Warming up the region
The impacts of climate change in the Yorkshire and Humber region

WS Atkins, Stockholm Environment Institute-York (SEI-Y), The Met Office
Warming up the region

The impacts of climate change in the Yorkshire and Humber region

WS Atkins, Stockholm Environment Institute, The Met Office

WS Atkins report: AK2970.068.dg.013

Project Steering Group : Yorkshire Forward, Yorkshire and Humber Assembly, GOYH, Environment Agency, Hull City Council, Business in the Community, AEP, UK Climate Impacts Programme (UKCIP)

Information about the UK Climate Impacts Programme can be found on their web site http://www.ukcip.org.uk  Email: enquiries@ukcip.org.uk

This report should be referenced as: WS Atkins, 2002. Warming up the region: The impacts of climate change in the Yorkshire and Humber Region. WS Atkins report no: AK2970.068.dg.013, Epsom. pp. 109.
| JOB NUMBER: AK2970 | DOCUMENT REF: AK2970/68/dg/013 |

<table>
<thead>
<tr>
<th>Rev 1</th>
<th>For Client Comment</th>
<th>G Darch S Wade</th>
<th>James Massey</th>
<th>Katherine Pygott</th>
<th>Steven Wade</th>
<th>30/5/02</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rev 2</td>
<td>(inc. client comments on Rev. 1)</td>
<td>G Darch S Wade</td>
<td>James Massey</td>
<td>Katherine Pygott</td>
<td>Steven Wade</td>
<td>14/6/02</td>
</tr>
</tbody>
</table>

| Originated | Checked | Reviewed | Authorised | Date |

| Revision | Purpose Description |
EXECUTIVE SUMMARY

The recent Intergovernmental Panel on Climate Change’s Third Assessment Report stated that “There is now stronger evidence that most of the warming observed over the last 50 years is attributable to human activities.” It is clear that we need to adapt to climate changes now and anticipate future impacts for this generation and future generations. This study focuses on impacts rather than mitigation which is the subject of a separate scoping study (Yorkshire Forward, forthcoming). It is a first step and may lead to further industry or community led studies of specific impacts and adaptation requirements.

This report is part of a series of sub-UK scoping studies completed with the support of the UK Climate Impacts Programme. This study aims to identify the main impacts of climate change, stakeholder perceptions and responses and gaps and uncertainties in our understanding of climate impacts. It covers the Yorkshire and Humber Region that includes the cities of Sheffield, Leeds, Hull, Bradford and York; the towns of Huddersfield, Wakefield and Grimsby and Scarborough; the Yorkshire Dales and North York Moors National Parks and the Humber Estuary. Collectively, the Regional Development Agency, local authorities and their partners recognise that climate change is an important consideration for future development:

“Climate change is another major challenge facing the region. The consequences seem to be beginning to manifest themselves through more frequent extreme weather events, sea level rise and increasing average temperatures. The region needs to plan for these consequences”


In order to provide a framework for dealing with this uncertainty the UK Climate Impacts Programme (UKCIP) has recently provided a new set of future climate scenarios\(^1\) that describe the rates of warming in response to different levels of emissions, namely Low Emissions, Medium-Low Emissions, Medium-High Emissions and High Emissions. These scenarios update and improve upon an earlier set of UKCIP scenarios released in 1998.

The new climate scenarios suggest that the region will be between 1 and 2.3 °C warmer by the 2050s and between 1.6 to 3.9 °C warmer by the 2080s. This warming will occur throughout the year with the greatest rises in the summer months of up to 2.9 °C in the Humber Estuary by the 2050s under the High Emissions scenario. This warming will be accompanied by wetter winters and drier summers. In a major departure from the findings of the 1998 scenarios, the 2002 scenarios suggest that summers will be drier throughout the region and, along with drier springs and autumns, will lead to a reduction in average annual rainfall of between 10 and 20%.

The climate will change significantly by the 2050s and dramatically by the 2080s. The major changes by the 2080s include:-

- Increases in sea level of between 6 and 82 cm, with the greatest rates of rise in the Humber Estuary under the **High Emissions** scenario. The scenarios for the Humber are centred on an average rate of 6 mm per year that is currently used for planning purposes.
- An increase in high rainfall intensities during the winter across the region, causing urban flooding problems in Bradford and other cities.
- Increases in the number of very hot days throughout the region with the greatest impact in large cities such as Leeds away from the coast.
- An increase in the length of the growing season by between 45 and 100 days along the Yorkshire and Lincolnshire coasts.

---

\(^1\) UKCIP02 scenarios released 26th April 2002.

© Crown Copyright 2002. The UKCIP02 climate scenario data have been made available by the Department for Environment, Food and Rural Affairs (DEFRA). DEFRA accepts no responsibility for any inaccuracies or omissions in the data nor for any loss or damage directly of indirectly caused to any person or body by reason of, or arising out of any use of, this data.
While changing average conditions will affect many human activities and natural processes, the main impacts of climate change are likely to be related to changing extreme events. The most notable changes for the 2080s Medium-High Emissions scenario include:-

- A fourfold increase in the frequency of “wet” winters with 60% more rainfall than average (1961-1990)
- A fourfold increase in the frequency of a “dry” summer with 50% less rainfall than average (1961-1990)
- A hot “1995” type summer nearly every year rather than once in hundred years based on the 1961 to 1990 climate

Changes in future climate will interact with future social and economic changes and other factors to shape the Yorkshire and Humber region over the next 50 years. This study has evaluated the potential impacts of climate change on changing flood risks, water resources, agriculture, forestry, the service sector, industry and commerce and transport. The analysis was based on literature review, consultations with over 100 stakeholders and expert opinion.

