050s High	0.128	0.054	0.027	0.015	0.216	0.105	0.056	0.033	0.350	0.198	0.119	0.074
Humber												
1961-90	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010
2020s Med	0.100	0.040	0.020	0.010	0.159	0.071	0.036	0.021	0.244	0.122	0.068	0.039
2050s Med	0.100	0.040	0.020	0.010	0.200	0.095	0.050	0.029	0.298	0.159	0.092	0.055
2080s Med	0.122	0.051	0.026	0.014	0.244	0.122	0.068	0.039	0.378	0.218	0.134	0.085
2080s High	0.159	0.071	0.036	0.021	0.274	0.143	0.081	0.048	0.458	0.283	0.184	0.121
2080s Low	0.116	0.048	0.024	0.013	0.214	0.103	0.056	0.032	0.321	0.176	0.104	0.063
2050s Low	0.100	0.040	0.020	0.010	0.179	0.082	0.043	0.025	0.263	0.135	0.076	0.045
2050s High	0.128	0.054	0.027	0.015	0.215	0.104	0.056	0.032	0.325	0.178	0.106	0.064
Anglian												
1961-90	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010
2020s Med	0.100	0.040	0.020	0.010	0.124	0.050	0.025	0.012	0.178	0.075	0.037	0.018
2050s Med	0.100	0.040	0.020	0.010	0.149	0.061	0.030	0.015	0.221	0.092	0.047	0.023
2080s Med	0.100	0.040	0.020	0.010	0.174	0.073	0.036	0.018	0.306	0.129	0.067	0.033
2080s High	0.113	0.046	0.023	0.011	0.200	0.085	0.042	0.021	0.371	0.161	0.084	0.042
2080s Low	0.100	0.040	0.020	0.010	0.159	0.066	0.033	0.016	0.253	0.104	0.054	0.027
2050s Low	0.100	0.040	0.020	0.010	0.139	0.057	0.028	0.014	0.196	0.083	0.041	0.021
2050s High	0.107	0.043	0.021	0.011	0.156	0.065	0.032	0.016	0.243	0.100	0.052	0.026
Thames												
1961-90	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010
2020s Med	0.100	0.040	0.020	0.010	0.125	0.051	0.026	0.013	0.186	0.081	0.041	0.021
2050s Med	0.100	0.040	0.020	0.010	0.151	0.064	0.032	0.016	0.244	0.108	0.057	0.029
2080s Med	0.100	0.040	0.020	0.010	0.182	0.079	0.040	0.020	0.325	0.149	0.080	0.041
2080s High	0.117	0.048	0.024	0.012	0.218	0.096	0.050	0.025	0.378	0.178	0.097	0.052
2080s Low	0.100	0.040	0.020	0.010	0.162	0.069	0.035	0.018	0.260	0.116	0.061	0.031
2050s Low	0.100	0.040	0.020	0.010	0.132	0.055	0.027	0.014	0.199	0.088	0.045	0.023
2050s High	0.107	0.043	0.022	0.011	0.158	0.068	0.034	0.017	0.265	0.118	0.063	0.032
South-East												
1961-90	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010
2020s Med	0.100	0.040	0.020	0.010	0.125	0.051	0.026	0.013	0.190	0.083	0.042	0.021
2050s Med	0.100	0.040	0.020	0.010	0.166	0.071	0.036	0.018	0.314	0.143	0.077	0.039
2080s Med	0.110	0.045	0.022	0.011	0.207	0.091	0.047	0.024	0.378	0.178	0.097	0.052
2080s High	0.128	0.053	0.027	0.013	0.260	0.116	0.061	0.031	0.378	0.178	0.097	0.052
2080s Low	0.107	0.043	0.022	0.011	0.186	0.081	0.041	0.021	0.357	0.167	0.090	0.047
2050s Low	0.100	0.040	0.020	0.010	0.153	0.065	0.032	0.016	0.271	0.121	0.065	0.033
2050s High	0.114	0.046	0.023	0.012	0.176	0.076	0.038	0.019	0.347	0.161	0.087	0.045
Severn												
1961-90	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010
2020s Med	0.100	0.040	0.020	0.010	0.144	0.060	0.030	0.016	0.211	0.093	0.049	0.025
2050s Med	0.100	0.040	0.020	0.010	0.184	0.080	0.040	0.021	0.288	0.133	0.072	0.037
2080s Med	0.121	0.050	0.025	0.013	0.224	0.099	0.052	0.027	0.394	0.196	0.109	0.060
2080s High	0.144	0.060	0.030	0.016	0.281	0.129	0.070	0.036	0.452	0.239	0.137	0.076
2080s Low	0.113	0.046	0.023	0.012	0.205	0.090	0.047	0.024	0.334	0.159	0.087	0.046
2050s Low	0.100	0.040	0.020	0.010	0.167	0.072	0.036	0.019	0.251	0.113	0.060	0.031
2050s High	0.121	0.050	0.025	0.013	0.198	0.087	0.045	0.023	0.315	0.148	0.081	0.042

Table A7.3 (continued) Change in river flood frequency

Data are shown as annual probabilities of flooding for present day events with annual probabilities of 0.1 (1:10), 0.04 (1:25), 0.02 (1:50) and 0.01 (1:100).

	P10				P50				P90			
	Return Period				Return Period				Return Period			
South-West	10	25	50	100	10	25	50	100	10	25	50	100
1961-90	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010
2020s Med	0.100	0.040	0.020	0.010	0.159	0.070	0.037	0.019	0.223	0.105	0.058	0.032
2050s Med	0.113	0.046	0.023	0.012	0.199	0.092	0.050	0.027	0.317	0.161	0.094	0.054
2080s Med	0.135	0.057	0.030	0.015	0.247	0.119	0.067	0.037	0.443	0.251	0.156	0.094
2080s High	0.159	0.070	0.037	0.019	0.304	0.153	0.089	0.050	0.443	0.251	0.156	0.094
2080s Low	0.130	0.055	0.028	0.014	0.217	0.102	0.056	0.030	0.362	0.189	0.114	0.067
2050s Low	0.100	0.040	0.020	0.010	0.167	0.074	0.039	0.021	0.262	0.127	0.072	0.040
2050s High	0.126	0.053	0.027	0.014	0.201	0.093	0.051	0.027	0.332	0.170	0.100	0.058
West Wales												
1961-90	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010
2020s Med	0.126	0.052	0.026	0.014	0.185	0.081	0.043	0.023	0.252	0.115	0.064	0.035
2050s Med	0.154	0.066	0.034	0.018	0.244	0.111	0.061	0.033	0.371	0.182	0.105	0.061
2080s Med	0.178	0.078	0.041	0.022	0.301	0.142	0.080	0.044		0.291	0.175	0.105
2080s High	0.220	0.098	0.054	0.029	0.388	0.193	0.112	0.065		0.326	0.198	0.121
2080s Low	0.166	0.072	0.037	0.020	0.260	0.119	0.066	0.036	0.423	0.217	0.128	0.075
2050s Low	0.100	0.040	0.020	0.010	0.185	0.081	0.043	0.023	0.289	0.135	0.076	0.042
2050s High	0.178	0.078	0.041	0.022	0.310	0.147	0.083	0.046	0.397	0.198	0.116	0.067
Dee												
1961-90	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010
2020s Med	0.100	0.040	0.020	0.010	0.154	0.066	0.034	0.018	0.228	0.102	0.056	0.030
2050s Med	0.100	0.040	0.020	0.010	0.191	0.084	0.045	0.024	0.285	0.133	0.074	0.041
2080s Med	0.131	0.054	0.028	0.014	0.220	0.098	0.054	0.029	0.336	0.162	0.092	0.052
2080s High	0.154	0.066	0.034	0.018	0.260	0.119	0.066	0.036	0.423	0.217	0.128	0.075
2080s Low	0.120	0.049	0.025	0.013	0.205	0.091	0.049	0.026	0.293	0.137	0.077	0.043
2050s Low	0.100	0.040	0.020	0.010	0.157	0.067	0.035	0.018	0.228	0.103	0.056	0.030
2050s High	0.126	0.052	0.026	0.014	0.220	0.098	0.054	0.029	0.353	0.172	0.098	0.056
North-West												
1961-90	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010
2020s Med	0.128	0.053	0.027	0.013	0.193	0.085	0.045	0.023	0.268	0.124	0.068	0.035
2050s Med	0.165	0.071	0.037	0.019	0.250	0.114	0.062	0.032	0.390	0.195	0.112	0.062
2080s Med	0.172	0.075	0.038	0.020	0.295	0.139	0.077	0.040		0.311	0.187	0.108
2080s High	0.216	0.097	0.052	0.027	0.399	0.201	0.116	0.064		0.367	0.228	0.135
2080s Low	0.159	0.068	0.035	0.018	0.259	0.119	0.065	0.034	0.428	0.222	0.129	0.072
2050s Low	0.100	0.040	0.020	0.010	0.181	0.079	0.041	0.021	0.300	0.142	0.078	0.041
2050s High	0.172	0.075	0.038	0.020	0.332	0.160	0.089	0.048	0.438	0.229	0.133	0.074
Solway												
1961-90	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010
2020s Med	0.120	0.051	0.025	0.013	0.152	0.070	0.034	0.017	0.185	0.091	0.046	0.022
2050s Med	0.138	0.061	0.030	0.015	0.178	0.086	0.043	0.021	0.266	0.120	0.065	0.031
2080s Med	0.138	0.061	0.030	0.015	0.197	0.099	0.051	0.024	0.430	0.162	0.094	0.046
2080s High	0.167	0.079	0.039	0.019	0.297	0.128	0.070	0.033		0.191	0.116	0.059
2080s Low	0.138	0.061	0.030	0.015	0.182	0.089	0.045	0.021	0.318	0.134	0.074	0.035
2050s Low	0.100	0.040	0.020	0.010	0.149	0.068	0.033	0.016	0.201	0.101	0.052	0.025
2050s High	0.167	0.079	0.039	0.019	0.228	0.109	0.058	0.027	0.340	0.139	0.078	0.037
Tweed												
1961-90	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010	0.100	0.040	0.020	0.010
2020s Med	0.110	0.045	0.023	0.011	0.141	0.063	0.031	0.015	0.182	0.089	0.045	0.021
2050s Med	0.124	0.053	0.026	0.013	0.167	0.079	0.039	0.019	0.228	0.109	0.058	0.027
2080s Med	0.131	0.057	0.028	0.014	0.182	0.089	0.045	0.021	0.318	0.134	0.074	0.035
2080s High	0.148	0.068	0.033	0.016	0.228	0.109	0.058	0.027	0.475	0.173	0.103	0.051
2080s Low	0.124	0.053	0.026	0.013	0.174	0.084	0.042	0.020	0.257	0.117	0.063	0.030
2050s Low	0.100	0.040	0.020	0.010	0.140	0.062	0.031	0.015	0.184	0.090	0.045	0.022
2050s High	0.135	0.059	0.029	0.014	0.193	0.096	0.049	0.023	0.340	0.139	0.078	0.037

Table A7.4 Change in tidal flood frequency

Data are shown as annual probabilities of flooding for present day events with annual probabilities of 0.1 (1:10), 0.04 (1:25), 0.02 (1:50), 0.01 (1:100), 0.004 (1:250), 0.002 (1:500) and 0.001 (1:1000).

Data are shown for the P50 Medium Emissions Scenario only. Data for the other scenarios are available.

UKCP09 Region	**Flood frequency: p50 Medium Emissions Scenario**							
	RP:	**10**	**25**	**50**	**100**	**250**	**500**	**1000**
	Frequency:	**0.1**	**0.04**	**0.02**	**0.01**	**0.004**	**0.002**	**0.001**
England	2008	0.100	0.040	0.020	0.010	0.004	0.002	0.001
East Midlands (Skegness)	2020s	0.158	0.062	0.036	0.014	0.006	0.004	0.002
	2050s	0.309	0.117	0.070	0.027	0.012	0.007	0.004
	2080s	0.682	0.259	0.153	0.065	0.023	0.015	0.008
England	2008	0.100	0.040	0.020	0.010	0.004	0.002	0.001
East of England (Happisburgh)	2020s	0.146	0.058	0.031	0.013	0.006	0.003	0.001
	2050s	0.251	0.098	0.056	0.021	0.010	0.006	0.003
	2080s	0.485	0.190	0.106	0.044	0.017	0.011	0.005
England	2008	0.100	0.040	0.020	0.010	0.004	0.002	0.001
London (Thamesmead)	2020s	0.147	0.059	0.033	0.014	0.006	0.003	0.001
	2050s	0.261	0.103	0.061	0.022	0.010	0.006	0.003
	2080s	0.521	0.205	0.120	0.050	0.018	0.011	0.006
England	2008	0.100	0.040	0.020	0.010	0.004	0.002	0.001
North East (Newcastle)	2020s	0.134	0.053	0.028	0.013	0.005	0.003	0.001
	2050s	0.212	0.083	0.047	0.018	0.009	0.005	0.002
	2080s	0.372	0.146	0.082	0.033	0.014	0.009	0.004
England	2008	0.100	0.040	0.020	0.010	0.004	0.002	0.001
North West (Walney Island)	2020s	0.130	0.052	0.027	0.012	0.005	0.003	0.001
	2050s	0.197	0.077	0.044	0.016	0.008	0.004	0.002
	2080s	0.329	0.126	0.071	0.026	0.012	0.007	0.003
England	2008	0.100	0.040	0.020	0.010	0.004	0.002	0.001
South East (Shoreham)	2020s	0.170	0.059	0.033	0.013	0.006	0.003	0.001
	2050s	0.370	0.108	0.060	0.021	0.009	0.005	0.002
	2080s	0.948	0.304	0.126	0.048	0.016	0.010	0.005
England	2008	0.100	0.040	0.020	0.010	0.004	0.002	0.001
South West (Lands End)	2020s	0.201	0.073	0.043	0.016	0.007	0.004	0.002
	2050s	0.550	0.184	0.101	0.043	0.015	0.009	0.004
	2080s	1.806	0.581	0.321	0.122	0.045	0.021	0.011
England	2008	0.100	0.040	0.020	0.010	0.004	0.002	0.001
Yorkshire and The Humber (Flamborough)	2020s	0.167	0.063	0.037	0.014	0.007	0.004	0.002
	2050s	0.357	0.128	0.075	0.029	0.013	0.008	0.004
	2080s	0.886	0.318	0.179	0.071	0.027	0.016	0.009
Wales (Cardigan)	2008	0.100	0.040	0.020	0.010	0.004	0.002	0.001
	2020s	0.162	0.063	0.037	0.014	0.007	0.004	0.002
	2050s	0.329	0.128	0.076	0.029	0.013	0.008	0.004
	2080s	0.784	0.310	0.177	0.072	0.028	0.016	0.009

Examples of the data from Table A7.4 are shown in Figures A7.1 and A7.2.

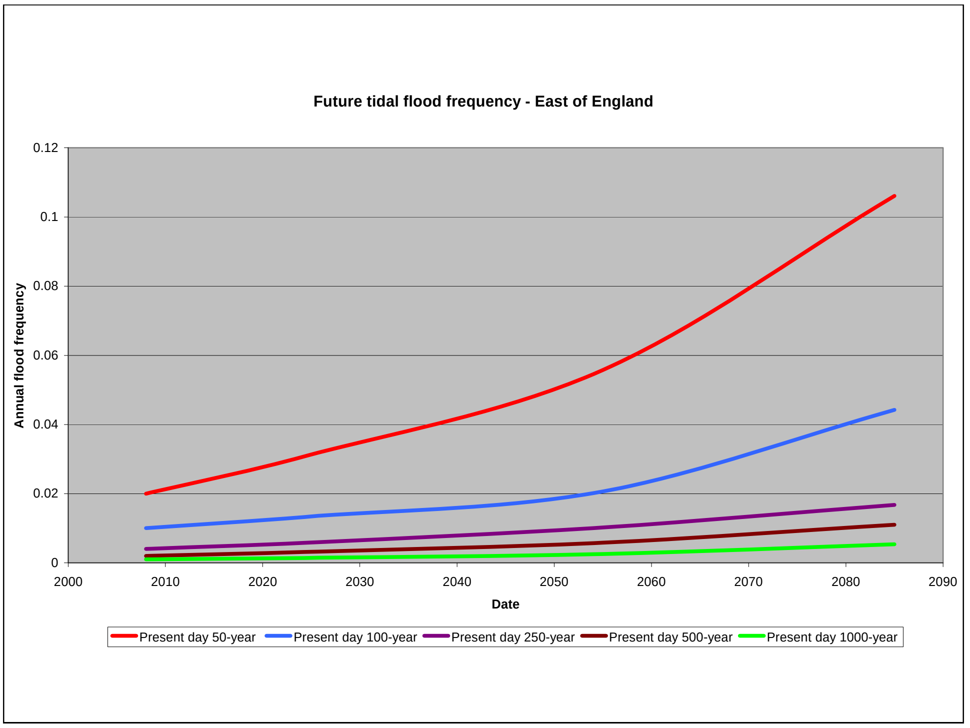


Figure A7.1 **Increase in tidal flood frequency – East of England**

(P50 Medium Emissions climate change scenario)

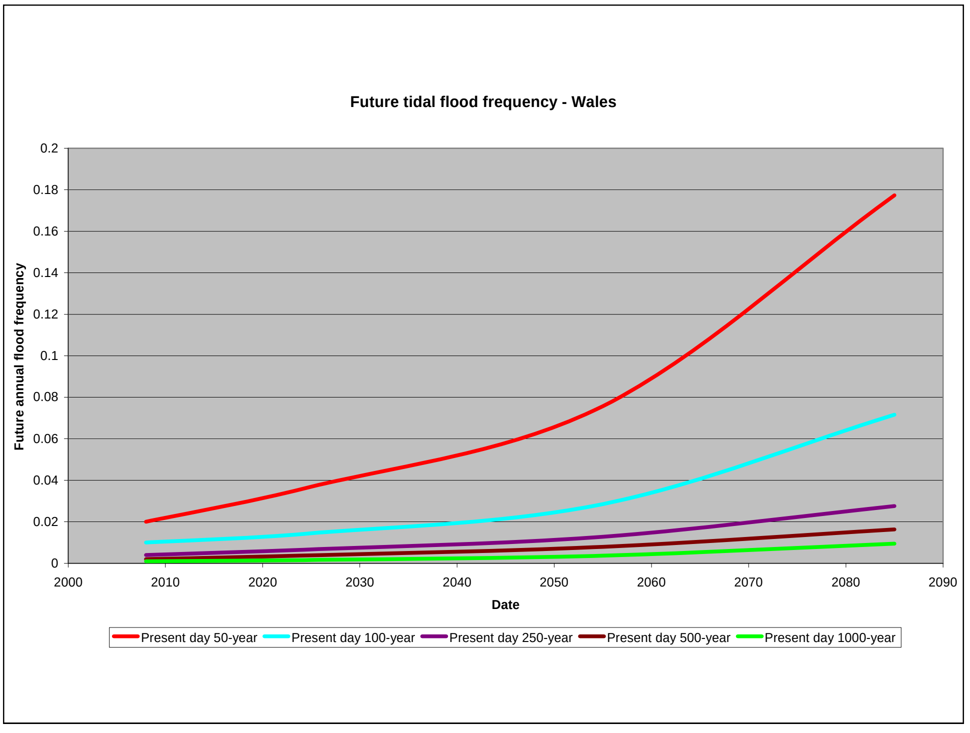


Figure A7.2 **Increase in tidal flood frequency – Wales**

(P50 Medium Emissions climate change scenario)

A7.2 Population projections

The population and residential property projections that have been used in the analysis are shown in Tables A7.5 to A7.9.