The study found that there is likely to be a range of positive and negative impacts on the region, for example:-

- Increases in flood frequency and adaptation in terms of the operation of flood defences and the development of washlands and other systems to manage runoff at source on a catchment scale.
- Adaptation in many sectors depends upon an adequate and reliable source of water. The potential for additional water storage within the region requires serious consideration.
- There will be a need for new management strategies of coastal defences under the changed climate conditions.
- Management procedures for the protection of landscape features and habitats will need to be adapted to changed climate conditions. The upland moorland of the North York Moors and Pennine areas are particularly vulnerable.
- The Humber estuary stands out as an area of high importance and high vulnerability to climate change. Flooding will affect internationally important wetlands, high quality agricultural land, ports and other industries in the flood plain and leisure facilities.
- A changing climate will present opportunities within the agricultural sector for both new crops and technical developments. It will also present a challenge to specific existing crop production systems.
- Increased tourist pressure under a changing climate will require the upgrading of existing leisure facilities and provision of new ones. There will be opportunities for new forms of coastal tourism and recreation.
- Industry will be challenged to develop new ranges of products under conditions of less intensive energy use. There are also opportunities to develop new technologies to support climate change adaptation.
- Significant threats to road and rail as a consequence of extreme weather conditions have been identified and a programme of "climate change proofing" is required. In addition, the transport sector can deliver GHG reductions but has not been tasked to do so.
- There is a low level of awareness in the region about the implications of climate change and its impacts on economic activities. This is a threat to the region's economic performance and suggests that a sustained programme of information delivery, awareness raising and discussion is required supported by target setting and resources to do this work.

In order to adapt to climate change, these potential impacts need to be considered within the mainstream framework for sustainable development. Climate change adaptation reinforces actions for sustainable development. In addition further work is required in climate change adaptation within the region including:

- **Consensus building.** Increasing awareness of climate change impacts and encouraging smaller businesses to consider energy efficiency, water efficiency, climate risks and climate opportunities.
- **Managing extremes.** Lessons learned from the 1995 drought and Autumn 2000 floods need to be incorporated into contingency plans for future more frequent flood and drought conditions.
- **Risk based decision making.** Decision makers need to be informed about risks and advised on how to take account of changing conditions. Professional regional bodies and trade organisations have an important role to play in developing simple guidelines on how to take account of future risks.
- **Spatial planning.** Planners are in a unique position to support climate change adaptation. Flood risks, the potential for new crops, changing health and transport patterns can all be mapped to develop scenarios of the future with and without planning inputs. Improved mapping of the potential impacts is needed to incorporate climate change in regional plans.

Dealing with climate change in the Yorkshire and Humber region presents all stakeholders with opportunities. The competitive position of UK regions in a wider European context will be determined by their success (or otherwise) of strategies to deal with climate change. This is an opportunity for the Yorkshire and Humber region to perform well and improve its competitive position.
# CONTENTS

1 Introduction ...................................................................................................................... 1  
1.1 Aims and objectives of the Yorkshire and Humber Study ........................................ 1  
1.2 Context .......................................................................................................................... 1  
1.3 Using this report .......................................................................................................... 2  
2 Methodology .................................................................................................................... 3  
3 Climate Change ................................................................................................................ 5  
3.1 Introduction .................................................................................................................. 5  
3.2 The IPCC Third Assessment Report ........................................................................... 8  
3.3 Climate Change in the UK ............................................................................................ 8  
3.4 The UKCIP 1998 scenarios .......................................................................................... 8  
3.5 The UKCIP 2002 scenarios .......................................................................................... 9  
4 Climate change in the Yorkshire and Humber Region ...................................................... 13  
4.1 Introduction .................................................................................................................. 13  
4.2 Context ........................................................................................................................ 13  
4.3 Rising Temperatures .................................................................................................... 13  
4.4 Changing rainfall patterns ........................................................................................... 16  
4.5 Temperature and Rainfall Anomalies ......................................................................... 19  
4.6 Changing Wind Speeds ............................................................................................... 19  
4.7 Other Climate Variables .............................................................................................. 20  
4.8 Derived Climate Variables .......................................................................................... 20  
4.9 Future Changes in the Context of Historical Data ....................................................... 21  
4.10 Sea Level Rise ............................................................................................................. 24  
5 The impacts of climate change in the Yorkshire and Humber region ........................... 25  
5.1 The Coastal Zone ....................................................................................................... 25  
5.2 Drainage, rivers and floodplains ............................................................................... 31  
5.3 Water Resources ....................................................................................................... 37  
5.4 Agriculture and Forestry ............................................................................................ 42  
5.5 Semi-Natural Habitats and Biodiversity ..................................................................... 47  
5.6 Industry and Commerce ............................................................................................ 54  
5.7 Services ........................................................................................................................ 57  
5.8 Transport ...................................................................................................................... 62  
6 Analysis of impacts between sectors and case studies ...................................................... 68  
6.1 Food and drink cluster: a case study of the reaction to climate change ...................... 73  
7 Conclusions .................................................................................................................... 79  
References .......................................................................................................................... 82  
Appendices .......................................................................................................................... 89
FIGURES