Table A7.5 Population projections (totals)

		Projection	Population in thousands								
			Low population			Principal projection			High population		
National Projections	Nation	2008 baseline population	2020s	2050s	2080s	**2020s**	**2050s**	**2080s**	2020s	2050s	2080s
	England	51,465	55,493	57,059	55,211	**57,965**	**66,732**	**74,686**	60,495	76,983	96,804
	Wales	2,990	3,093	2,918	2,562	**3,249**	**3,511**	**3,710**	3,411	4,149	5,040
	Scotland	5,169	5,185	4,521	3,626	**5,470**	**5,570**	**5,517**	5,766	6,679	7,735
	Northern Irelan	1,775	1,828	1,592	1,143	**1,963**	**2,076**	**2,044**	2,101	2,596	3,107

Table A7.6 Population projections (change from present day)

		Projection	Population change from baseline in thousands								
			Low population			Principal projection			High population		
National Projections	Nation	2008 baseline population	2020s	2050s	2080s	**2020s**	**2050s**	**2080s**	2020s	2050s	2080s
	England	51,465	4,028	5,595	3,746	**6,500**	**15,267**	**23,222**	9,030	25,518	45,339
	Wales	2,990	102	-72	-428	**259**	**521**	**720**	421	1,158	2,050
	Scotland	5,169	17	-648	-1,542	**302**	**401**	**349**	598	1,510	2,566
	Northern Irelan	1,775	53	-183	-632	**188**	**301**	**269**	326	821	1,332

Table A7.7 Population projections by UKCP09 Region (totals)

			Projection	Population in thousands								
				Low population			Principal projection			High population		
Regional projections	Nation	UKCP09 Region	2008 baseline population	2020s	2050s	2080s	**2020s**	**2050s**	**2080s**	2020s	2050s	2080s
	England	East Midlands	4,429	4,823	4,976	4,795	**5,065**	**5,922**	**6,700**	5,312	6,925	8,863
	England	East of England	5,717	6,326	6,563	6,284	**6,700**	**8,026**	**9,229**	7,083	9,577	12,575
	England	London	7,668	8,344	8,607	8,297	**8,759**	**10,231**	**11,566**	9,184	11,952	15,280
	England	North East	2,571	2,685	2,729	2,677	**2,755**	**3,003**	**3,228**	2,826	3,293	3,854
	England	North West	6,874	7,138	7,241	7,120	**7,300**	**7,875**	**8,397**	7,466	8,547	9,847
	England	South East	8,369	9,090	9,370	9,039	**9,532**	**11,101**	**12,525**	9,985	12,936	16,483
	England	South West	5,210	5,685	5,870	5,652	**5,976**	**7,010**	**7,947**	6,275	8,218	10,555
	England	West Midlands	5,408	5,714	5,832	5,692	**5,901**	**6,566**	**7,170**	6,093	7,344	8,848
	England	Yorkshire and The Humber	5,218	5,687	5,870	5,654	**5,975**	**6,996**	**7,923**	6,270	8,190	10,499
	Wales	Wales	2,990	3,093	2,918	2,562	**3,249**	**3,511**	**3,710**	3,411	4,149	5,040
	Scotland	Eastern Scotland	2,368	2,381	1,844	1,122	**2,612**	**2,692**	**2,650**	2,851	3,588	4,441
	Scotland	Northern Scotland	287	289	225	139	**316**	**325**	**320**	344	432	533
	Scotland	Western Scotland	2,513	2,515	2,451	2,365	**2,542**	**2,552**	**2,547**	2,571	2,658	2,760
	Northern Ireland	Northern Ireland	1,775	1,828	1,592	1,143	**1,963**	**2,076**	**2,044**	2,101	2,596	3,107

Table A7.8 Population projections by UKCP09 Region

(change from present day)

			Projection	Population change from baseline in thousands								
				Low population			Principal projection			High population		
	Nation	UKCP09 Region	2008 baseline population	2020s	2050s	2080s	2020s	2050s	2080s	2020s	2050s	2080s
Regional projections	England	East Midlands	4,429	394	547	366	636	1,493	2,271	883	2,496	4,434
	England	East of England	5,717	609	846	567	983	2,309	3,512	1,366	3,860	6,858
	England	London	7,668	676	939	629	1,091	2,563	3,898	1,516	4,284	7,612
	England	North East	2,571	114	158	106	184	432	657	255	722	1,283
	England	North West	6,874	264	367	246	426	1,001	1,523	592	1,673	2,973
	England	South East	8,369	721	1,001	670	1,163	2,732	4,156	1,616	4,567	8,114
	England	South West	5,210	475	660	442	766	1,800	2,737	1,065	3,008	5,345
	England	West Midlands	5,408	306	424	284	493	1,158	1,762	685	1,936	3,440
	England	Yorkshire and The Humber	5,218	469	652	436	757	1,778	2,705	1,052	2,972	5,281
	Wales	Wales	2,990	99	-75	-431	256	518	717	418	1,155	2,047
	Scotland	Eastern Scotland	2,368	13	-524	-1,246	244	324	282	483	1,220	2,073
	Scotland	Northern Scotland	287	2	-62	-148	29	38	33	57	145	246
	Scotland	Western Scotland	2,513	2	-62	-148	29	39	34	58	145	247
	Northern Ireland	Northern Ireland	1,775	53	-183	-632	188	301	269	326	821	1,332

Table A7.9 Residential property projections by UKCP09 Region

(change from present day)

				Project	Residential property change from baseline in thousands								
					Low population			Principal projection			High population		
	Nation	UKCP09 Regio	Mean residency (Census 2001)	2008 baseline residential properties	2020s	2050s	2080s	2020s	2050s	2080s	2020s	2050s	2080s
Regional projections	England	East Midlands	2.408	1,839	164	227	152	264	620	943	367	1,036	1,841
	England	East of England	2.414	2,368	252	350	235	407	956	1,455	566	1,599	2,841
	England	London	2.378	3,224	284	395	264	459	1,078	1,639	637	1,801	3,201
	England	North East	2.359	1,090	48	67	45	78	183	279	108	306	544
	England	North West	2.393	2,873	110	153	103	178	418	637	247	699	1,243
	England	South East	2.434	3,439	296	411	275	478	1,123	1,708	664	1,876	3,334
	England	South West	2.363	2,205	201	279	187	324	762	1,158	451	1,273	2,262
	England	West Midlands	2.446	2,211	125	173	116	202	473	720	280	792	1,406
	England	Yorkshire and The Humber	2.405	2,170	195	271	181	315	739	1,125	437	1,236	2,196
	Wales	Wales	2.400	1,246	41	-31	-180	107	216	299	174	481	853
	Scotland	Eastern Scotland											
	Scotland	Northern Scotland											
	Scotland	Western Scotland											
	Northern I	Northern Ireland											

Appendix 8 Calculated risk metrics

The modelling and other analysis is high level, to provide indicative projections that are appropriate for the UK risk assessment. The results should not be used for re-analysis or interpretation at a regional, local or site-specific scale.

The tables of results have been derived from regional data. Numbers have been rounded to avoid giving a false impression of accuracy.

Risk Metric FL1 – Number of people at significant likelihood of river flooding (England and Wales):

- With climate change only
- With climate change and low population growth
- With climate change and principal population growth
- With climate change and high population growth

Table FL1_01 - Number of people at significant likelihood of river flooding, including climate change

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	600,000	680,000	1,080,000	1,300,000	600,000	1,150,000	1,220,000	1,260,000	1,400,000	850,000	1,260,000	1,300,000	1,360,000	1,490,000
Wales only	65,000	80,000	110,000	120,000	65,000	110,000	115,000	120,000	120,000	95,000	120,000	120,000	120,000	125,000

Table FL1_02a - Number of people at significant likelihood of river flooding, including climate change and low growth in population

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	600,000	730,000	1,160,000	1,400,000	660,000	1,260,000	1,340,000	1,380,000	1,540,000	890,000	1,330,000	1,370,000	1,430,000	1,570,000
Wales only	65,000	80,000	110,000	120,000	65,000	110,000	115,000	115,000	120,000	85,000	100,000	100,000	105,000	105,000

Table FL1_02b - Number of people at significant likelihood of river flooding including climate change and principal growth in population

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	600,000	760,000	1,210,000	1,470,000	790,000	1,480,000	1,580,000	1,620,000	1,810,000	1,210,000	1,810,000	1,880,000	1,960,000	2,150,000
Wales only	65,000	85,000	115,000	130,000	75,000	130,000	135,000	140,000	145,000	120,000	145,000	150,000	150,000	155,000

Table FL1_02c - Number of people at significant likelihood of river flooding including climate change and high growth in population

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	600,000	800,000	1,270,000	1,530,000	910,000	1,710,000	1,830,000	1,870,000	2,100,000	1,570,000	2,370,000	2,450,000	2,550,000	2,800,000
Wales only	65,000	90,000	125,000	135,000	90,000	155,000	160,000	165,000	170,000	165,000	200,000	200,000	205,000	210,000

Risk Metric FL1 – Number of people at significant likelihood of tidal flooding (England and Wales):

- With climate change only
- With climate change and low population growth
- With climate change and principal population growth
- With climate change and high population growth

Table FL1_01 - Number of people at significant likelihood of tidal flooding, including climate change

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	276,700	470,000	580,000	680,000	660,000	810,000	860,000	910,000	1,010,000	830,000	970,000	1,010,000	1,050,000	1,120,000
Wales	42,200	55,000	65,000	70,000	70,000	75,000	75,000	80,000	85,000	75,000	80,000	85,000	90,000	95,000

Table FL1_02a - Number of people at significant likelihood of tidal flooding, including climate change and low growth in population

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	276,700	500,000	630,000	730,000	730,000	890,000	950,000	1,010,000	1,110,000	880,000	1,020,000	1,070,000	1,110,000	1,190,000
Wales	42,200	55,000	65,000	70,000	65,000	75,000	75,000	80,000	85,000	65,000	70,000	75,000	75,000	80,000

Table FL1_02b - Number of people at significant likelihood of tidal flooding including climate change and principal growth in population

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	276,700	530,000	660,000	770,000	870,000	1,060,000	1,130,000	1,200,000	1,320,000	1,220,000	1,420,000	1,490,000	1,540,000	1,660,000
Wales	42,200	60,000	70,000	75,000	80,000	90,000	90,000	95,000	100,000	95,000	100,000	105,000	110,000	115,000

Table FL1_02c - Number of people at significant likelihood of tidal flooding including climate change and high growth in population

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	276,700	550,000	690,000	800,000	1,020,000	1,240,000	1,320,000	1,400,000	1,540,000	1,610,000	1,880,000	1,960,000	2,030,000	2,180,000
Wales	42,200	60,000	70,000	80,000	95,000	105,000	105,000	110,000	120,000	125,000	140,000	145,000	150,000	160,000

Risk Metric FL1 – Number of people at significant likelihood of river or tidal flooding (England and Wales):

- With climate change only
- With climate change and low population growth
- With climate change and principal population growth
- With climate change and high population growth

Table FL1_01 - Number of people at significant likelihood of tidal or river flooding, including climate change

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	876,700	1,150,000	1,660,000	1,980,000	1,260,000	1,960,000	2,080,000	2,170,000	2,410,000	1,680,000	2,230,000	2,310,000	2,410,000	2,610,000
Wales	107,200	135,000	175,000	190,000	135,000	185,000	190,000	200,000	205,000	170,000	200,000	205,000	210,000	220,000

Table FL1_02a - Number of people at significant likelihood of tidal or river flooding, including climate change and low growth in population

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	876,700	1,230,000	1,790,000	2,130,000	1,390,000	2,150,000	2,290,000	2,390,000	2,650,000	1,770,000	2,350,000	2,440,000	2,540,000	2,760,000
Wales	107,200	135,000	175,000	190,000	130,000	185,000	190,000	195,000	205,000	150,000	170,000	175,000	180,000	185,000

Table FL1_02b - Number of people at significant likelihood of tidal or river flooding including climate change and principal growth in population

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	876,700	1,290,000	1,870,000	2,240,000	1,660,000	2,540,000	2,710,000	2,820,000	3,130,000	2,430,000	3,230,000	3,370,000	3,500,000	3,810,000
Wales	107,200	145,000	185,000	205,000	155,000	220,000	225,000	235,000	245,000	215,000	245,000	255,000	260,000	270,000

Table FL1_02c - Number of people at significant likelihood of tidal or river flooding including climate change and high growth in population

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	876,700	1,350,000	1,960,000	2,330,000	1,930,000	2,950,000	3,150,000	3,270,000	3,640,000	3,180,000	4,250,000	4,410,000	4,580,000	4,980,000
Wales	107,200	150,000	195,000	215,000	185,000	260,000	265,000	275,000	290,000	290,000	340,000	345,000	355,000	370,000

Risk Metric FL2 – Number of residential properties in the highest 20% of deprived areas at significant likelihood of river flooding (England and Wales):

- With climate change only
- With climate change and low population growth
- With climate change and principal population growth
- With climate change and high population growth

Table FL2_01 - Number of properties in the highest 20% of deprived areas at significant likelihood of river flooding, including climate change

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	39,300	50,000	90,000	110,000	40,000	100,000	100,000	110,000	130,000	70,000	110,000	110,000	120,000	140,000
Wales	6,100	8,000	12,000	14,000	6,000	12,000	12,000	14,000	14,000	10,000	14,000	14,000	14,000	16,000

Table FL2_02a - Number of properties in the highest 20% of deprived areas at significant likelihood of river flooding, including climate change and low growth in population

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	39,300	60,000	100,000	120,000	40,000	100,000	100,000	120,000	140,000	70,000	110,000	120,000	130,000	150,000
Wales	6,100	8,000	12,000	14,000	6,000	12,000	12,000	14,000	14,000	8,000	12,000	12,000	12,000	14,000

Table FL2_02b - Number of properties in the highest 20% of deprived areas at significant likelihood of river flooding, including climate change and principal growth in population

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	39,300	60,000	100,000	130,000	50,000	120,000	130,000	140,000	160,000	100,000	150,000	160,000	170,000	210,000
Wales	6,100	8,000	12,000	14,000	8,000	14,000	16,000	16,000	16,000	12,000	16,000	16,000	18,000	20,000

Table FL2_02c - Number of properties in the highest 20% of deprived areas at significant likelihood of river flooding, including climate change and high growth in population

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	39,300	60,000	100,000	130,000	60,000	140,000	150,000	160,000	190,000	120,000	190,000	200,000	220,000	270,000
Wales	6,100	8,000	14,000	16,000	10,000	16,000	18,000	20,000	20,000	18,000	22,000	22,000	24,000	26,000

Risk Metric FL2 – Number of residential properties in the highest 20% of deprived areas at significant likelihood of tidal flooding (England and Wales):

- With climate change only
- With climate change and low population growth
- With climate change and principal population growth
- With climate change and high population growth

Table FL2_01 - Number of properties in the highest 20% of deprived areas at significant likelihood of tidal flooding, including climate change

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	30,400	50,000	70,000	80,000	80,000	100,000	110,000	110,000	130,000	100,000	120,000	130,000	140,000	150,000
Wales	6,300	8,000	10,000	10,000	10,000	12,000	12,000	12,000	14,000	12,000	12,000	14,000	14,000	14,000

Table FL2_02a - Number of properties in the highest 20% of deprived areas at significant likelihood of tidal flooding, including climate change and low growth in population

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	30,400	60,000	70,000	90,000	90,000	110,000	120,000	130,000	140,000	110,000	130,000	140,000	140,000	160,000
Wales	6,300	8,000	10,000	10,000	10,000	12,000	12,000	12,000	14,000	10,000	12,000	12,000	12,000	12,000

Table FL2_02b - Number of properties in the highest 20% of deprived areas at significant likelihood of tidal flooding, including climate change and principal growth in population

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	30,400	60,000	80,000	90,000	100,000	130,000	140,000	150,000	170,000	150,000	180,000	190,000	200,000	220,000
Wales	6,300	8,000	10,000	10,000	12,000	14,000	14,000	14,000	16,000	14,000	16,000	16,000	18,000	18,000