Figure 2-1 Outline of the approach used in the scoping study ................................................................. 3
Figure 2-2 Pie Chart of Sectors involved in the Consultation ................................................................. 9
Figure 3-1 Changes in Global Temperature (relative to the 1961-1990 mean) ........................................ 6
Figure 3-2 Example UKCIP02 output showing 50km grid over England and Wales ................................. 12
Figure 4-1 Changes in annual mean temperature in the Yorkshire and Humber region .................... 15
Figure 4-2 Changes in annual mean winter rainfall in the Yorkshire and Humber region ................. 17
Figure 4-3 Daily Rainfall Distribution near Leeds in Winter for the Present Climate and the 2080s .... 18
Figure 4-4 Daily Rainfall Distribution near Leeds in Summer for the Present Climate and the 2080s .... 18
Figure 4-5 Mean Winter (Dec-Feb) Temperature at Sheffield (1883-2001) with Estimates for the 2020s, 2050s and 2080s ................................................................. 21
Figure 4-6 Mean Summer (June-August) Temperature at Sheffield (1883-2001) with Estimates for the 2020s, 2050s and 2080s ................................................................. 22
Figure 4-7 Winter Rainfall at Hull (1872-2001) with Mean 30-Year Estimates for the 2020s, 2050s and 2080s ................................................................. 23
Figure 4-8 Summer Rainfall at Hull (1871-2001) with Mean 30-Year Estimates for the 2020s, 2050s and 2080s ................................................................. 23
Figure 4-9 Annual Mean Water Level at Blacktoft, Immingham and Spurn ........................................ 24
Figure 5-1 A flood barrier on the Aire, breached during the Autumn 2000 floods ................................. 34
Figure 5-2 Permeable pavement, gravel drains and tree catch pits designed to slow rates of urban runoff and improve water quality ........................................... 36
Figure 5-3 Top tourist attractions and number of visitors in the Yorkshire and Humber region (1997) 57
Figure 6-1 Climate change on the Foods and Drinks cluster ................................................................. 78
Figure D-0-1 Workshop Analysis ........................................................................................................... 94
TABLES

Table 3-1 Estimates of confidence for selected observed and projected changes in extreme weather and climate events ................................................................. 10
Table 4-1 30-Year Mean Annual, Winter and Summer Temperature Increase (°C), relative to 1961-1990 .......... 14
Table 4-2 Changes in the Frequency of High and Low Temperatures at Sheffield and Bradford................. 14
Table 4-3 30-Year Mean Percent Change in Mean Annual, Winter and Summer Rainfall, relative to 1961-1990 ..... 16
Table 4-4 Changes in the Frequency of Monthly, Seasonal and Annual Temperature and Rainfall Anomalies..... 19
Table 5-1 Designated Areas of the Regional Coastal Zone.................................................................................. 26
Table 5-2 Cliff Erosion Rates............................................................................................................................ 27
Table 5-3 Example calculation of future extreme levels for Immingham......................................................... 28
Table 5-4 Environment Agency Water Resource Recommendations and Alternative Actions for the north east .... 39
Table 5-5 GDP (1997) and forecasted GDP (1997-2005) in the Yorkshire and Humber Region ..................... 54
Table 5-6 Employment Profile, and Forecasts, of the Region ........................................................................ 54
Table 6-1 The Effect of Climate Change on the Fifteen Aims for Sustainable Development in Yorkshire and Humberside ................................................................. 69
Table D-0-1 Workshop Summary..................................................................................................................... 92
1 Introduction

This report describes the potential impacts of climate change on the Yorkshire and Humber Region. A shorter summary report provides an overview of future climate scenarios and the main findings of the study whereas this report provides technical details for public and private sector decision makers that need to incorporate climate change into long term strategies.

The study was commissioned by Business in the Community on behalf of a consortium of organisations and funded by the Environment Agency, Yorkshire Forward, the Yorkshire and Humber Assembly and the Government Office for Yorkshire and Humber. A full list of the organisations that were involved in the study is included in Appendix 1. This study is one of a number of studies conducted within the UK Climate Impacts Programme (UKCIP) framework. UKCIP helps organisations assess how they might be affected by climate change, so they can prepare for its impacts.

1.1 Aims and objectives of the Yorkshire and Humber Study

The overall aim of the scoping study is to assess the potential impacts of climate change of the region. The objectives of the study are as follows:

- To establish an overview of the region’s current baseline position with regard to climate change
- To predict the likely impact of climate change within the region
- To identify the likely effects arising from climate change impacts in the region, assess the broad significance of these and identify the main issues for key stakeholders
- To recommend targets and indicators of change that can be monitored
- To identify key information gaps and uncertainties in assessing the impacts and recommend ways to respond

The study makes reference to climate change mitigation, i.e. reducing greenhouse gas emissions (GGEs) but it is mostly concerned with climate change impacts and adaptation. The reduction of GGEs is the subject of a parallel scoping study completed in June 2002 (Yorkshire Forward, forthcoming). Even with a dramatic reduction in GGEs globally, global warming will continue over the next century due to the inertia in the climate system; adaptation strategies will still be required.

1.2 Context

The Yorkshire and Humber region is an area of nearly 15,000 km², stretching from the North Sea to within 15 km of the Irish Sea. It is home to over 5 million people and includes the cities of Sheffield, Leeds, Bradford, Kingston-upon-Hull and York. The region is divided into four sub-regions; North Yorkshire, West Yorkshire, South Yorkshire and the Humber and includes two significant National Parks; the North Yorkshire Moors and Yorkshire Dales (Figure 1).

The Yorkshire and Humber region is characterised by its strong regional identity and great diversity of landscapes, businesses and communities. Despite massive economic change over the last 20 to 30 years, the major urban centres still form part of the industrial heartland of the UK. Outside these areas the region is predominantly rural and of high environmental quality. Upland areas, such as the Pennines, provide a range of valued natural and semi-natural habitats and are of great natural beauty. Lowland valleys, such as the Vale of York, support highly productive agricultural activities. The region’s coastal areas include long stretches of designated Heritage Coast as well as the major ports of Hull and Grimsby.

It has been recognized for some time that climate change is an important issue for sustainable development in the region. Many local authorities have made a commitment to combat climate change through the Nottingham Declaration that commits local authorities to cut greenhouse gas emissions and to work in partnership with key providers and the community to assess the potential effects of climate change (Appendix G). In addition, the Yorkshire and Humber Assembly has recognised that:-

"Climate change is another major challenge facing the region. The consequences seem to be beginning
to manifest themselves through more frequent extreme weather events, sea level rise and increasing average temperatures. The region needs to plan for these consequences.”

However, the vulnerability of particular economic sectors, regional landscapes and individual communities to climate change is uncertain. This study provides information on the potential impacts of climate change over a number of important planning horizons that can be fed into the planning process as part of the RSDF and other initiatives. It is one of the final UKCIP scoping studies of regional climate change impacts in the UK; others have been completed for the North-West (Shackley et al., 1998), South-East (Wade et al., 1999), Scotland (Kerr et al., 1999), Wales (National Assembly for Wales, 2000) and the East Midlands (Kersey et al., 2000). This study meets the need to undertake a climate change impact study, as highlighted in the Regional Sustainable Development Framework (Regional Assembly for Yorkshire and Humber, 2001).

The adopted methodology involved a review of the research literature, expert judgement by consultants and the wide consultation with other experts and stakeholders in economic, social and environmental disciplines. The report is regarded as an important first step in developing more detailed adaptation strategies for sectors that were identified as particularly vulnerable to climate change.

1.3 Using this report

This report is structured into 7 sections and the subsequent sections are as follows:-

Section 2.0 Methodology
Section 3.0 Climate Change
Section 4.0 Climate Change in Yorkshire and Humber Region
Section 5.0 The Impacts of Climate Change Yorkshire and Humber Region
Section 6.0 Cross-sectoral Analysis
Section 7.0 Conclusions

Section 2 describes the methodology used for climate change impacts assessment including the stakeholder consultation. It provides definitions of key terms such as climate impacts, vulnerability, uncertainty and risk that are used in subsequent sections.

Section 3 provides a review of the recent research and major publications on climate change, including the outputs from the Intergovernmental Panel on Climate Change’s (IPCC) Third Assessment Report (TAR) published in January 2002 and the UKCIP 2002 scenarios published in April 2002. The UKCIP02 Climate Scenario data were prepared by the Met Office Hadley Centre and Tyndall Centre for Climate Research and have been made available by the Department for Environment, Food and Rural Affairs (DEFRA)2 for use in this study.

Section 4 describes the future climate scenarios for the region. It includes tables of summary data and a set of maps that indicate the average change across the region. This section highlights aspects of climate change and natural variation that will impact on the environment and forms the basis of the impacts assessment in Section 5.

Section 5 examines the likely impacts of climate change and is divided into 8 main sectors. For each sector, a description of the baseline environment is provided. The analysis then considers the baseline position, the climate scenarios described in Section 4 and other factors, such as social and economic change, that will influence the developments of the region over the next 20, 50 and 80 years.

Section 6 examines the interactions between different sectors. Impacts will rarely only affect one sector as they normally have knock-on effects through supply chains and spatial scales. This section includes a case study of an important group of businesses in the region collectively called the “food and drinks cluster.”

The main conclusions of the study are described in Section 7, with some prioritisation of adaptation responses based on analysis of the consultation and the opinion of the study team. This list of priorities requires further refinement based on more detailed sectoral or case study impacts assessments and the development of partnerships for action.

---

2 DEFRA accepts no responsibility for any inaccuracies or omissions in the data, nor for any loss or damage directly or indirectly caused to any person or body by reason of, or arising out of any use of, this data. © Crown Copyright 2002.
2 Methodology

The scoping study adopted a standard approach to assessing the potential impacts of climate change. This is based on understanding the sensitivity of environmental processes to both climate variation and other factors, for example socio-economic change. Climate variation has a number of direct impacts, for example on the length of the growing season, or the demand for drinking water, but the overall magnitude of the impact depends upon more complex interactions and is dependent on the overall vulnerability of the environment or economic sector to change.