Table FL2_02c - Number of properties in the highest 20% of deprived areas at significant likelihood of tidal flooding, including climate change and high growth in population

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	30,400	60,000	80,000	90,000	120,000	150,000	160,000	180,000	200,000	200,000	240,000	250,000	270,000	290,000
Wales	6,300	8,000	10,000	12,000	14,000	16,000	16,000	18,000	18,000	20,000	22,000	22,000	24,000	26,000

Risk Metric FL2 – Number of residential properties in the highest 20% of deprived areas at significant likelihood of river or tidal flooding (England and Wales):

- With climate change only
- With climate change and low population growth
- With climate change and principal population growth
- With climate change and high population growth

Table FL2_01 - Number of properties in the highest 20% of deprived areas at significant likelihood of tidal or river flooding, including climate change

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	69,700	100,000	160,000	190,000	120,000	200,000	210,000	220,000	260,000	170,000	230,000	240,000	260,000	290,000
Wales	12,400	16,000	22,000	24,000	16,000	24,000	24,000	26,000	28,000	22,000	26,000	28,000	28,000	30,000

Table FL2_02a - Number of properties in the highest 20% of deprived areas at significant likelihood of tidal or river flooding, including climate change and low growth in population

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	69,700	120,000	170,000	210,000	130,000	210,000	220,000	250,000	280,000	180,000	240,000	260,000	270,000	310,000
Wales	12,400	16,000	22,000	24,000	16,000	24,000	24,000	26,000	28,000	18,000	24,000	24,000	24,000	26,000

Table FL2_02b - Number of properties in the highest 20% of deprived areas at significant likelihood of tidal or river flooding, including climate change and principal growth in population

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	69,700	120,000	180,000	220,000	150,000	250,000	270,000	290,000	330,000	250,000	330,000	350,000	370,000	430,000
Wales	12,400	16,000	22,000	24,000	20,000	28,000	30,000	30,000	32,000	26,000	32,000	32,000	36,000	38,000

Table FL2_02c - Number of properties in the highest 20% of deprived areas at significant likelihood of tidal or river flooding, including climate change and high growth in population

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	69,700	120,000	180,000	220,000	180,000	290,000	310,000	340,000	390,000	320,000	430,000	450,000	490,000	560,000
Wales	12,400	16,000	24,000	28,000	24,000	32,000	34,000	38,000	38,000	38,000	44,000	44,000	48,000	52,000

Risk Metric FL4 – Area of agricultural land at risk of frequent flooding
Summary tables for England and Wales

The following tables provide summary data on the areas of agricultural land at risk of frequent flooding, in the following categories:

- Return period < 3 years (annual frequency >33%)
- Return period 3 to 5 years (annual frequency 20 to 33%)
- Return period 5 to 10 years (annual frequency 10 to 20%).

Agricultural land is divided into the following grades:

- Grades 1, 2 and 3. These grades are mainly arable and horticulture land use
- Grades 4 and 5. These grades are mainly grazing land for livestock.

The tables show overall totals for the **P50 Medium Emissions** climate change scenario. Data have been calculated for English Areas and Wales for all climate change scenarios. Data have not been calculated for socio economic scenarios, as these focus on growth in population and property numbers.

The data refers to areas of agricultural land where the inundation is projected to exceed 0.5 m depth. It therefore does not include shallow flooding or waterlogging.

Data on the area of agricultural land in England and Wales for the purposes of this analysis was taken from the Agricultural Land Classification (1974) and the Land Cover Map (2000) (Defra, 2010c):

- 12,600,000 ha (126,000 km^2) in England and Wales

Current statistics on the area of agricultural land in the UK is held by Defra and is slightly less that this earlier study indicates (Defra, 2011b).

- 11,000,000 ha (110,000 km^2) in England and Wales.

(a) River flooding (area in hectares)

EPOCH	Grades 1,2,3			Grades 4,5			Total
	<3	3 to 5	5 to 10	<3	3 to 5	5 to 10	
1961-1990	24,300	9,900	44,400	15,100	8,300	43,400	145,300
2020s	28,900	32,400	50,700	19,600	33,600	40,200	205,400
2050s	40,100	38,600	68,500	32,000	35,600	47,400	262,200
2080s	54,400	42,900	79,400	43,000	38,700	47,100	305,400

(b) Tidal flooding (area in hectares)

EPOCH	Grades 1,2,3			Grades 4,5			Total
	<3	3 to 5	5 to 10	<3	3 to 5	5 to 10	
2008	5,200	2,000	10,100	3,400	1,300	5,200	27,300
2020s	5,200	5,100	26,700	3,500	2,100	9,700	52,100
2050s	17,400	17,400	25,200	6,400	7,800	5,400	79,600
2080s	42,700	23,800	41,000	16,200	4,700	4,800	133,200

(c) Areas affected by river and tidal flooding (area in hectares)

EPOCH	Grades 1,2,3			Grades 4,5			Total
	<3	3 to 5	5 to 10	<3	3 to 5	5 to 10	
1961-1990	1,700	1,400	9,500	3,300	1,700	4,800	22,400
2020s	1,800	7,200	17,100	3,500	2,800	7,000	39,400
2050s	17,600	8,000	11,300	7,300	5,900	3,500	53,600
2080s	30,600	10,600	23,400	14,600	3,000	3,700	85,900

(d) Total (area in hectares)

EPOCH	Grades 1,2,3			Grades 4,5			Total
	<3	3 to 5	5 to 10	<3	3 to 5	5 to 10	
1961-1990/2008	31,200	13,300	64,000	21,800	11,300	53,400	195,000
2020s	35,900	44,700	94,500	26,600	38,500	56,900	296,900
2050s	75,100	64,000	105,000	45,700	49,300	56,300	395,400
2080s	127,700	77,300	143,800	73,800	46,400	55,600	524,500

Risk Metric FL6a – Number of residential properties at significant likelihood of river flooding (England and Wales):

- With climate change only
- With climate change and low population growth
- With climate change and principal population growth
- With climate change and high population growth

Table FL6a_01 - Number of residential properties at significant likelihood of river flooding including climate change

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	250,300	280,000	450,000	540,000	250,000	480,000	510,000	520,000	580,000	350,000	520,000	540,000	570,000	620,000
Wales	26,800	30,000	45,000	50,000	30,000	45,000	50,000	50,000	50,000	40,000	50,000	50,000	50,000	50,000

Table FL6a_02a - Number of residential properties at significant likelihood of river flooding including climate change and low growth in population

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	250,300	300,000	480,000	580,000	280,000	520,000	560,000	570,000	640,000	370,000	550,000	570,000	600,000	650,000
Wales	26,800	35,000	45,000	50,000	25,000	45,000	45,000	50,000	50,000	35,000	40,000	45,000	45,000	45,000

Table FL6a_02b - Number of residential properties at significant likelihood of river flooding including climate change and principal growth in population

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	250,300	320,000	510,000	610,000	330,000	620,000	660,000	670,000	750,000	500,000	750,000	780,000	820,000	890,000
Wales	26,800	35,000	50,000	55,000	30,000	55,000	55,000	60,000	60,000	50,000	60,000	60,000	65,000	65,000

Table FL6a_02c - Number of residential properties at significant likelihood of river flooding including climate change and high growth in population

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	250,300	330,000	530,000	640,000	380,000	710,000	760,000	780,000	870,000	650,000	980,000	1,020,000	1,060,000	1,170,000
Wales	26,800	35,000	50,000	55,000	40,000	65,000	65,000	70,000	70,000	70,000	85,000	85,000	85,000	85,000

Risk Metric FL6a – Number of residential properties at significant likelihood of tidal flooding (England and Wales):

- With climate change only
- With climate change and low population growth
- With climate change and principal population growth
- With climate change and high population growth

Table FL6a_01 - Number of residential properties at significant likelihood of tidal flooding including climate change

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	115,300	190,000	240,000	280,000	280,000	340,000	360,000	380,000	420,000	340,000	400,000	420,000	440,000	470,000
Wales	17,600	25,000	25,000	30,000	30,000	30,000	30,000	35,000	35,000	30,000	35,000	35,000	35,000	40,000

Table FL6a_02a - Number of residential properties at significant likelihood of tidal flooding including climate change and low growth in population

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	115,300	210,000	260,000	300,000	300,000	370,000	400,000	420,000	460,000	360,000	430,000	440,000	460,000	500,000
Wales	17,600	25,000	25,000	30,000	30,000	30,000	30,000	30,000	35,000	25,000	30,000	30,000	30,000	35,000

Table FL6a_02b - Number of residential properties at significant likelihood of tidal flooding including climate change and principal growth in population

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	115,300	220,000	270,000	320,000	360,000	440,000	470,000	500,000	550,000	510,000	590,000	620,000	640,000	690,000
Wales	17,600	25,000	30,000	30,000	35,000	35,000	40,000	40,000	40,000	40,000	45,000	45,000	45,000	50,000

Table FL6a_02c - Number of residential properties at significant likelihood of tidal flooding including climate change and high growth in population

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	115,300	230,000	290,000	330,000	420,000	520,000	550,000	580,000	640,000	670,000	780,000	810,000	850,000	910,000
Wales	17,600	25,000	30,000	35,000	40,000	45,000	45,000	45,000	50,000	55,000	60,000	60,000	60,000	65,000

Risk Metric FL6a – Number of residential properties at significant likelihood of river or tidal flooding (England and Wales):

- With climate change only
- With climate change and low population growth
- With climate change and principal population growth
- With climate change and high population growth

Table FL6a_01 - Number of residential properties at significant likelihood of tidal or river flooding including climate change

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	365,600	470,000	690,000	820,000	530,000	820,000	870,000	900,000	1,000,000	690,000	920,000	960,000	1,010,000	1,090,000
Wales	44,400	55,000	70,000	80,000	60,000	75,000	80,000	85,000	85,000	70,000	85,000	85,000	85,000	90,000

Table FL6a_02a - Number of residential properties at significant likelihood of tidal or river flooding including climate change and low growth in population

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	365,600	510,000	740,000	880,000	580,000	890,000	960,000	990,000	1,100,000	730,000	980,000	1,010,000	1,060,000	1,150,000
Wales	44,400	60,000	70,000	80,000	55,000	75,000	75,000	80,000	85,000	60,000	70,000	75,000	75,000	80,000

Table FL6a_02b - Number of residential properties at significant likelihood of tidal or river flooding including climate change and principal growth in population

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	365,600	540,000	780,000	930,000	690,000	1,060,000	1,130,000	1,170,000	1,300,000	1,010,000	1,340,000	1,400,000	1,460,000	1,580,000
Wales	44,400	60,000	80,000	85,000	65,000	90,000	95,000	100,000	100,000	90,000	105,000	105,000	110,000	115,000

Table FL6a_02c - Number of residential properties at significant likelihood of tidal or river flooding including climate change and high growth in population

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	365,600	560,000	820,000	970,000	800,000	1,230,000	1,310,000	1,360,000	1,510,000	1,320,000	1,760,000	1,830,000	1,910,000	2,080,000
Wales	44,400	60,000	80,000	90,000	80,000	110,000	110,000	115,000	120,000	125,000	145,000	145,000	145,000	150,000

Risk metric FL6b assumes future costs of damage are at present day prices.

Risk Metric FL6b – EAD to residential properties at risk due to river flooding (England and Wales):

- With climate change only
- With climate change and low population growth
- With climate change and principal population growth
- With climate change and high population growth

Table FL6b_01 - EAD to residential property at risk due to river flooding including climate change (£ millions)

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	427	450	750	1,150	450	850	1,000	1,100	1,600	550	1,050	1,200	1,400	2,150
Wales	56	60	80	110	60	90	100	110	120	70	110	110	120	130

Table FL6b_02a - EAD to residential property at risk due to river flooding including climate change and low growth in population (£ millions)

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	427	500	800	1,250	500	900	1,100	1,200	1,800	550	1,100	1,250	1,500	2,300
Wales	56	60	90	110	50	90	100	110	120	60	90	100	100	110

Table FL6b_02c - EAD to residential property at risk due to river flooding including climate change and principal growth in population (£ millions)

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	427	500	850	1,300	550	1,100	1,300	1,400	2,100	800	1,550	1,750	2,050	3,100
Wales	56	60	90	120	70	100	120	130	140	80	130	140	150	150

Table FL6b_02c - EAD to residential property at risk due to river flooding including climate change and high growth in population (£ millions)

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	427	500	900	1,400	650	1,250	1,500	1,650	2,400	1,000	2,000	2,250	2,650	4,050
Wales	56	60	90	120	80	120	140	150	170	110	180	190	200	210

Risk Metric FL6b – EAD to residential properties at risk due to tidal flooding (England and Wales):

- With climate change only
- With climate change and low population growth
- With climate change and principal population growth
- With climate change and high population growth

Table FL6b_01 - EAD to residential property at risk due to tidal flooding including climate change (£ millions)

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	212	300	350	450	450	550	600	700	850	600	800	900	1,000	1,300
Wales	49	60	60	70	60	70	80	90	100	80	90	100	110	130

Table FL6b_02a - EAD to residential property at risk due to tidal flooding including climate change and low growth in population (£ millions)

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	212	350	400	500	500	600	700	750	950	600	850	950	1,050	1,350
Wales	49	60	60	70	60	70	80	80	100	60	80	90	90	110

Table FL6b_02c - EAD to residential property at risk due to tidal flooding including climate change and principal growth in population (£ millions)

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	212	350	400	500	550	750	800	900	1,150	850	1,150	1,300	1,450	1,900
Wales	49	60	70	70	80	90	90	100	120	90	110	120	130	150

Table FL6b_02c - EAD to residential property at risk due to tidal flooding including climate change and high growth in population (£ millions)

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	212	350	450	500	650	850	950	1,050	1,350	1,150	1,550	1,700	1,950	2,500
Wales	49	70	70	80	90	110	130	140	160	160	180	200	220	260

Risk Metric FL6b – EAD to residential properties at risk due to river or tidal flooding (England and Wales):

- With climate change only
- With climate change and low population growth
- With climate change and principal population growth
- With climate change and high population growth

Table FL6b_01 - EAD to residential property at risk due to tidal or river flooding including climate change (£ millions)

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	639	750	1,100	1,600	900	1,400	1,600	1,800	2,450	1,150	1,850	2,100	2,400	3,450
Wales	105	120	140	180	120	160	180	200	220	150	200	210	230	260

Table FL6b_02a - EAD to residential property at risk due to tidal or river flooding including climate change and low growth in population (£ millions)

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	639	850	1,200	1,750	1,000	1,500	1,800	1,950	2,750	1,150	1,950	2,200	2,550	3,650
Wales	105	120	150	180	110	160	180	190	220	120	170	190	190	220

Table FL6b_02c - EAD to residential property at risk due to tidal or river flooding including climate change and principal growth in population (£ millions)

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	639	850	1,250	1,800	1,100	1,850	2,100	2,300	3,250	1,650	2,700	3,050	3,500	5,000
Wales	105	120	160	190	150	190	210	230	260	170	240	260	280	300

Table FL6b_02c - EAD to residential property at risk due to tidal or river flooding including climate change and high growth in population (£ millions)

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	639	850	1,350	1,900	1,300	2,100	2,450	2,700	3,750	2,150	3,550	3,950	4,600	6,550
Wales	105	130	160	200	170	230	270	290	330	270	360	390	420	470

Risk Metric FL7a – Number of non-residential properties at significant likelihood of river flooding (England and Wales):

- With climate change only
- With climate change and low population growth
- With climate change and principal population growth
- With climate change and high population growth

Table FL7a_01 - Number of non-residential properties at significant likelihood of river flooding, including climate change

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	135,800	150,000	210,000	240,000	140,000	220,000	230,000	240,000	250,000	180,000	240,000	240,000	250,000	260,000
Wales	19,100	20,000	25,000	25,000	20,000	25,000	25,000	25,000	30,000	20,000	25,000	25,000	30,000	30,000

Table FL7a_02a - Number of non-residential properties at significant likelihood of river flooding, including climate change and low growth in population

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	135,800	160,000	230,000	260,000	150,000	240,000	250,000	260,000	280,000	190,000	250,000	250,000	260,000	280,000
Wales	19,100	20,000	25,000	30,000	20,000	25,000	25,000	25,000	30,000	20,000	25,000	25,000	25,000	25,000

Table FL7a_02b - Number of non-residential properties at significant likelihood of river flooding, including climate change and principal growth in population

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	135,800	170,000	240,000	270,000	180,000	290,000	300,000	310,000	330,000	260,000	340,000	350,000	360,000	380,000
Wales	19,100	20,000	30,000	30,000	20,000	30,000	30,000	30,000	35,000	25,000	35,000	35,000	35,000	35,000

Table FL7a_02c - Number of non-residential properties at significant likelihood of river flooding, including climate change and high growth in population

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	135,800	180,000	250,000	280,000	200,000	330,000	350,000	350,000	380,000	330,000	440,000	450,000	470,000	490,000
Wales	19,100	20,000	30,000	30,000	25,000	35,000	35,000	35,000	40,000	35,000	45,000	45,000	45,000	50,000

Risk Metric FL7a – Number of non-residential properties at significant likelihood of tidal flooding (England and Wales):

- With climate change only
- With climate change and low population growth
- With climate change and principal population growth
- With climate change and high population growth

Table FL7a_01 - Number of non-residential properties at significant likelihood of tidal flooding, including climate change

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	55,600	80,000	90,000	100,000	100,000	110,000	120,000	120,000	130,000	110,000	130,000	130,000	140,000	150,000
Wales	7,100	10,000	10,000	15,000	10,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000

Table FL7a_02a - Number of non-residential properties at significant likelihood of tidal flooding, including climate change and low growth in population

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	55,600	80,000	100,000	110,000	110,000	120,000	130,000	140,000	150,000	120,000	140,000	140,000	150,000	150,000
Wales	7,100	10,000	10,000	15,000	10,000	15,000	15,000	15,000	15,000	10,000	15,000	15,000	15,000	15,000

Table FL7a_02b - Number of non-residential properties at significant likelihood of tidal flooding, including climate change and principal growth in population

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	55,600	90,000	100,000	110,000	130,000	150,000	160,000	160,000	180,000	170,000	190,000	200,000	200,000	210,000
Wales	7,100	10,000	10,000	15,000	15,000	15,000	15,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000

Table FL7a_02c - Number of non-residential properties at significant likelihood of tidal flooding, including climate change and high growth in population

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	55,600	90,000	100,000	120,000	150,000	170,000	180,000	190,000	210,000	220,000	250,000	260,000	270,000	280,000
Wales	7,100	10,000	15,000	15,000	15,000	20,000	20,000	20,000	25,000	25,000	25,000	30,000	30,000	30,000

Risk Metric FL7a – Number of non-residential properties at significant likelihood of river or tidal flooding (England and Wales):

- With climate change only
- With climate change and low population growth
- With climate change and principal population growth
- With climate change and high population growth

Table FL7a_01 - Number of non-residential properties at significant likelihood of tidal or river flooding, including climate change

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	191,400	230,000	300,000	340,000	240,000	330,000	350,000	360,000	380,000	290,000	370,000	370,000	390,000	410,000
Wales	26,200	30,000	35,000	40,000	30,000	40,000	40,000	40,000	45,000	35,000	40,000	40,000	45,000	45,000

Table FL7a_02a - Number of non-residential properties at significant likelihood of tidal or river flooding, including climate change and low growth in population

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	191,400	240,000	330,000	370,000	260,000	360,000	380,000	400,000	430,000	310,000	390,000	390,000	410,000	430,000
Wales	26,200	30,000	35,000	45,000	30,000	40,000	40,000	40,000	45,000	30,000	40,000	40,000	40,000	40,000

Table FL7a_02b - Number of non-residential properties at significant likelihood of tidal or river flooding, including climate change and principal growth in population

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	191,400	260,000	340,000	380,000	310,000	440,000	460,000	470,000	510,000	430,000	530,000	550,000	560,000	590,000
Wales	26,200	30,000	40,000	45,000	35,000	45,000	45,000	50,000	55,000	45,000	55,000	55,000	55,000	55,000

Table FL7a_02c - Number of non-residential properties at significant likelihood of tidal or river flooding, including climate change and high growth in population

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	191,400	270,000	350,000	400,000	350,000	500,000	530,000	540,000	590,000	550,000	690,000	710,000	740,000	770,000
Wales	26,200	30,000	45,000	45,000	40,000	55,000	55,000	55,000	65,000	60,000	70,000	75,000	75,000	80,000

Risk metric FL7b assumes future costs of damage are at present day prices.

Risk Metric FL7b – EAD to non-residential properties at risk due to river flooding (England and Wales):

- With climate change only
- With climate change and low population growth
- With climate change and principal population growth
- With climate change and high population growth

Table FL7b_01 - EAD to non-residential property at risk due to river flooding including climate change (£ millions)

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	373	400	700	1,000	400	750	900	1,000	1,400	500	950	1,050	1,250	1,850
Wales	55	60	90	110	60	90	100	120	150	80	110	120	140	190

Table FL7b_02a - EAD to non-residential property at risk due to river flooding including climate change and low growth in population (£ millions)

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	373	450	750	1,100	400	800	950	1,050	1,550	500	1,000	1,100	1,300	1,950
Wales	55	70	90	110	60	90	100	110	140	70	90	100	120	160

Table FL7b_02c - EAD to non-residential property at risk due to river flooding including climate change and principal growth in population (£ millions)

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	373	450	750	1,150	500	950	1,100	1,250	1,800	700	1,350	1,500	1,750	2,600
Wales	55	70	90	120	70	110	120	140	170	90	140	150	170	230

Table FL7b_02c - EAD to residential property at risk due to river flooding including climate change and high growth in population (£ millions)

		2020s			2050s					2080s				
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	373	450	800	1,200	600	1,100	1,300	1,450	2,050	950	1,750	1,950	2,250	3,400
Wales	55	70	100	130	80	120	140	160	200	130	180	200	230	320

Risk Metric FL7b – EAD to non-residential properties at risk due to tidal flooding (England and Wales):

- With climate change only
- With climate change and low population growth
- With climate change and principal population growth
- With climate change and high population growth

Table FL7b_01 - EAD to non-residential property at risk due to tidal flooding including climate change (£ millions)

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	188	250	300	350	350	450	500	500	600	450	550	600	700	850
Wales	37	50	50	60	50	60	60	70	80	60	70	80	80	100

Table FL7b_02a - EAD to non-residential property at risk due to tidal flooding including climate change and low growth in population (£ millions)

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	188	250	350	400	400	500	500	550	700	450	600	650	700	900
Wales	37	50	50	60	50	60	60	70	80	60	60	70	70	80

Table FL7b_02c - EAD to non-residential property at risk due to tidal flooding including climate change and principal growth in population (£ millions)

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	188	300	350	400	450	600	650	700	800	650	850	900	1,000	1,250
Wales	37	50	60	60	60	70	80	80	90	80	90	100	100	120

Table FL7b_02c - EAD to residential property at risk due to tidal flooding including climate change and high growth in population (£ millions)

		2020s			2050s					2080s				
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	188	300	350	400	550	650	750	800	950	900	1,100	1,200	1,350	1,650
Wales	37	50	60	60	70	90	90	90	110	100	120	130	140	160

Risk Metric FL7b – EAD to non-residential properties at risk due to river or tidal flooding (England and Wales):

- With climate change only
- With climate change and low population growth
- With climate change and principal population growth
- With climate change and high population growth

Table FL7b_01 - EAD to non-residential property at risk due to tidal or river flooding including climate change (£ millions)

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	560	650	1,000	1,350	750	1,200	1,350	1,500	2,000	950	1,500	1,650	1,950	2,700
Wales	92	110	140	170	110	150	160	190	230	140	180	200	220	290

Table FL7b_02a - EAD to non-residential property at risk due to tidal or river flooding including climate change and low growth in population (£ millions)

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	560	700	1,100	1,500	800	1,300	1,450	1,600	2,250	950	1,600	1,750	2,000	2,850
Wales	92	120	140	170	110	150	160	180	220	130	150	170	190	240

Table FL7b_02c - EAD to non-residential property at risk due to tidal or river flooding including climate change and principal growth in population (£ millions)

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	560	750	1,100	1,550	950	1,550	1,750	1,950	2,600	1,350	2,200	2,400	2,750	3,850
Wales	92	120	150	180	130	180	200	220	260	170	230	250	270	350

Table FL7b_02c - EAD to residential property at risk due to tidal or river flooding including climate change and high growth in population (£ millions)

		2020s			2050s					2080s				
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	560	750	1,150	1,600	1,150	1,750	2,050	2,250	3,000	1,850	2,850	3,150	3,600	5,050
Wales	92	120	160	190	150	210	230	250	310	230	300	330	370	480

Risk Metric FL8 – Transport links (road and rail) at significant likelihood of flooding (England and Wales)
Summary tables

The following tables provide summary data on the lengths of road and rail at significant likelihood of flooding. Roads are divided into the following categories:

- Motorway
- A Roads
- B Roads
- Minor Roads.

The tables show overall totals for the **P50 Medium Emissions** climate change scenario. Data have not been calculated for socio economic scenarios, as these focus on growth in population and property numbers.

(a) Roads (length at risk in kilometres)

Road type	1961-90	2008	2020s	2050s	2080s
Motorways					
Fluvial	165		216	244	265
Tidal		81	95	120	137
Total			311	363	402

A Roads					
Fluvial	2318		2804	3004	3172
Tidal		818	919	1084	1211
Total			3724	4088	4383

B Roads					
Fluvial	1264		1502	1597	1677
Tidal		323	359	425	477
Total			1861	2022	2155

Minor roads					
Fluvial	5417		6447	6840	7220
Tidal		1949	2199	2600	2936
Total			8646	9440	10155

Total - roads					
Fluvial	9165		10970	11684	12333
Tidal		3172	3573	4229	4761
Overall total			14542	15913	17094

(b) Rail (length at risk in kilometres)

	1961-90	2008	2020s	2050s	2080s
Fluvial	1325		1598	1716	1823
Tidal		675	749	842	920
Overall total			2347	2558	2742

The following tables provide more detailed data by climate change scenario.

Motorways

FL8 Length of Motorway with significant likelihood (1:75) of river flooding (km)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	165	170	220	260	170	220	240	260	300	190	250	270	290	330
Wales	8	8	9	10	8	9	9	10	12	9	10	10	11	12

FL8 Length of Motorway with significant likelihood (1:75) of coastal / tidal flooding (km)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	81	90	100	100	100	110	120	130	140	120	130	140	140	150
Wales	14	14	14	14	14	14	14	14	15	14	15	15	15	15

FL8 Length of Motorway with significant likelihood (1:75) of tidal or river flooding (km)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	246	260	320	360	270	330	360	390	440	310	380	410	430	480
Wales	21	22	23	24	21	23	24	24	27	23	25	25	26	27

A Roads

FL8 Length of A Road with significant likelihood (1:75) of river flooding (km)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	2,318	2,400	2,800	3,150	2,300	2,850	3,000	3,100	3,450	2,550	3,050	3,150	3,350	3,600
Wales	553	590	620	670	550	630	660	670	730	600	670	670	710	750

FL8 Length of A Road with significant likelihood (1:75) of coastal / tidal flooding (km)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	818	900	900	950	950	1,050	1,100	1,150	1,200	1,050	1,150	1,200	1,250	1,300
Wales	235	240	250	260	260	270	280	280	280	270	280	280	290	290

FL8 Length of A Road with significant likelihood (1:75) of tidal or river flooding (km)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	3,136	3,300	3,700	4,100	3,250	3,900	4,100	4,250	4,650	3,600	4,200	4,350	4,600	4,900
Wales	788	830	870	930	810	900	940	950	1,010	870	950	950	1,000	1,040

B Roads

FL8 Length of B Road with significant likelihood (1:75) of river flooding (km)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	1,264	1,300	1,500	1,650	1,250	1,550	1,600	1,650	1,800	1,400	1,650	1,700	1,750	1,900
Wales	287	310	330	350	290	330	340	350	380	320	350	350	370	390

FL8 Length of B Road with significant likelihood (1:75) of coastal / tidal flooding (km)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	323	340	360	380	380	410	430	440	480	410	460	480	490	510
Wales	80	80	85	90	90	90	95	95	100	90	95	100	100	105

FL8 Length of B Road with significant likelihood (1:75) of tidal or river flooding (km)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	1,588	1,640	1,860	2,030	1,630	1,960	2,030	2,090	2,280	1,810	2,110	2,180	2,240	2,410
Wales	367	390	415	440	380	420	435	445	480	410	445	450	470	495

Minor roads

FL8 Length of Minor Road with significant likelihood (1:75) of river flooding (km)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	5,417	5,500	6,450	7,150	5,400	6,550	6,850	7,000	7,850	5,900	7,000	7,200	7,650	8,250
Wales	925	1,000	1,050	1,100	950	1,050	1,100	1,150	1,250	1,000	1,100	1,100	1,200	1,250

FL8 Length of Minor Road with significant likelihood (1:75) of coastal / tidal flooding (km)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	1,949	2,100	2,200	2,300	2,300	2,500	2,600	2,750	2,950	2,550	2,850	2,950	3,000	3,100
Wales	245	250	250	250	250	300	300	300	300	300	300	300	300	300

FL8 Length of Minor Road with significant likelihood (1:75) of tidal or river flooding (km)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	7,367	7,600	8,650	9,450	7,700	9,050	9,450	9,750	10,800	8,450	9,850	10,150	10,650	11,350
Wales	1,170	1,250	1,300	1,350	1,200	1,350	1,400	1,450	1,550	1,300	1,400	1,400	1,500	1,550

Rail

FL8 Length of railway with significant likelihood (1:75) of river flooding (km)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	1,325	1,360	1,600	1,800	1,330	1,640	1,720	1,770	1,980	1,440	1,760	1,820	1,930	2,080
Wales	221	240	250	270	220	250	260	270	300	240	270	270	290	300

FL8 Length of railway with significant likelihood (1:75) of coastal / tidal flooding (km)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	675	720	750	780	780	820	840	870	920	830	900	920	940	970
Wales	219	230	230	240	240	240	250	250	260	240	250	260	260	260

FL8 Length of railway with significant likelihood (1:75) of tidal or river flooding (km)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	2,000	2,080	2,350	2,580	2,110	2,460	2,560	2,640	2,900	2,270	2,660	2,740	2,870	3,050
Wales	440	470	480	510	460	490	510	520	560	480	520	530	550	560

Risk Metric FL11 – Energy generation and distribution installations at significant likelihood of flooding

The following tables provide summary data on the number of energy generation and distribution installations at significant likelihood of flooding in England and Wales. Installations are divided into the following categories:

- Power stations
- Substations.

The tables show overall totals for the **P50 Medium Emissions** climate change scenario.

Data have not been calculated for socio economic scenarios, as these focus on growth in population and property numbers.

Installation type	1961-90	2008	2020s	2050s	2080s
Power Stations					
Fluvial	6		9	10	11
Tidal		13	17	24	27
Total (out of 112)			26	34	38

Sub-stations					
Fluvial	27		32	35	36
Tidal		19	21	29	32
Total (out of 271)			53	64	68

Overall total					
Fluvial	33		41	45	47
Tidal		32	38	53	59
Total (out of 383)			79	98	106

The following table shows the change in generation capacity at significant likelihood of flooding for the **P50 Medium Emissions** climate change scenario.

Generation capacity (MW)	1961-90	2008	2020s	2050s	2080s
Fluvial	2208		3580	4295	6023
Tidal		8045	12018	14795	16035
Total			15598	19090	22058

The following table shows the flood and coastal erosion risk to proposed new nuclear power station sites, existing radioactive waste storage sites and nuclear decommissioning sites in England, Wales and Scotland. The assessment is qualitative and applies to the 2080s, based on site assessments (DECC, 2010; Nirex, 2005 and NDA, 2008). The reason why the totals are often less than the sum of new sites, waste stores and NDA sites is that some sites perform more than one function.

Flood Risk	Erosion Risk	Number of sites			
		TOTAL	New site	Waste Store	NDA site
High	High	4	3	4	4
High	Medium	1	1		
High	No	1	1	1	1
Medium	High	1		1	1
Medium	Medium	1	1	1	1
No	Medium	1		1	1
Low	Low	1	1		
No	Low	2	1	2	2
No	No	7		2	6
TOTAL		19	8	12	16

The following tables provide more detailed data for power stations and substations by climate change scenario.

Power Stations: number (England and Wales)

FL11 Number of power stations with significant likelihood (1:75) of river flooding

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	6	6	9	10	8	10	10	10	12	9	11	11	12	12
Wales	-	-	-	-	-	-	-	-	1	1	1	1	1	1

FL11 Number of power stations with significant likelihood (1:75) of tidal / coastal flooding

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	13	15	17	17	17	19	24	25	27	22	27	27	29	29
Wales	3	5	5	5	5	5	5	5	5	5	5	5	5	5

FL11 Number of power stations with significant likelihood (1:75) of tidal or river flooding

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	19	21	26	27	25	29	34	35	39	31	38	38	41	41
Wales	3	5	5	5	5	5	5	5	6	6	6	6	6	6

Power Stations: capacity (England and Wales)

FL11 Capacity of power stations with significant likelihood (1:75) of river flooding

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	2,208	2,200	3,600	4,300	2,700	4,300	4,300	4,300	6,300	4,450	6,000	6,000	6,300	6,300
Wales	-	-	-	-	-	-	-	-	1,750	1,750	1,750	1,750	1,750	1,750

FL11 Capacity of power stations with significant likelihood (1:75) of tidal / coastal flooding

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	8,045	8,750	12,000	12,000	12,000	13,350	14,800	15,150	16,050	14,750	16,050	16,050	18,600	18,600
Wales	1,973	2,650	2,650	2,650	2,650	2,650	2,650	2,650	2,650	2,650	2,650	2,650	2,650	2,650

FL11 Capacity of power stations with significant likelihood (1:75) of tidal or river flooding

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	10,253	10,950	15,600	16,300	14,700	17,650	19,100	19,450	22,350	19,200	22,050	22,050	24,900	24,900
Wales	1,973	2,650	2,650	2,650	2,650	2,650	2,650	2,650	4,400	4,400	4,400	4,400	4,400	4,400

Major Electricity Substations: number (England and Wales)

FL11 Number of electricity substations with significant likelihood (1:75) of fluvial flooding

		2020s			2050s					2080s				
Nation	0 2008 baseline	1 Medium p10	2 Medium p50	3 Medium p90	4 Low p10	5 Low p50	6 Medium p50	7 High p50	8 High p90	9 Low p10	10 Low p50	11 Medium p50	12 High p50	13 High p90
England & Wales	27	27	32	36	27	33	35	36	41	29	36	36	40	46
Wales	4	4	4	4	4	4	4	4	4	4	4	4	4	4

FL11 Number of electricity substations with significant likelihood (1:75) of tidal flooding

		2020s			2050s					2080s				
Nation	0 Baseline	1 Medium p10	2 Medium p50	3 Medium p90	4 Low p10	5 Low p50	6 Medium p50	7 High p50	8 High p90	9 Low p10	10 Low p50	11 Medium p50	12 High p50	13 High p90
England & Wales	19	21	21	24	24	28	29	29	32	28	30	32	32	33
Wales	8	8	8	9	9	10	10	10	10	10	10	10	10	10

FL11 Number of electricity substations with significant likelihood (1:75) of tidal or river flooding

		2020s			2050s					2080s				
Nation	0 Baseline	1 Medium p10	2 Medium p50	3 Medium p90	4 Low p10	5 Low p50	6 Medium p50	7 High p50	8 High p90	9 Low p10	10 Low p50	11 Medium p50	12 High p50	13 High p90
England & Wales	46	48	53	60	51	61	64	65	73	57	66	68	72	79
Wales	12	12	12	13	13	14	14	14	14	14	14	14	14	14

Risk Metric FL12 – Hospitals and schools at significant likelihood of flooding (England and Wales)

The following table provides summary data on the following at significant likelihood of flooding:

- Hospitals
- Hospital beds
- Primary and secondary schools
- Pupils at primary and secondary schools.