The first stages of this scoping study involved a literature review on (i) climate change and (ii) the baseline environment of the region. The climate change information is included in Sections 3 and 4. The baseline information is included at the beginning of each impacts sub-section in Section 5.

The impacts assessment involved both expert opinion and stakeholder consultation to explore the potential 1\textsuperscript{st}, 2\textsuperscript{nd} and 3\textsuperscript{rd} order impacts of climate change and its importance relative to other factors. The methodology is summarised in Figure 2.1 and definitions of terms used in climate impacts research are provided in Section 2.1 to provide clarity for the remaining sections.

**Figure 2-1 Outline of the approach used in the scoping study**

![Outline diagram showing the approach used in the scoping study](image-url)

- **Baseline environment**
  - e.g. vulnerability (or robustness) of agriculture to external forces
- **Other factors**
  - e.g. social and economic change (agricultural policy)
- **1\textsuperscript{st} order impacts**
  - e.g. longer growing season (Ch. 5)
- **2\textsuperscript{nd} order impacts**
  - e.g. profitability of farm enterprises
- **3\textsuperscript{rd} order impacts**
  - e.g. regional economy
- **Climate change**
  - e.g. warmer all year round
- **Literature review**
- **Stakeholder consultation & expert opinion**
Stakeholders were contacted from a cross-section of businesses, public sector and non-governmental organisations (Figure 2.2). An interim workshop provided a first opportunity for discussion and thereafter stakeholders attended a series of smaller workshops and others were contacted to take part in telephone interviews. All those involved were provided with information on future climate scenarios and asked to discuss potential impacts on their sectors or areas of interest.

Definitions

The following terms used throughout the study are defined here:

**Impact**
A climate change impact has a significant effect on the environment (or other receptor such as a community or business) due to changes in one or a combination of climate variables. Some impacts are direct, for example increased rainfall increases flood risk, and others, regarded as second and third order impacts, are indirect, for example the effect of flood risks on the location of development.

**Probability**
The chance of an event occurring. Engineering approaches typically describe probabilities in terms of the return periods, for example the 1 in 100 year flood event (equivalent to an event with an annual probability of 1%).

**Risk**
An event or change with a particular probability of occurrence and severity. The significance of any risk is related to a combination of it these two characteristics.

**Scenario**
Due to the uncertainty surrounding climate change, future climates are describes as scenarios. The UKCIP02 scenarios consist of four possible climate futures. Unlike risk assessments, where events are given specific probabilities, scenario analysis is based on “possibilities” that are all equally likely.

**Severity**
The magnitude of an impact is described in terms of its severity or consequence. In some cases this can be measured, for example changes in water quality or loss of revenue due to decreased crop yield.

**Vulnerability**
Describes the system’s (habitat, catchment, economic sector) resilience to external change.

![Figure 2.2 Pie chart of Sectors involved in the consultation](image-url)
3 Climate Change

3.1 Introduction

The concentration of carbon dioxide (CO\textsubscript{2}) in the atmosphere in 1750, before the onset of the industrial revolution, was about 280 parts per million (ppm). Today it is about 370 ppm, an increase of over 30 per cent and probably the highest it has ever been over the last 20 million years. Human activities are responsible for this increase through the combustion of coal, oil and gas, and through other industrial processes such as the smelting of ores and cement manufacture. Land use change is also responsible for rises in atmospheric CO\textsubscript{2} concentrations.

Carbon dioxide reflects heat lost from the Earth back to the Earth’s surface and results in the phenomenon known as global warming. For this reason it is known as a “greenhouse gas”. Other gases, also enhanced by man’s activities (or entirely generated by them) are also greenhouse gases: water vapour (H\textsubscript{2}O), methane (CH\textsubscript{4}), nitrous oxide (N\textsubscript{2}O), ozone (O\textsubscript{3}) and CFCs (chlorofluorocarbons). Carbon dioxide is responsible for about 60 per cent of the temperature changes that result from increased concentrations of greenhouse gases. The various greenhouse gases have different lifetimes in the atmosphere and varying radiative properties. Thus equivalent amounts of a greenhouse gas do not produce equivalent effects on global warming.

In looking at climate change in the Yorkshire and Humber region, it is necessary to understand what might happen to global temperatures. It is not possible to provide “proof” or “experimental evidence” of this, but it is possible to benefit from the informed consensus that has developed from a large number of climate change studies and assessments. These include the likely degree of global warming, the impacts it might have and the responses that could be made.

Future changes in climate are described in terms of average climate over 30 year periods. The period 1961 to 1990 (inclusive) is the standard reference or “control” period and future 30 year periods are centred on the decades on the 2020s, 2050s and 2080s. Hence the “2020s” refer to the period 2011 to 2040, the “2050s” refer to 2041 to 2060 and the “2080s” refer to the period 2071 to 2100.

Attempts have been made to estimate using Atmosphere-Ocean General Circulation Models (AOGCMs), the warming that would result in relation to increases in atmospheric CO\textsubscript{2} concentrations. Doubling CO\textsubscript{2} concentrations from pre-industrial concentrations (to 560 ppm) is estimated to increase mean annual global temperature between 1.5-4.5°C by 2080s or by 1.5-2.0°C by 2050s. This range represents a degree of uncertainty in the general circulation models but there is also the spatial variation in warming that would be expected in relation to latitude, with larger changes at higher latitudes. Thus regional variations in climate change would be expected and it is against this background that climate change and its impacts are being assessed for the Yorkshire and Humber Region.