The table shows overall totals for the P50 Medium Emissions climate change scenario.

Data have not been calculated for socio economic scenarios. All future scenarios therefore assume present day numbers of hospitals and schools.

Hospitals

	1961-90	2008	2020s	2050s	2080s
Fluvial	32		42	45	47
Tidal		21	25	32	35
Overall total			67	77	82

Hospital beds

	1961-90	2008	2020s	2050s	2080s
Fluvial	2508		4539	5076	5187
Tidal		979	1058	1996	2150
Overall total			5597	7072	7337

Primary schools

	1961-90	2008	2020s	2050s	2080s
Fluvial	531		692	751	801
Tidal		245	293	399	477
Overall total			985	1150	1278

Primary school pupils

	1961-90	2008	2020s	2050s	2080s
Fluvial	95061		127745	139275	150701
Tidal		55695	67387	95193	114693
Overall total			195132	234468	265394

Secondary schools

	1961-90	2008	2020s	2050s	2080s
Fluvial	100		129	138	148
Tidal		51	57	79	99
Overall total			186	217	247

Secondary school pupils

	1961-90	2008	2020s	2050s	2080s
Fluvial	69545		85325	89772	95692
Tidal		42458	45766	60564	74674
Overall total			131091	150336	170366

Primary and secondary schools

	1961-90	2008	2020s	2050s	2080s
Fluvial	631		821	889	949
Tidal		296	350	478	576
Overall total			1171	1367	1525

Primary and secondary school pupils

	1961-90	2008	2020s	2050s	2080s
Fluvial	164606		213070	229047	246393
Tidal		98153	113153	155757	189367
Overall total			326223	384804	435760

The following tables provide more detailed data by climate change scenario.

Number of hospitals

FL12a - Number of hospitals at significant likelihood of river flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	32	32	42	47	32	44	45	46	54	32	46	47	53	55
Wales	8	8	12	13	8	12	13	13	14	8	13	13	13	14

FL12a - Number of hospitals at significant likelihood of coastal / tidal flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	21	22	25	27	27	29	32	32	35	32	33	35	37	39
Wales	4	4	4	5	5	5	5	5	5	5	5	5	5	5

FL12a - Number of hospitals at significant likelihood of tidal or river flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	53	54	67	74	59	73	77	78	89	64	79	82	90	94
Wales	12	12	16	18	13	17	18	18	19	13	18	18	18	19

Number of hospital beds

FL12b - Sum of hospital beds at significant likelihood of river flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	2,508	2,500	4,550	5,250	2,500	5,100	5,100	5,100	5,600	2,500	5,100	5,200	5,550	5,600
Wales	1,296	1,300	2,150	2,150	1,300	2,150	2,150	2,150	2,150	1,300	2,150	2,150	2,150	2,150

FL12b - Sum of hospital beds at significant likelihood of coastal / tidal flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	979	1,000	1,050	1,150	1,150	1,200	2,000	2,000	2,150	2,000	2,000	2,150	2,150	2,800
Wales	90	90	90	200	200	200	200	200	200	200	200	200	200	200

FL12b - Sum of hospital beds at significant likelihood of tidal or river flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	3,487	3,500	5,600	6,400	3,650	6,300	7,100	7,100	7,750	4,500	7,100	7,350	7,700	8,400
Wales	1,386	1,390	2,240	2,350	1,500	2,350	2,350	2,350	2,350	1,500	2,350	2,350	2,350	2,350

Number of schools

Number of schools at significant likelihood of river flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	631	660	820	940	630	840	890	930	1,080	730	910	950	1,030	1,170
Wales	119	130	140	160	120	150	150	160	170	140	150	160	170	180

Number of schools at significant likelihood of coastal or tidal flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	296	320	350	390	390	460	480	510	570	460	550	580	600	610
Wales	68	70	70	80	80	80	80	80	90	80	80	90	90	90

Number of schools at significant likelihood of river or tidal flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	927	980	1,170	1,330	1,020	1,300	1,370	1,440	1,650	1,190	1,460	1,530	1,630	1,780
Wales	187	200	210	240	200	230	230	240	260	220	230	250	260	270

Number of primary schools

Number of primary schools at significant likelihood of river flooding (1:75)

		2020s			2050s					2080s				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	531	560	690	790	530	710	750	780	900	610	770	800	870	980
Wales	104	120	130	140	100	130	130	140	150	120	140	140	150	160

Number of primary schools at significant likelihood of coastal or tidal flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	245	270	290	320	320	380	400	420	480	380	460	480	490	500
Wales	58	60	60	70	70	70	70	70	80	70	70	80	80	80

Number of primary schools at significant likelihood of river or tidal flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	776	830	980	1,110	850	1,090	1,150	1,200	1,380	990	1,230	1,280	1,360	1,480
Wales	162	180	190	210	170	200	200	210	230	190	210	220	230	240

Number of secondary schools

Number of secondary schools at significant likelihood of river flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	100	100	130	145	100	130	140	145	175	110	140	150	160	190
Wales	15	15	15	15	15	15	15	15	20	15	15	15	20	20

Number of secondary schools at significant likelihood of coastal or tidal flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	51	55	55	70	70	75	80	85	100	75	90	100	105	110
Wales	10	10	10	10	10	10	10	10	10	10	10	10	10	10

Number of secondary schools at significant likelihood of river or tidal flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	151	155	185	215	170	205	220	230	275	185	230	250	265	300
Wales	25	25	25	25	25	25	25	25	30	25	25	25	30	30

Number of school pupils

Number of school pupils at significant likelihood of river flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	164,606	172,000	213,000	244,000	165,000	216,000	229,000	239,000	292,000	187,000	236,000	246,000	276,000	323,000
Wales	25,343	28,000	31,000	33,000	25,000	31,000	32,000	33,000	37,000	30,000	32,000	33,000	37,000	38,000

Number of school pupils at significant likelihood of coastal or tidal flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	98,153	105,000	113,000	127,000	127,000	149,000	156,000	167,000	189,000	150,000	179,000	189,000	198,000	203,000
Wales	22,839	23,000	24,000	25,000	25,000	26,000	26,000	26,000	27,000	26,000	27,000	27,000	28,000	28,000

Number of school pupils at significant likelihood of river or tidal flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	262,759	277,000	326,000	371,000	292,000	365,000	385,000	406,000	481,000	337,000	415,000	435,000	474,000	526,000
Wales	48,182	51,000	55,000	58,000	50,000	57,000	58,000	59,000	64,000	56,000	59,000	60,000	65,000	66,000

Number of primary school pupils

Number of primary school pupils at significant likelihood of river flooding (1:75)

		2020s			2050s					2080s				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	95,061	101,000	128,000	148,000	95,000	130,000	139,000	146,000	176,000	112,000	144,000	151,000	168,000	193,000
Wales	11,679	14,000	16,000	18,000	12,000	16,000	17,000	18,000	20,000	15,000	17,000	18,000	20,000	20,000

Number of primary school pupils at significant likelihood of coastal or tidal flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	55,695	61,000	67,000	75,000	74,000	91,000	95,000	102,000	114,000	91,000	110,000	115,000	118,000	121,000
Wales	12,799	13,000	13,000	15,000	15,000	16,000	16,000	16,000	17,000	16,000	17,000	17,000	17,000	17,000

Number of primary school pupils at significant likelihood of river or tidal flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	150,756	162,000	195,000	223,000	169,000	221,000	234,000	248,000	290,000	203,000	254,000	266,000	286,000	314,000
Wales	24,478	27,000	29,000	33,000	27,000	32,000	33,000	34,000	37,000	31,000	34,000	35,000	37,000	37,000

Number of secondary school pupils

Number of secondary school pupils at significant likelihood of river flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	1961-90 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	69,545	70,000	85,000	95,000	70,000	86,000	90,000	93,000	116,000	75,000	92,000	96,000	109,000	130,000
Wales	13,664	14,000	15,000	15,000	14,000	15,000	15,000	15,000	17,000	15,000	15,000	15,000	17,000	18,000

Number of secondary school pupils at significant likelihood of coastal or tidal flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	2008 baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	42,458	44,000	46,000	53,000	52,000	58,000	61,000	64,000	75,000	59,000	70,000	75,000	80,000	82,000
Wales	10,040	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	11,000	11,000

Number of secondary school pupils at significant likelihood of river or tidal flooding (1:75)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	112,003	114,000	131,000	148,000	122,000	144,000	151,000	157,000	191,000	134,000	162,000	171,000	189,000	212,000
Wales	23,704	24,000	25,000	25,000	24,000	25,000	25,000	25,000	27,000	25,000	25,000	25,000	28,000	29,000

Risk Metric FL15 – Scheduled Ancient Monuments (SAM) at significant likelihood of flooding (England and Wales)

The following table provides summary data on the area (in hectares) of SAM sites at significant likelihood of flooding.

The table shows overall totals for the P50 Medium Emissions climate change scenario.

Data have not been calculated for socio economic scenarios, as these focus on growth in population and property numbers.

	1961-90	2008	2020s	2050s	2080s
Fluvial	3672		4189	4363	4559
Tidal		3404	3889	4055	4218
Overall total			8078	8418	8777

The following tables provide more detailed data by climate change scenario.

FL15 Area of Scheduled Ancient Monuments with significant likelihood (1:75) of river flooding (Ha)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	3,672	3,750	4,200	4,500	3,650	4,250	4,350	4,450	4,800	3,900	4,450	4,550	4,700	5,000
Wales	268	290	300	310	270	300	310	310	330	290	310	310	330	340

FL15 Area of Scheduled Ancient Monuments with significant likelihood (1:75) of coastal / tidal flooding (Ha)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	3,404	3,450	3,900	4,200	3,400	3,950	4,050	4,150	4,400	3,650	4,150	4,200	4,350	4,550
Wales	334	330	430	500	330	450	470	490	530	390	480	500	530	530

FL15 Area of Scheduled Ancient Monuments with significant likelihood (1:75) of tidal or river flooding (Ha)

		2020s			2050s					2080s				
Scenario	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Nation	Baseline	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England & Wales	7,076	7,200	8,100	8,700	7,050	8,200	8,400	8,600	9,200	7,550	8,600	8,750	9,050	9,550
Wales	602	620	730	810	600	750	780	800	860	680	790	810	860	870

Risk Metric FL14a – Area of agricultural land lost to coastal erosion (England and Wales)

The following table provides summary data on the area (in hectares) of agricultural land that may be lost due to coastal erosion in England and Wales.

The table shows overall totals for the P50 Medium Emissions climate change scenario.

Data have not been calculated for socio economic scenarios, as these focus on growth in population and property numbers.

Current statistics on the area of agricultural land in the UK is held by Defra (Defra, 2011b).

- 11,000,000 ha (110,000 km^2) in England and Wales

Agricultural land Grade	Area of land affected (ha)		
	2020s	2050s	2080s
1	30	96	125
2	39	144	236
3	792	2591	4211
4	346	1213	1919
5	155	644	1229
Total	1361	4687	7721

The following tables provide more detailed data by Area and climate change scenario.

Grade 1

		2020s			2050s					2080s				
Nation	UKCP09 Region	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England	East Midlands	1	2	2	5	7	9	12	19	5	11	15	20	36
England	East of England	25	26	28	69	76	80	85	99	78	91	98	106	129
England	London	0	0	0	0	0	0	0	0	0	0	0	0	0
England	North East	0	0	0	0	0	0	0	0	0	0	0	0	0
England	North West	0	0	0	0	0	0	0	0	0	0	0	0	0
England	South East	1	1	1	4	5	6	6	7	10	11	11	12	13
England	South West	0	0	0	1	1	1	1	1	1	1	1	1	1
England	West Midlands	0	0	0	0	0	0	0	0	0	0	0	0	0
England	Yorkshire and The Humber	0	0	0	0	0	0	0	0	0	0	0	0	0
Wales	Wales	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	England and Wales	28	30	31	78	89	96	103	126	94	114	125	139	179

Grade 2

		2020s			2050s					2080s				
Nation	UKCP09 Region	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England	East Midlands	3	3	4	7	10	11	13	17	8	12	15	17	24
England	East of England	9	10	11	27	33	36	40	52	28	39	45	53	75
England	London	0	0	0	0	0	0	0	0	0	0	0	0	0
England	North East	0	0	0	1	1	1	1	1	1	1	2	2	2
England	North West	0	0	0	0	0	0	0	0	0	0	0	0	0
England	South East	7	7	8	20	23	25	26	30	35	38	40	42	48
England	South West	4	4	4	14	14	14	15	16	25	26	26	27	28
England	West Midlands	0	0	0	0	0	0	0	0	0	0	0	0	0
England	Yorkshire and The Humber	0	0	0	0	0	1	1	2	1	2	3	3	7
Wales	Wales	12	14	15	46	51	56	60	71	92	102	107	112	132
Total	England and Wales	35	39	42	116	132	144	156	188	191	221	236	256	317

Grade 3

		2020s			2050s					2080s				
Nation	UKCP09 Region	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England	East Midlands	0	0	0	0	0	0	0	0	0	0	0	0	0
England	East of England	177	191	204	350	417	450	480	567	384	492	538	590	712
England	London	0	0	0	0	0	0	0	0	0	0	0	0	0
England	North East	23	25	27	82	87	94	100	116	158	171	177	184	215
England	North West	26	28	31	93	102	112	119	139	182	199	208	219	259
England	South East	64	69	74	185	229	253	272	324	355	406	432	463	555
England	South West	186	193	201	600	620	648	672	737	1105	1146	1166	1192	1271
England	West Midlands	0	0	0	0	0	0	0	0	0	0	0	0	0
England	Yorkshire and The Humber	164	177	188	426	556	591	629	733	753	857	909	972	1157
Wales	Wales	97	109	119	342	406	443	474	556	686	745	781	878	1002
Total	England and Wales	736	792	843	2078	2418	2591	2746	3172	3623	4015	4211	4498	5172

Grade 4

		2020s			2050s					2080s				
Nation	UKCP09 Region	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England	East Midlands	121	139	155	287	367	408	454	575	311	450	506	586	744
England	East of England	29	33	38	94	116	128	143	185	110	150	170	196	270
England	London	0	0	0	0	0	0	0	0	0	0	0	0	0
England	North East	3	3	3	10	10	11	11	13	17	19	19	20	23
England	North West	8	9	9	27	29	32	33	38	51	55	57	59	69
England	South East	16	18	19	45	58	65	70	84	83	97	104	112	137
England	South West	53	56	59	181	190	201	211	237	346	364	373	384	418
England	West Midlands	0	0	0	0	0	0	0	0	0	0	0	0	0
England	Yorkshire and The Humber	8	8	9	19	24	26	27	31	33	37	39	41	48
Wales	Wales	71	80	89	276	310	342	368	441	563	622	651	695	815
Total	England and Wales	307	346	381	940	1105	1213	1319	1604	1515	1793	1919	2093	2523

Grade 5

		2020s			2050s					2080s				
Nation	UKCP09 Region	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England	East Midlands	0	0	0	0	0	0	0	0	0	0	0	0	0
England	East of England	0	0	0	0	0	0	0	0	0	0	0	0	0
England	London	0	0	0	0	0	0	0	0	0	0	0	0	0
England	North East	0	0	0	0	1	1	1	1	1	1	1	1	2
England	North West	8	9	9	28	31	34	37	43	55	61	64	67	81
England	South East	14	15	16	39	48	53	57	67	78	89	95	102	121
England	South West	38	41	43	132	141	151	159	181	245	263	272	283	316
England	West Midlands	0	0	0	0	0	0	0	0	0	0	0	0	0
England	Yorkshire and The Humber	0	0	0	0	0	0	0	0	0	0	0	0	0
Wales	Wales	78	90	101	328	367	405	438	523	693	763	797	829	981
Total	England and Wales	138	155	170	527	587	644	691	815	1073	1177	1229	1283	1500

Overall total	1245	1361	1467	3739	4331	4687	5014	5905	6495	7320	7721	8269	9692

Risk Metric FL14b – Area of BAP habitat lost to coastal erosion (England)

The following table provides summary data on the area (in hectares) of BAP habitat that may be lost due to coastal erosion in England.

The table shows overall totals for the P50 Medium Emissions climate change scenario.

Data have not been calculated for socio economic scenarios, as these focus on growth in population and property numbers.

BAP habitat type	2020s	2050s	2080s
Coastal Floodplain and Grazing Marsh	7	36	66
Deciduous Woodland	24	115	239
Fen	2	6	7
Purple Moor Grass and Rush Pasture	1	2	3
Reedbed	2	11	21
Saline Lagoon	6	23	41
Total	41	193	377

The following tables provide more detailed data by Area and climate change scenario.

Coastal Floodplain and Grazing Marsh

		2020s			2050s					2080s				
Nation	UKCP09 Region	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England	East Midlands	0	0	0	0	0	0	0	0	0	0	0	0	0
England	East of England	4	4	5	16	20	23	27	38	16	25	31	38	58
England	London	0	0	0	0	0	0	0	0	0	0	0	0	0
England	North East	0	0	0	0	0	0	0	0	0	0	0	0	0
England	North West	0	0	0	0	0	0	0	0	0	1	1	1	2
England	South East	1	1	1	2	2	3	3	4	3	4	5	6	8
England	South West	2	2	2	8	9	10	11	14	25	28	30	32	38
England	West Midlands	0	0	0	0	0	0	0	0	0	0	0	0	0
England	Yorkshire and The Humber	0	0	0	0	0	0	0	0	0	0	0	0	0
Wales	Wales													
Total	England	6	7	8	26	32	36	41	57	45	58	66	76	106

Deciduous Woodland

		2020s			2050s					2080s				
Nation	UKCP09 Region	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England	East Midlands	0	0	0	0	0	0	0	0	0	0	0	0	0
England	East of England	2	2	3	7	8	9	10	12	7	11	12	14	19
England	London	0	0	0	0	0	0	0	0	0	0	0	0	0
England	North East	0	0	0	0	0	0	0	0	0	0	0	0	0
England	North West	0	0	0	2	3	4	4	6	7	9	9	10	14
England	South East	11	12	13	38	50	57	62	76	82	96	103	113	140
England	South West	8	9	9	37	40	44	47	55	98	106	110	115	130
England	West Midlands	0	0	0	0	0	0	0	0	0	0	0	0	0
England	Yorkshire and The Humber	1	1	1	2	2	2	2	3	4	4	5	5	6
Wales	Wales													
Total	England	22	24	26	87	103	115	125	152	198	225	239	256	309

Fen

		2020s			2050s					2080s				
Nation	UKCP09 Region	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England	East Midlands	0	0	0	0	0	0	0	0	0	0	0	0	0
England	East of England	1	1	1	3	4	4	4	5	3	4	4	5	6
England	London	0	0	0	0	0	0	0	0	0	0	0	0	0
England	North East	0	0	0	0	0	0	0	0	0	0	0	0	0
England	North West	0	0	0	0	0	0	0	0	0	0	1	1	1
England	South East	0	0	0	0	0	0	0	0	0	0	0	0	0
England	South West	0	0	1	1	1	1	2	2	2	3	3	3	3
England	West Midlands	0	0	0	0	0	0	0	0	0	0	0	0	0
England	Yorkshire and The Humber	0	0	0	0	0	0	0	0	0	0	0	0	0
Wales	Wales													
Total	England	2	2	2	5	5	6	6	7	6	7	7	8	10

Purple Moor Grass and Rush Pasture

		2020s			2050s					2080s				
Nation	UKCP09 Region	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England	East Midlands	0	0	0	0	0	0	0	0	0	0	0	0	0
England	East of England	0	0	0	1	1	1	1	1	1	1	1	1	1
England	London	0	0	0	0	0	0	0	0	0	0	0	0	0
England	North East	0	0	0	1	1	1	1	1	1	1	1	1	2
England	North West	0	0	0	0	0	0	0	0	0	0	0	0	0
England	South East	0	0	0	0	0	0	0	0	0	0	0	0	0
England	South West	0	0	0	0	0	0	0	0	0	0	0	0	0
England	West Midlands	0	0	0	0	0	0	0	0	0	0	0	0	0
England	Yorkshire and The Humber	0	0	0	0	0	0	0	0	0	0	0	0	0
Wales	Wales													
Total	England	1	1	1	2	2	2	2	2	2	2	3	3	3

Reedbed

		2020s			2050s					2080s				
Nation	UKCP09 Region	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England	East Midlands	0	0	0	0	0	0	0	0	0	0	0	0	0
England	East of England	0	0	0	2	3	5	6	9	4	8	10	12	19
England	London	0	0	0	0	0	0	0	0	0	0	0	0	0
England	North East	0	0	0	2	2	2	2	3	3	4	4	4	5
England	North West	0	0	0	0	0	0	0	0	0	0	0	0	0
England	South East	0	0	0	1	1	1	1	1	1	1	1	1	1
England	South West	1	1	1	4	4	4	4	5	7	7	7	7	8
England	West Midlands	0	0	0	0	0	0	0	0	0	0	0	0	0
England	Yorkshire and The Humber	0	0	0	0	0	0	0	0	0	0	0	0	0
Wales	Wales													
Total	England	2	2	2	8	10	11	13	17	14	19	21	24	33

Saline Lagoon

		2020s			2050s					2080s				
Nation	UKCP09 Region	Medium p10	Medium p50	Medium p90	Low p10	Low p50	Medium p50	High p50	High p90	Low p10	Low p50	Medium p50	High p50	High p90
England	East Midlands	0	0	0	0	0	0	0	0	0	0	0	0	0
England	East of England	2	2	2	5	8	11	16	28	6	15	22	30	51
England	London	0	0	0	0	0	0	0	0	0	0	0	0	0
England	North East	0	0	0	0	1	1	1	1	1	1	1	1	2
England	North West	0	0	0	0	0	0	0	0	0	0	0	0	0
England	South East	0	0	0	2	2	2	2	3	5	5	5	5	6
England	South West	0	0	0	0	0	0	0	0	1	1	1	1	1
England	West Midlands	0	0	0	0	0	0	0	0	0	0	0	0	0
England	Yorkshire and The Humber	3	3	3	6	8	9	9	10	10	11	12	12	14
Wales	Wales													
Total	England	5	6	6	14	19	23	28	43	22	33	41	50	74

Overall total	37	41	45	141	171	193	215	277	288	345	377	417	534

Appendix 9 Magnitude, confidence and presentation of results

The table below defines the magnitude classes used in the assessment. These were used for scoring impacts in the Tier 2 selection process as well as for scoring risk levels for the scorecards presented for each metric in Chapter 5. For the scorecard, the risk/opportunity level relates to the most relevant of the economic / environmental / social criteria.

Guidance on classification of relative magnitude: qualitative descriptions of high, medium and low classes

Class	Economic	Environmental	Social
High	• Major and recurrent damage to property and infrastructure • Major consequence on regional and national economy • Major cross-sector consequences • Major disruption or loss of national or international transport links • Major loss/gain of employment opportunities *~ £100 million for a single event or per year*	• Major loss or decline in long-term quality of valued species/habitat/landscape • Major or long-term decline in status/condition of sites of international/national significance • Widespread Failure of ecosystem function or services • Widespread decline in land/water/air quality • Major cross-sector consequences *~ 5000 ha lost/gained* *~ 10000 km river water quality affected*	• Potential for many fatalities or serious harm • Loss or major disruption to utilities (water/gas/electricity) • Major consequences on vulnerable groups • Increase in national health burden • Large reduction in community services • Major damage or loss of cultural assets/high symbolic value • Major role for emergency services • Major impacts on personal security e.g. increased crime *~million affected* *~1000's harmed* *~100 fatalities*
Medium	• Widespread damage to property and infrastructure • Influence on regional economy • Consequences on operations & service provision initiating contingency plans • Minor disruption of national transport links • Moderate cross-sector consequences • Moderate loss/gain of employment opportunities *~ £10 million per event or year*	• Important/medium-term consequences on species/habitat/landscape • Medium-term or moderate loss of quality/status of sites of national importance • Regional decline in land/water/air quality • Medium-term or Regional loss/decline in ecosystem services • Moderate cross-sector consequences *~ 500 ha lost/gained* *~ 1000 km river water quality affected*	• Significant numbers affected • Minor disruption to utilities (water/gas/electricity) • Increased inequality, e.g. through rising costs of service provision • Consequence on health burden • Moderate reduction in community services • Moderate increased role for emergency services • Minor impacts on personal security *~tens of thousands affected, ~100s harmed, ~10 fatalities*
Low	• Minor or very local consequences • No consequence on national or regional economy • Localised disruption of transport *~ £1 million per event or year*	• Short-term/reversible effects on species/habitat/landscape or ecosystem services • Localised decline in land/water/air quality • Short-term loss/minor decline in quality/status of designated sites *~ 50 ha of valued habitats damaged/improved* *~ 100 km river quality affected*	• Small numbers affected • Small reduction in community services • Within 'coping range' *~1000's affected*

The levels of confidence used by the CCRA can be broadly summarised as follows:

Low - Expert view based on limited information, e.g. anecdotal evidence.

Medium - Estimation of potential impacts or consequences, grounded in theory, using accepted methods and with some agreement across the sector.

High - Reliable analysis and methods, with a strong theoretical basis, subject to peer review and accepted within a sector as 'fit for purpose'.

The lower, central and upper estimates provided in the scorecards relate to the range of the estimated risk or opportunity level. For risk metrics that have been quantified with UKCP09 and response functions, this range relates to the results that are given for the low emissions, 10% probability level (lower); medium emissions, 50% probability level (central); and high emissions, 90% probability level (upper). For the risk metrics that have been estimated with a more qualitative approach, these estimates cover the range of potential outcomes given the evidence provided.

The CCRA analysis uses three discrete time periods to estimate future risks up to the year 2100: the 2020s (2010 to 2039), 2050s (2040 to 2069) and the 2080s (2070 to 2099).This is consistent with the UKCP09 projections.

Appendix 10 Summary of results by area

Variations in the results by country and region (Wales and English Areas) are summarised in the following figures:

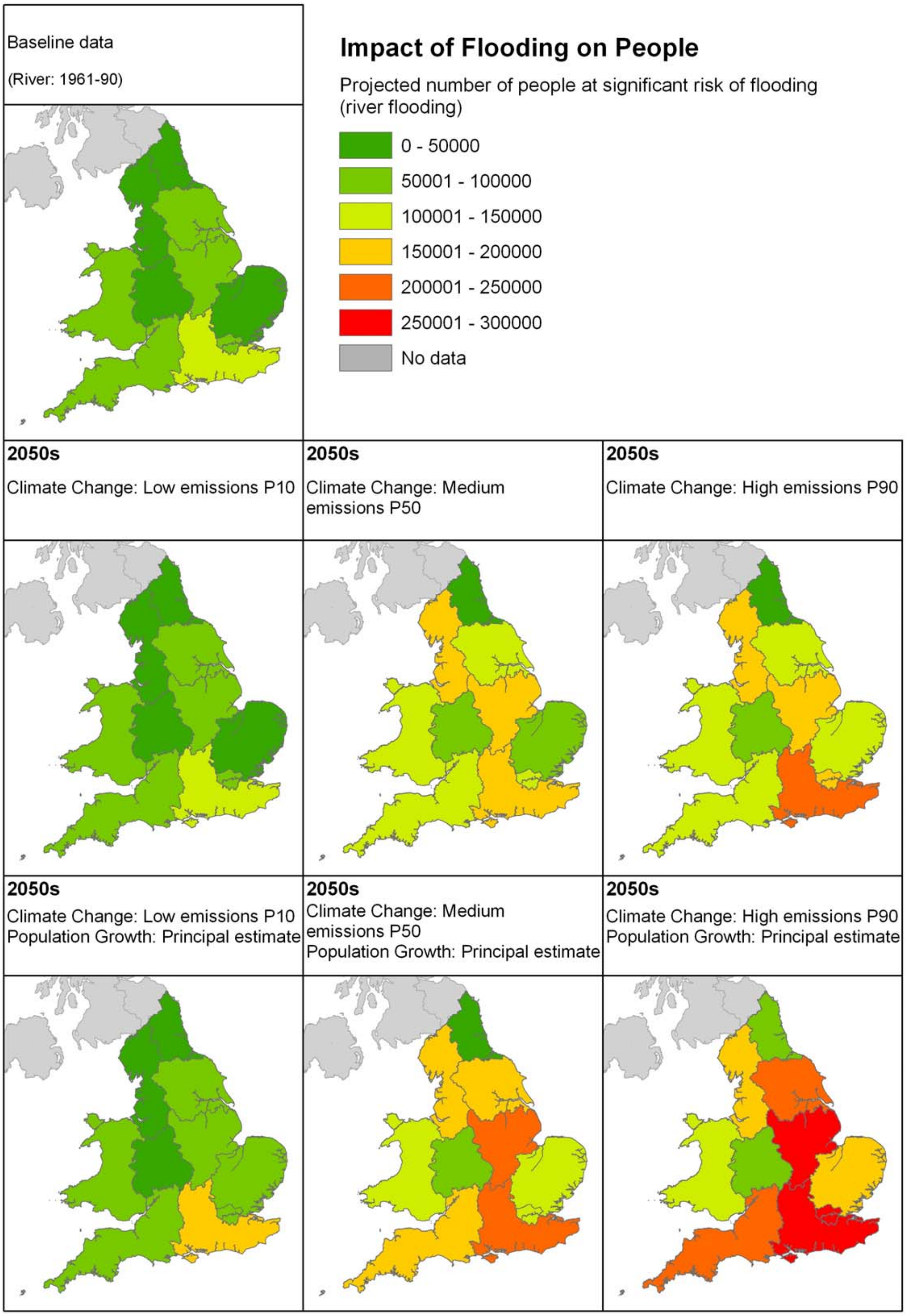
- Impact of flooding on people
  Projected number of people at significant likelihood of flooding (river flooding)
- Impact of flooding on people
  Projected number of people at significant likelihood of flooding (tidal flooding)
- Impact of flooding on vulnerable people
  Projected number of properties in the highest 20% of deprived areas at significant likelihood of flooding (river and tidal flooding)
- Impact of flooding on residential property
  Projected number of residential properties at significant likelihood of flooding (river and tidal flooding)
- Impact of flooding on residential property
  EAD (£ millions) of residential properties at significant likelihood of flooding (river and tidal flooding)
- Impact of flooding on non-residential property
  Projected number of non-residential properties at significant likelihood of flooding (river and tidal flooding)
- Impact of flooding on non-residential property
  EAD (£ millions) of non-residential properties at significant likelihood of flooding (river and tidal flooding)
- Impact of flooding on property
  Projected number of properties at significant likelihood of flooding (river and tidal flooding)
- Impact of flooding on energy infrastructure
  Projected number of power stations and major substations at significant likelihood of flooding (river and tidal flooding)
- Impact of flooding on transport infrastructure
  Projected length of roads and railways (km) at significant likelihood of flooding (river and tidal flooding)

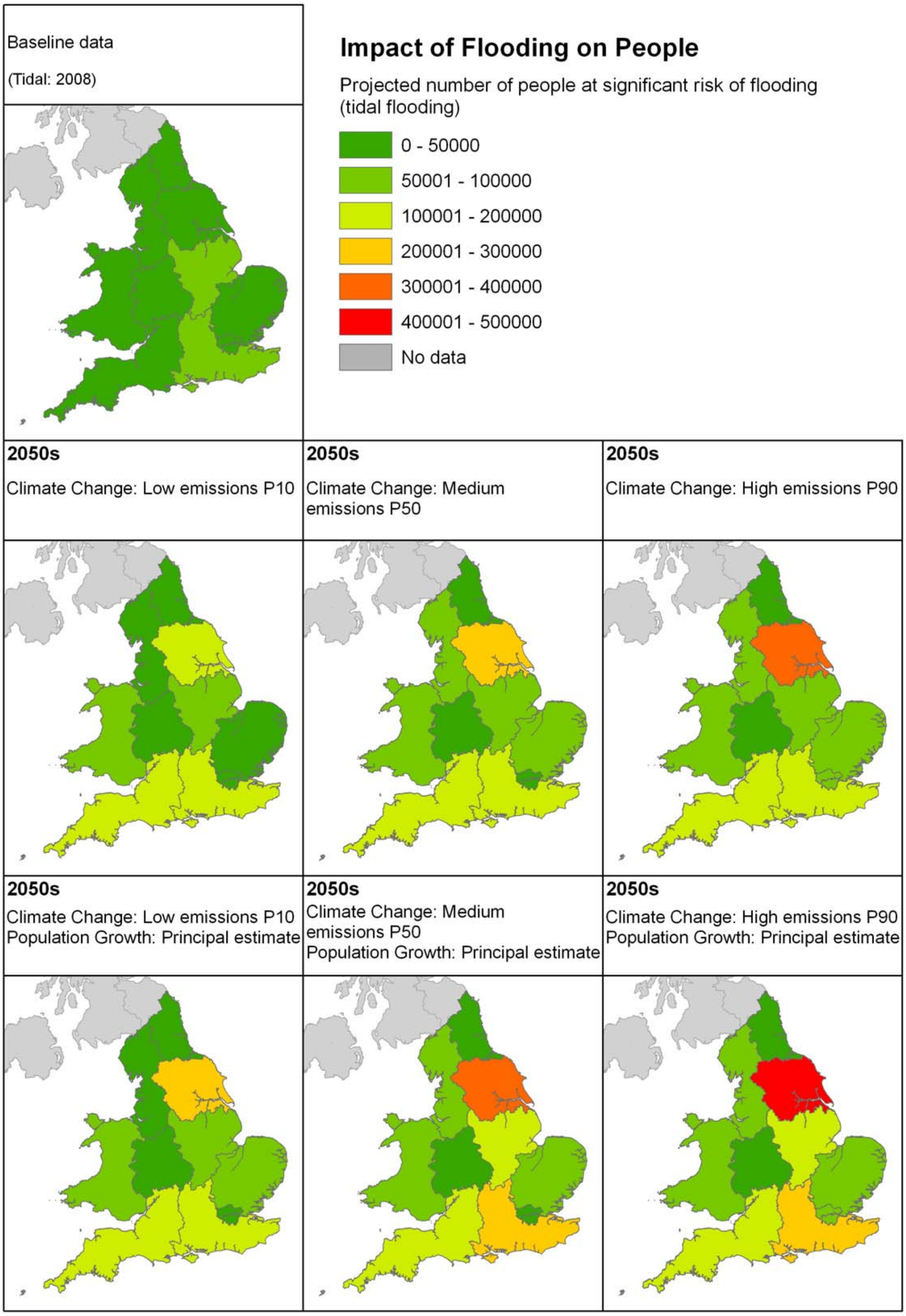
These results provide an indication of the variation across countries and regions, although the modelling is intended for national assessments. The baseline data are 1961-90 for river flooding and 2008 for tidal flooding.