Since the middle of the nineteenth century global temperature has increased between 0.4-0.8°C (Figure 3-1). The rise has been most rapid in the twentieth century with the 1990s the warmest decade and 1998 the warmest year in the 142-year global instrumental record.

There are still diverse points of view on climate change (Box 3-1). While the Inter-governmental Panel on Climate Change (IPCC) has concluded that human induced climate change is happening (Section 3.2), there is disagreement on the extent to which climate scenarios can be used, the probability of different emissions scenarios and the sensitivity of the climate to greenhouse gases. For some environmental issues the uncertainty related to climate futures is relatively unimportant compared to possible social and economic change. In other areas a changing climate represents a severe risk that must be considered in long term decision making.
Figure 3-1 Changes in Global Temperature (relative to the 1961-1990 mean)

(Source: http://www.cru.uea.ac.uk/cru/info/; reproduced with permission from the Climate Research Unit, University of East Anglia; from Jones et al., 1999).
Box 3-1 Recent Statements and Points of View on Climate Change and Climate Impacts

Viewpoints

Globally, the first three months of 2002 “were the warmest January, February and March since records began in 1860...Proxy records, for instance from tree rings, suggest that they are in fact the warmest for a thousand years” (Geoff Jenkins, Hadley Centre for Climate Prediction and Research, April 2002).

“In Europe, mean annual temperature has risen by about 0.8 °C during the twentieth century, with the last decade (1990-99) being the warmest on record, both annually and for the winter season.” “Precipitation in northern Europe has increased between 10 and 40 per cent during the twentieth century...” (Parry et al., 2000a).

“April 2000 has been the wettest April across England and Wales since records began in 1766”. (The Met Office, 1 May 2000 Release number 410).

“Latest figures from the Met Office show that the autumn rainfall total for England and Wales is the highest since records began in 1766.” .......... a total of 469 mm has fallen over England and Wales since the beginning of September. This beats the previous autumn highest rainfall of 456 mm set in 1852.” (The Met. Office, 27 November 2000 Release number 446).

“Rainfall patterns appear to be changing, with more extreme events occurring in the past 10 to 15 years. The heaviest daily rainfalls now contribute about twice as much to total winter rainfall as they did in the early 1960s” (Osbourn et al. 2000).

Panorama November 19th 2000 – Following the extreme flooding across the UK

Martin Parry, Professor at the Jackson Environment Institute in East Anglia, says: "It may be the result of simply extreme weather but it is the sort of event that we would expect to occur more in the future as a result of global warming."

Merylyn Mckenzie-Hedger, former Head of the UK Climate Impacts Programme tells Panorama: "there are going to be very big decisions made about the scale of resources that are needed for investment to protect on climate change...Big decisions, big money."

“In the last few weeks some 6,000 homes have been flooded, an estimated 500 million pounds worth of damage has been caused. Is this the first bill for global warming? ” (Panorama, 2000)

"It is easy to fool oneself into thinking that an unusual number of extremes has occurred. Conversely, detecting (in a statistical sense) a significant change in the frequency of extremes is a difficult task---the changes have to be larger than one might imagine in order to get a significant result." (Tom Wigley, IPCC participant, Sep. 12, 1995).

The Sceptics

"The global warmers . . . predict that global warming is coming, and our emissions are to blame. They do that to keep us worried about our role in the whole thing. If we aren't worried and guilty, we might not pay their salaries. It's that simple." Kary Mullis, Nobel prize winner in Chemistry.
3.2 The IPCC Third Assessment Report

The Inter-governmental Panel on Climate Change (IPCC) is an international network of climate change experts working together to understand the linkages between climate variability and greenhouse gas emissions. The Third Assessment Report (TAR) of Working Group I of the IPCC presents a stronger case for the link between human influence and climate change than previous reports (IPCC WGI, 2001). The authors state that:

“There is now stronger evidence that most of the warming observed over the last 50 years is attributable to human activities”

In terms of trends in the historic climate there are now more observations available, particularly from remote sensing systems, for estimating average global warming. There is still insufficient evidence to make definite statements on how much the climate has warmed over the last 50 years so the IPCC have applied a qualitative classification to their statements on global trends indicating confidence levels: virtually certain (greater than 99% chance that the statement is true); very likely (90-99% chance); likely (66-90% chance) and so on. In this report only the ‘likely’ to ‘virtually certain’ trends are discussed in any detail. Table 3-1 summarises some key changes in the global climate and Box 3-2 presents some of the most relevant comments made in the IPPC reports.

The IPCC TAR foresees average global surface temperatures increasing by between 1.4-5.8°C by 2100 compared to 1990. In Northern Europe it is envisaged that increases in mean winter temperature will be much greater than average warming. Projections of future changes in winter precipitation across the whole of Northern Europe are for a large increase whereas for summer there may be no change or even a small decrease in precipitation. Global changes in sea-level may range from increases of 0.09-0.88 m.

The key changes in climate phenomenon and highlights from the IPCC TAR are summarised in Table 3-1 and Box 3-2, respectively. These are important in the context of this scoping study because the global impacts of climate change may also affect the development of the Yorkshire and Humber region as well as having direct impacts in the region.

3.3 Climate Change in the UK

In the UK the average temperature has risen by about 0.5°C during the twentieth century. The decade from 1988-1997 warmed 0.53°C above the 1961-90 mean. The 1988-97 decade had more than twice the average of hot days and also had well below the average of cold days. Precipitation changes in the UK show little in the way of any clear trends in the last 40 years with, perhaps, an indication of slightly higher proportions of winter rainfall. Tide gauge data shows an increase in sea-level around the southern and northern coasts of England.

Future UK climate change is assessed using the output from the relevant grid squares of global and regional climate models. To date, two sets of climate scenarios have been published for the UK; these are described below.

3.4 The UKCIP 1998 scenarios

In 1998 a set of scenarios were published for UKCIP describing possible future climate change for 30 year periods centred on 2020s, 2050s and 2080s based on the Met Office Hadley Centre model runs and work undertaken by the Hadley Centre and the Climatic Research Unit (CRU) at the University of East Anglia (UEA). A report described the development of the climate scenarios in detail (Hulme and Jenkins, 1998). Four scenarios - low, medium-low, medium-high and high for each time period are provided based on different levels of carbon emissions and climate sensitivity. These scenarios cover a wide but not full range of possible climate futures and it is also important to consider other Global and Regional Circulation Model results for climate impacts assessments.

The UKCIP98 scenarios are based on the Hadley Centre Model known as HadCM2. This model consists of full atmospheric and ocean components that are coupled together so that HadCM2 allows the simulation of climate response to gradually increasing greenhouse gases. The models can also be run while the concentration of carbon dioxide is kept constant, allowing natural climate variability to be studied without the influence of increasing carbon dioxide.

Typically scenario data are presented with reference to the 1961-1990 climate and many of the figures in this report plot the changes from the 61-90 control period. It is important to appreciate the difference between the 61-90 period and (i) the full historic
record that may include much wetter, drier, warmer or cooler periods and (ii) the 1990s that were particularly warm compared to the 61-90 average annual temperature and were characterised by dry summers. In fact some summers in the 1990s were similar to the UKCIP projections for the 2020s under the two medium scenarios.

### 3.5 The UKCIP 2002 scenarios

In April 2002 a new set of UK climate scenarios were published\(^3\). There are four recently defined scenarios that describe the rates of warming in response to different levels of emissions, namely **Low Emissions**, **Medium-Low Emissions**, **Medium-High Emissions** and **High Emissions**. These scenarios show higher rates of warming than the 1998 scenarios, slightly lower rates of sea level rise and, in a major departure from the 1998 scenarios, drier summers across the whole of the UK.

The scenarios have been developed using a hierarchy of Hadley Centre models including the HadRM3 Regional Climate Model (RCM) that provides data for a 50 km grid over the UK. This can be downscaled further using a 5 km national climatology but these data were not available for this study. The scenarios also provide more information on changes to daily extremes in the form of probability plots and maps of variables such as daily maximum temperature, daily precipitation and daily mean wind speed. Further details are included in a comprehensive technical report (Hulme et al., 2002) that is available through the UKCIP web site ([http://www.ukcip.org.uk/climate_change/future_uk.html](http://www.ukcip.org.uk/climate_change/future_uk.html)). An example of the UKCIP02 50 km grid data is shown in Figure 3-2. The data for the Yorkshire and Humber region are described in Section 4.

---

\(^3\) UKCIP02 scenarios released 26th April 2002. The data are used in this report under license from DEFRA © Crown Copyright 2002.
Table 3-1 IPCC Estimates of confidence for selected observed and projected changes in extreme weather and climate events

<table>
<thead>
<tr>
<th>Change in Phenomenon</th>
<th>Confidence in observed changes (latter half of the 20th century)</th>
<th>Confidence in projected changes (during the 21st century)</th>
<th>Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher maximum temperatures and more hot days over nearly all land areas.</td>
<td>Likely</td>
<td>Very likely</td>
<td>Peak demand for water</td>
</tr>
<tr>
<td>Higher minimum temperature, fewer cold days and frost days over nearly all land areas.</td>
<td>Very likely</td>
<td>Very likely</td>
<td>Agricultural change</td>
</tr>
<tr>
<td>Reduced diurnal temperature range over most land areas</td>
<td>Very likely</td>
<td>Very likely</td>
<td>Water quality processes</td>
</tr>
<tr>
<td>Increase in heat index over land areas</td>
<td>Likely over many areas</td>
<td>Very likely, over many areas</td>
<td>Timing of the seasons – earlier spring.</td>
</tr>
<tr>
<td>More intense precipitation events</td>
<td>Likely over Northern hemisphere, mid- to high latitudes</td>
<td>Very likely, over many areas</td>
<td>Flood risks – require regional model data for the UK.</td>
</tr>
<tr>
<td>Increased summer continental drying and associated risk of drought</td>
<td>Likely in a few areas</td>
<td>Likely, over mid-latitude continental interiors (lack of consistent projections in other areas)</td>
<td>Drought – require regional model data for the UK.</td>
</tr>
</tbody>
</table>

Note: The IPCC have applied a qualitative classification to their statements on global trends indicating confidence levels: - Virtually certain (greater than 99% chance that the statement is true); very likely (90-99% chance); likely (66-99% chance).
Box 3-1 Highlights of the Third Assessment Report (Text taken directly from the final report ‘Summary for Policymakers’ of IPPC Working Group 1 unless indicated otherwise)

**Historic trends**
Globally, it is very likely that the 1990s was the warmest decade and 1998 the warmest year in the instrumental record, since 1861.
New analysis of proxy data for the Northern Hemisphere indicates that the increase in temperature in the 20th century is likely to have been the largest of any century during the past 1000 years.
Tide gauge data show that global average sea level rose between 0.1 and 0.2 metres during the 20th century.