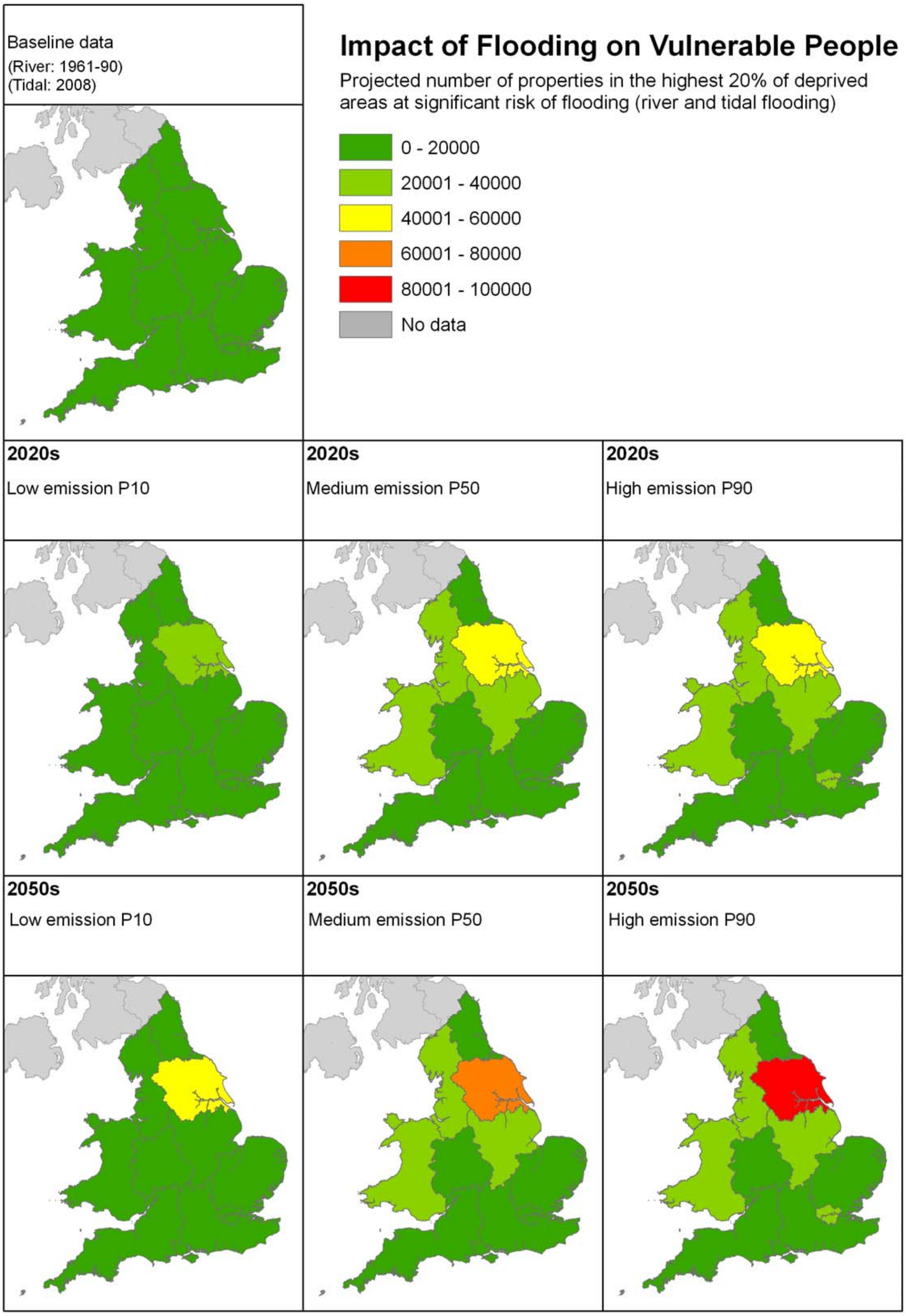
The estimates are based on the following scenarios:

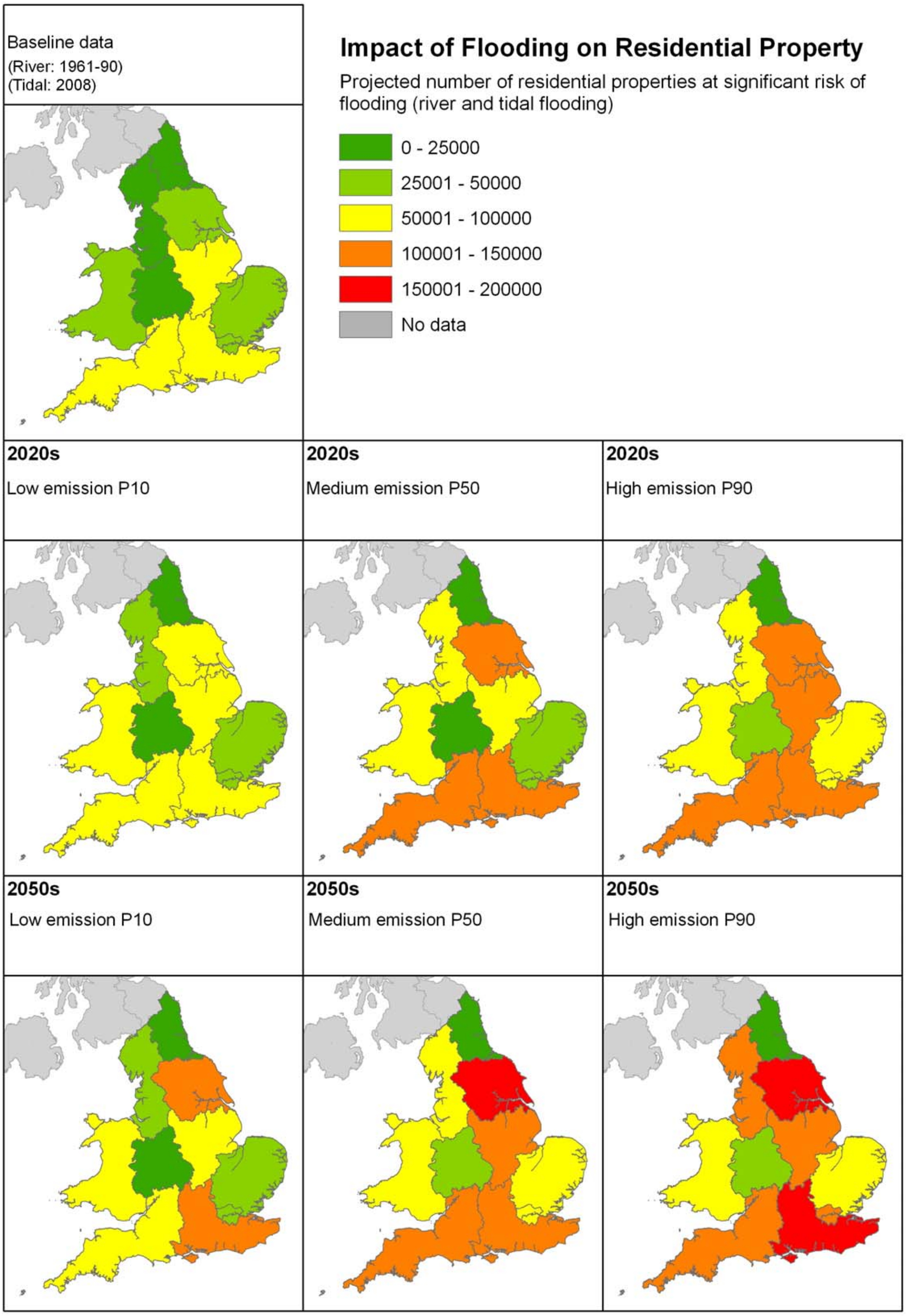
Estimate	**Climate change scenario**	**Population projection**
2020s Low	P10 Medium Emissions	Low growth
2020s Central	P50 Medium Emissions	Principal growth
2020s High	P90 Medium Emissions	High growth
2050s Low	P10 Low Emissions	Low growth
2050s Central	P50 Medium Emissions	Principal growth
2050s High	P90 High Emissions	High growth

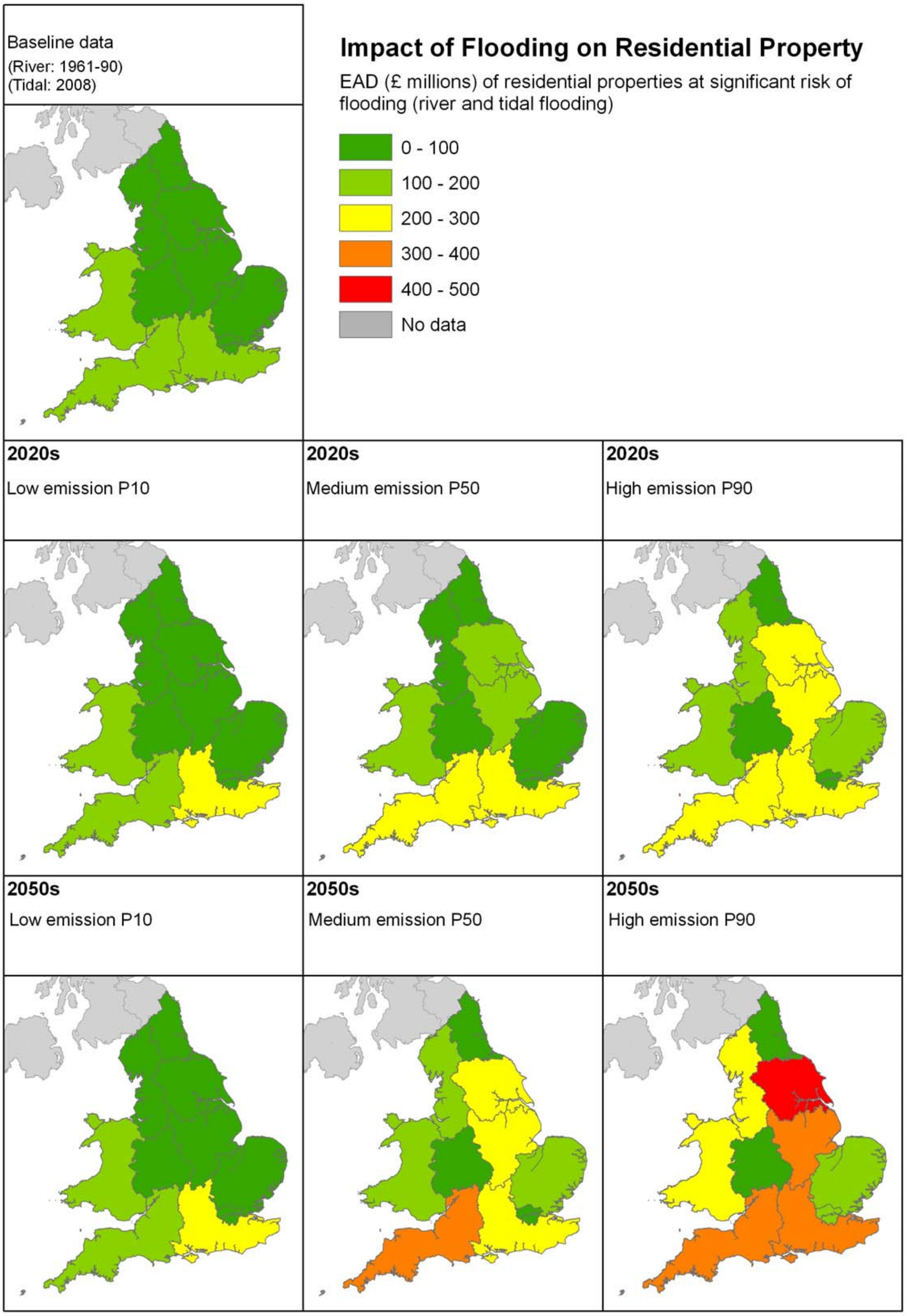
Wales and the English Areas

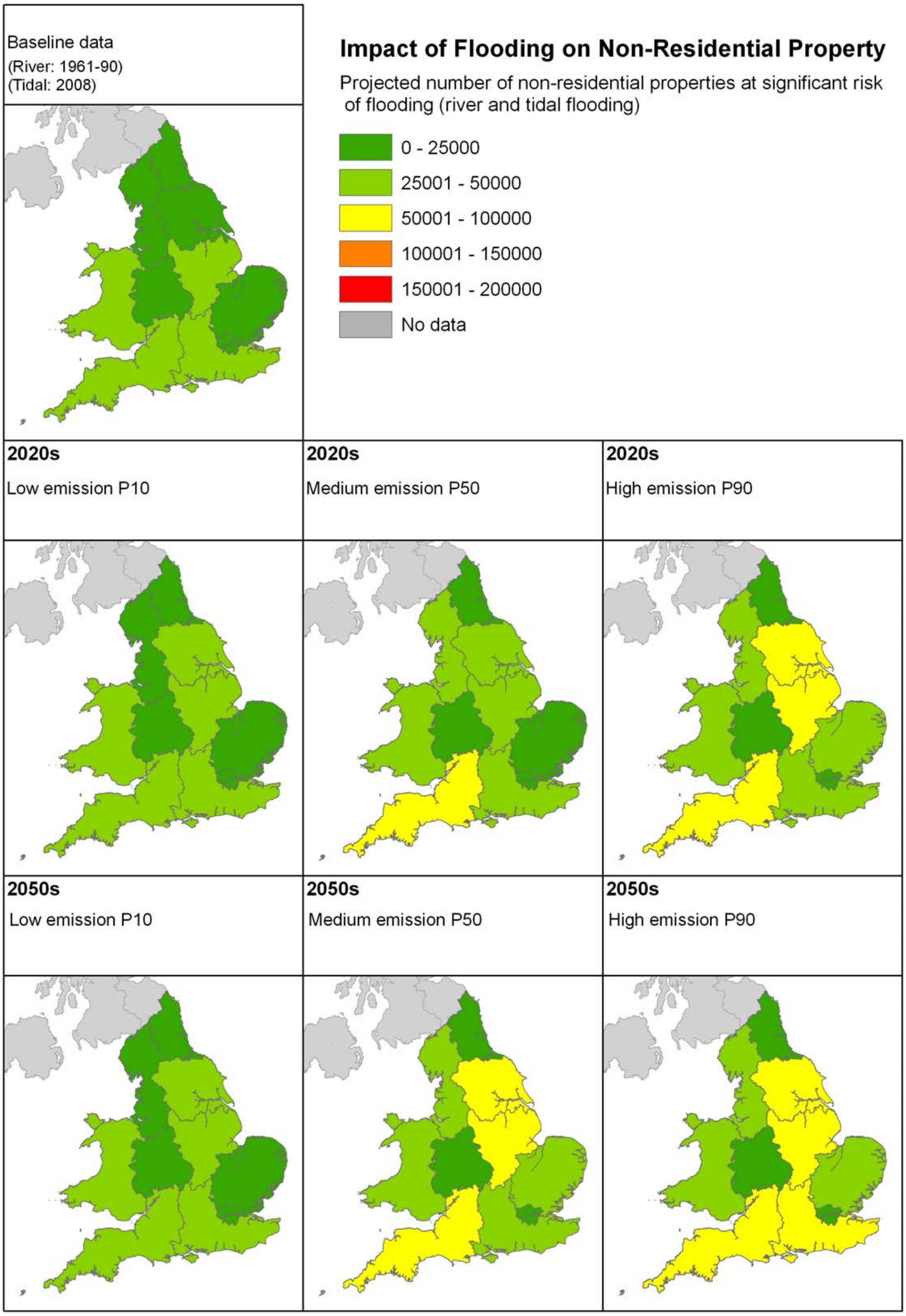

Baseline data
(River: 1961-90)
Impact of Flooding on People
Projected number of people at significant risk of flooding (river flooding)
0 - 50000
50001 - 100000
100001 - 150000
150001 - 200000
200001 - 250000
250001 - 300000
No data
2050s
Climate Change: Low emissions P10
2050s
Climate Change: Medium emissions P50
2050s
Climate Change: High emissions P90
2050s
Climate Change: Low emissions P10
Population Growth: Principal estimate
2050s
Climate Change: Medium emissions P50
Population Growth: Principal estimate
2050s
Climate Change: High emissions P90
Population Growth: Principal estimate

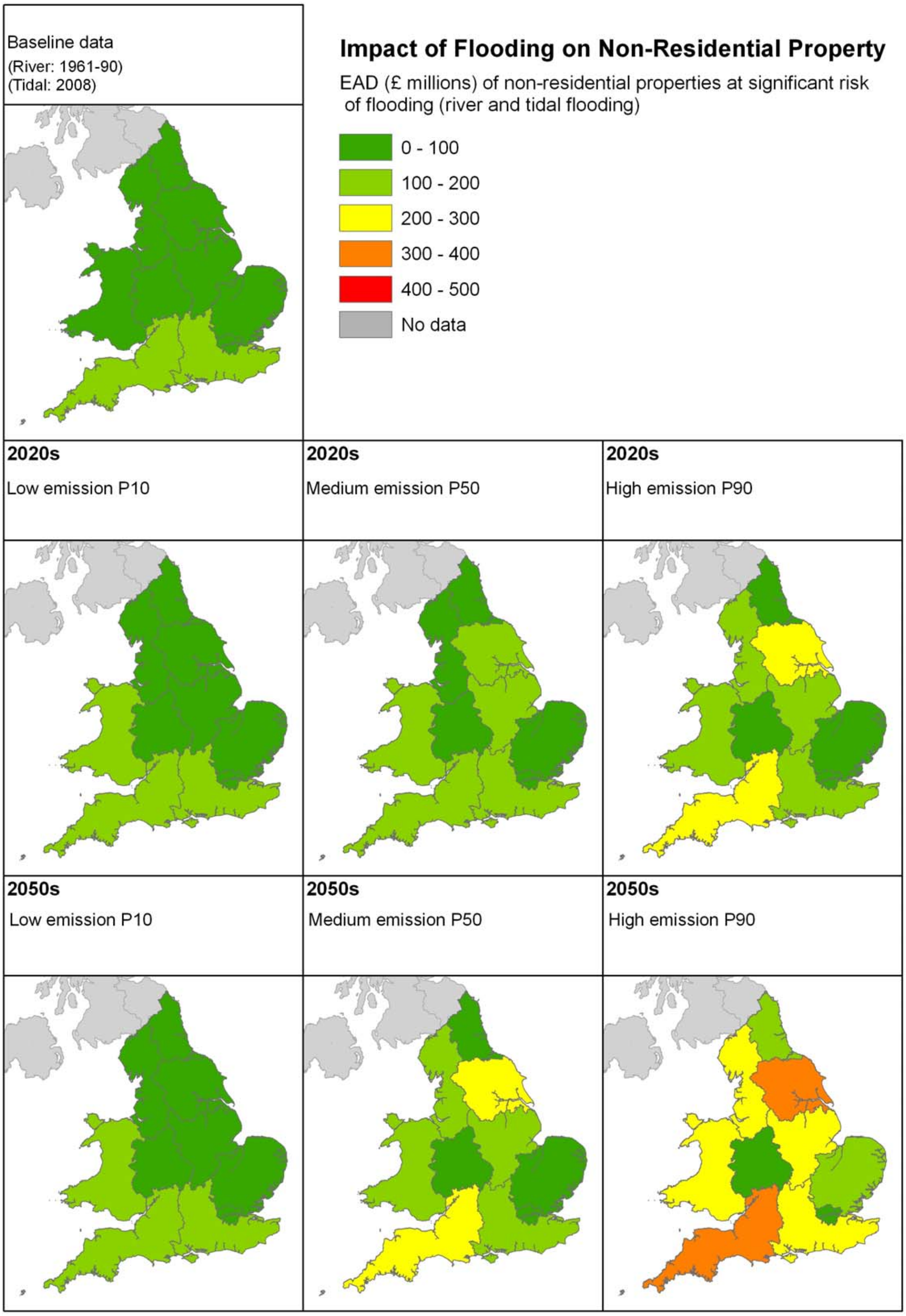

Baseline data
(Tidal: 2008)
Impact of Flooding on People
Projected number of people at significant risk of flooding (tidal flooding)
0 - 50000
50001 - 100000
100001 - 200000
200001 - 300000
300001 - 400000
400001 - 500000
No data
2050s
Climate Change: Low emissions P10
2050s
Climate Change: Medium emissions P50
2050s
Climate Change: High emissions P90
2050s
Climate Change: Low emissions P10
Population Growth: Principal estimate
2050s
Climate Change: Medium emissions P50
Population Growth: Principal estimate
2050s
Climate Change: High emissions P90
Population Growth: Principal estimate

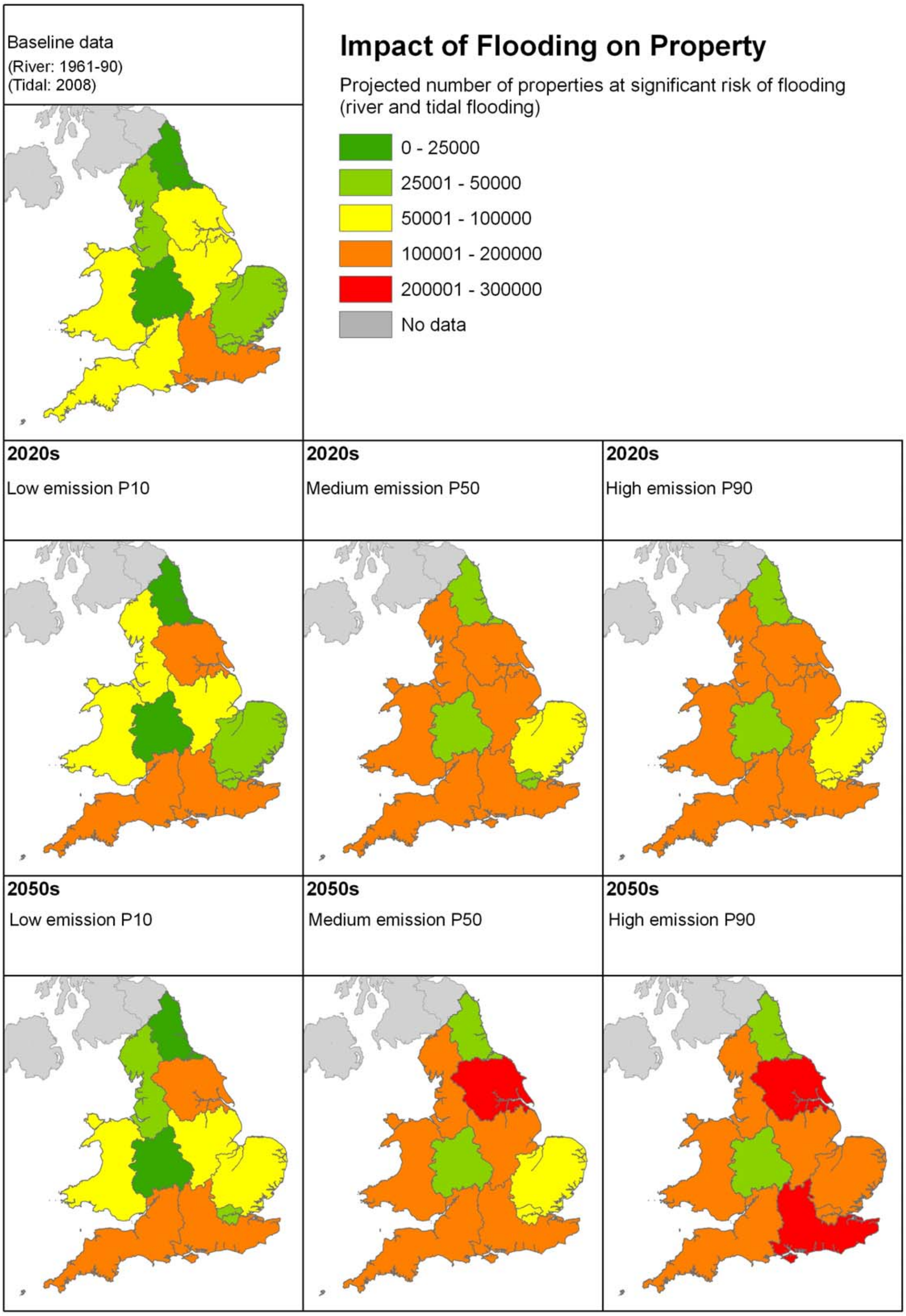

Baseline data
(River: 1961-90)
(Tidal: 2008)
Impact of Flooding on Vulnerable People
Projected number of properties in the highest 20% of deprived areas at significant risk of flooding (river and tidal flooding)
0 - 20000
20001 - 40000
40001 - 60000
60001 - 80000
80001 - 100000
No data
2020s
Low emission P10
2020s
Medium emission P50
2020s
High emission P90
2050s
Low emission P10
2050s
Medium emission P50
2050s
High emission P90

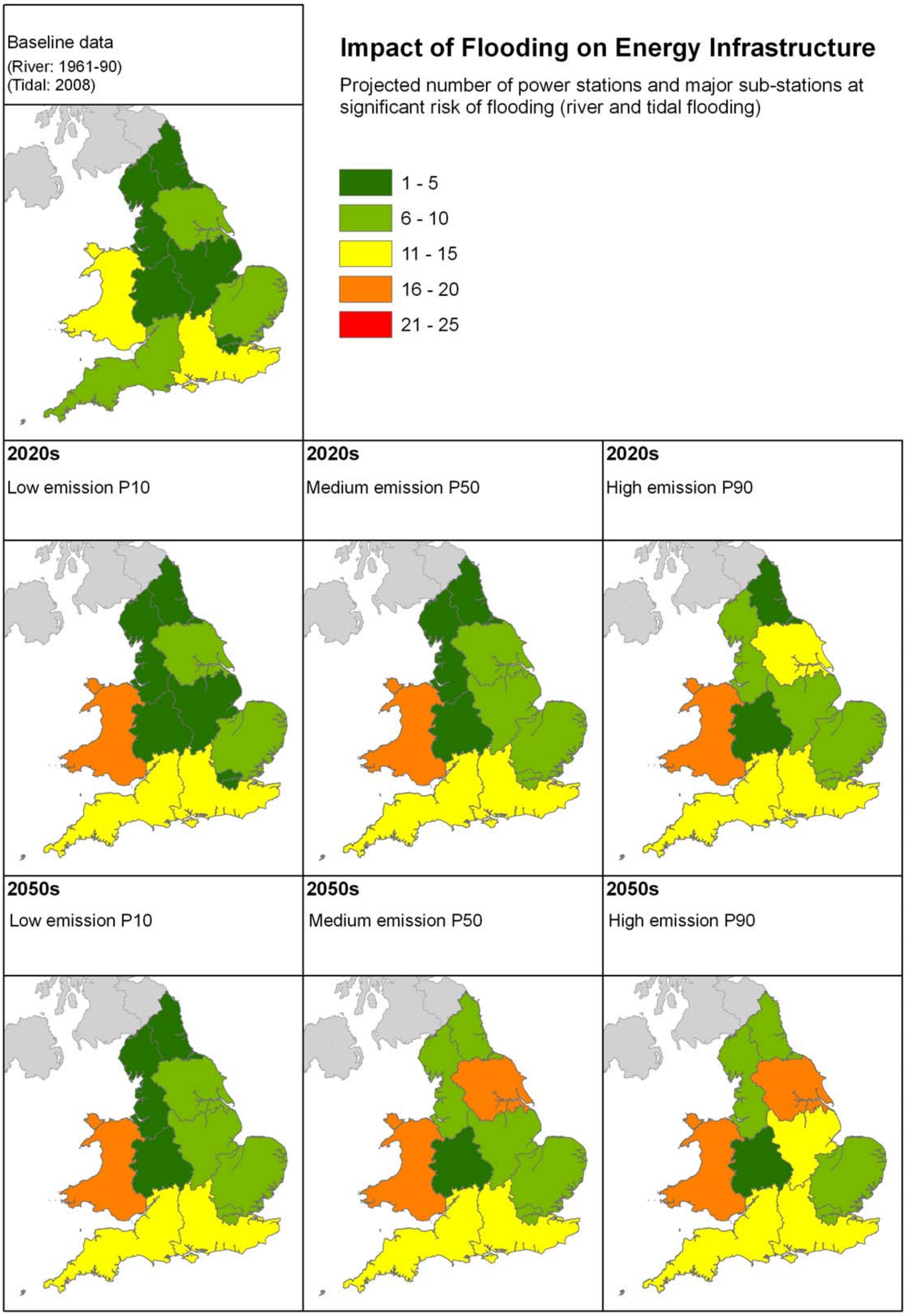

Impact of Flooding on Residential Property
Projected number of residential properties at significant risk of flooding (river and tidal flooding)
0 - 25000
25001 - 50000
50001 - 100000
100001 - 150000
150001 - 200000
No data
Baseline data
(River: 1961-90)
(Tidal: 2008)
2020s
Low emission P10
2020s
Medium emission P50
2020s
High emission P90
2050s
Low emission P10
2050s
Medium emission P50
2050s
High emission P90

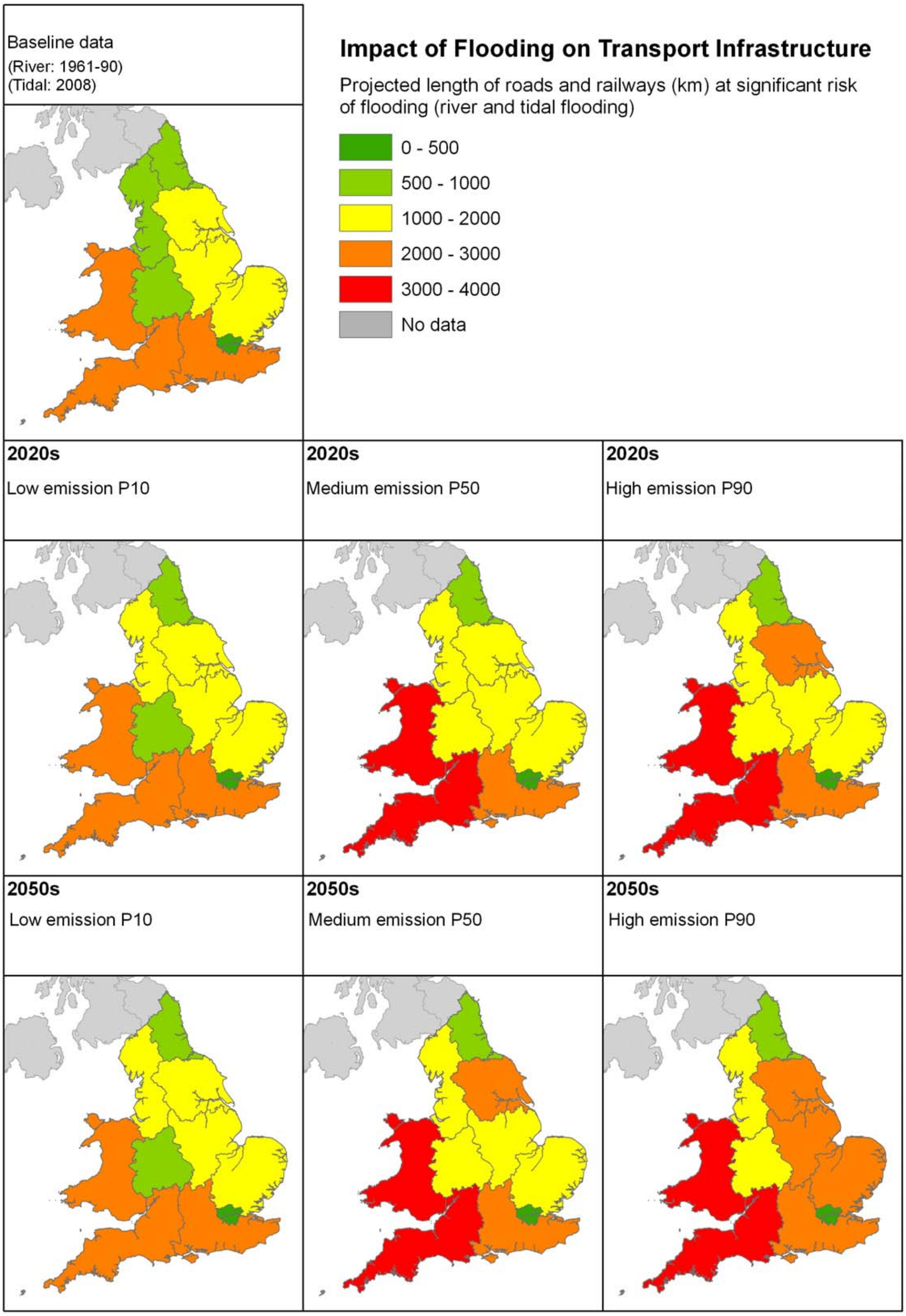

Impact of Flooding on Residential Property
EAD (£ millions) of residential properties at significant risk of flooding (river and tidal flooding)
0 - 100
100 - 200
200 - 300
300 - 400
400 - 500
No data
Baseline data
(River: 1961-90)
(Tidal: 2008)
2020s
Low emission P10
2020s
Medium emission P50
2020s
High emission P90
2050s
Low emission P10
2050s
Medium emission P50
2050s
High emission P90


Impact of Flooding on Non-Residential Property
Projected number of non-residential properties at significant risk of flooding (river and tidal flooding)
0 - 25000
25001 - 50000
50001 - 100000
100001 - 150000
150001 - 200000
No data
Baseline data
(River: 1961-90)
(Tidal: 2008)
2020s
Low emission P10
2020s
Medium emission P50
2020s
High emission P90
2050s
Low emission P10
2050s
Medium emission P50
2050s
High emission P90


Baseline data
(River: 1961-90)
(Tidal: 2008)
Impact of Flooding on Non-Residential Property
EAD (£ millions) of non-residential properties at significant risk of flooding (river and tidal flooding)
0 - 100
100 - 200
200 - 300
300 - 400
400 - 500
No data
2020s
Low emission P10
2020s
Medium emission P50
2020s
High emission P90
2050s
Low emission P10
2050s
Medium emission P50
2050s
High emission P90


Impact of Flooding on Property
Projected number of properties at significant risk of flooding
(river and tidal flooding)
0 - 25000
25001 - 50000
50001 - 100000
100001 - 200000
200001 - 300000
No data
Baseline data
(River: 1961-90)
(Tidal: 2008)
2020s
Low emission P10
2020s
Medium emission P50
2020s
High emission P90
2050s
Low emission P10
2050s
Medium emission P50
2050s
High emission P90


Baseline data
(River: 1961-90)
(Tidal: 2008)
Impact of Flooding on Energy Infrastructure
Projected number of power stations and major sub-stations at significant risk of flooding (river and tidal flooding)
1 - 5
6 - 10
11 - 15
16 - 20
21 - 25
2020s
Low emission P10
2020s
Medium emission P50
2020s
High emission P90
2050s
Low emission P10
2050s
Medium emission P50
2050s
High emission P90


Baseline data
(River: 1961-90)
(Tidal: 2008)
Impact of Flooding on Transport Infrastructure
Projected length of roads and railways (km) at significant risk of flooding (river and tidal flooding)
0 - 500
500 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
No data
2020s
Low emission P10
2020s
Medium emission P50
2020s
High emission P90
2050s
Low emission P10
2050s
Medium emission P50
2050s
High emission P90