**SRES scenarios**
There are 4 storylines (termed A1, A2, B1 and B2) that were used in the Special Report on Emission Scenarios to provide human greenhouse gas inputs to climate models.

**Models**
Confidence in the ability of models to project future climate has increased.
Global average temperature and sea level are projected to rise under all IPCC SRES scenarios.

**Temperature**
The globally averaged surface temperature is projected to increase by 1.4 to 5.8°C over a period 1990 to 2100. These results are for the full range of 35 SRES scenarios based on a number of climate models.

**Precipitation**
…By the second half of the 21st century, it is likely that precipitation will have increased over northern mid- to high latitudes…
…Larger year to year variations in precipitation are very likely over most areas where an increase in mean precipitation is projected.

**Sea level**
Global mean sea level is projected to rise by 0.09 to 0.88 metres between 1990 and 2100, for the full range of SRES scenarios. …Despite the higher temperature change projections in this assessment, the sea level projections are slightly lower, primarily due to the use of improved models, which give a smaller contribution from glaciers and ice sheets.

**Extreme Events**
For some other extreme phenomena, many of which may have important impacts on the environment and society, there is currently insufficient information to assess recent trends, and climate models currently lack the spatial detail required to make confident predictions. For example, very small scale phenomena like thunderstorms, tornadoes, hail and lightning, are not simulated in climate models.

Flood magnitude and frequency could increase in many regions as a consequence of the increased frequency of heavy precipitation events (WGII, Draft Summary for Policy Makers, p.7).
More intense precipitation events are very likely over many areas (WGII, Draft Summary for Policy Makers, p.15).

---

4 The UKCIP02 climate change scenarios are based on these emission scenarios.
Figure 3-2 Example UKCIP02 output showing 50km grid over England and Wales
4 Climate change in the Yorkshire and Humber Region

4.1 Introduction

This chapter is based on results from the Hadley Centre Global Climate Model (GCM) and the Regional Climate Model (RCM). Some of the results are from UKCIP02 (Hulme, et al., 2002) and others are from UKCIP98 (Hulme and Jenkins, 1998); the historical data are from the archives kept at The Met Office. The new UKCIP02 climate scenarios describe the rates of warming in response to different levels of emissions, namely Low Emissions, Medium-Low Emissions, Medium-High Emissions and High Emissions. These scenarios update and improve upon an earlier set of UKCIP scenarios released in 1998.

Increases in greenhouse gases and sulphate emissions are assumed to be the only source of possible future climate change in these scenarios; other natural or man-made causes of climate change are not considered. However, the general consensus is that the release of greenhouse gases by man is likely to be the major cause of future climate changes over the next 100 years.

4.2 Context

As part of the British Isles, the Yorkshire and Humber region has a climate which is largely affected by the prevailing west to south west winds from the Atlantic Ocean. This situation is modified by the Pennines which shelter much of the region from the rain bearing west winds and also the North Sea which has a cooling influence on the east coast especially in summer.

The temperature of the North Sea is relatively lower than the sea around other parts of UK. As a result coastal regions of Yorkshire and the Humber are cool especially in summer when onshore sea breezes and sea fogs are common. Inland areas of the Vale of York are warmer in summer and cooler in winter than the coast since they are sheltered by the Pennines and the North York Moors and are partly cut off from the moderating influence of the sea. The lowest winter temperatures are to be found high in the Pennines, but also in the Vale of York when stagnant cold air in winter can linger. In summer the warmest parts are the low lying southern areas away from the North Sea. Mean temperature decreases with altitude at the rate of about 0.5°C per 100 m so that the Pennines are the coldest part of the region; associated increases in rainfall, cloudiness and windspeed with height means that this area has the harshest climate in general.

The pattern of rainfall tends to follow the distribution of high ground so that annual totals are highest in the Yorkshire Pennines and lowest in the southern part of the Vale of York and some coastal areas. On individual days the rainfall distribution depends on the wind direction and the Pennines form a rain shadow barrier for eastern areas when the wind is from the south west. Rain associated with wind from between north and south east is usually heaviest over the North York Moors and Wolds and in winter these areas often have the heaviest snowfall from showery northerly winds. The high Pennines tend to have snow from chilly westerly winds in winter with milder air often arriving soon after snow has fallen causing the snow to melt. Melting snow accompanied by rain poses a significant flood risk to the rivers which drain east from the Pennines. Summer thunderstorms are less common than in other parts of UK, but the Pennine slopes intensify these storms. Several notable downpours have been recorded especially in West and South Yorkshire. Low level places tend to have the highest monthly rain total in August, but more elevated sites have theirs in late autumn and winter.

The strongest winds come from the west in the UK. Although the high Pennines can have winds nearly as strong as west coast places the eastern side of the hills is generally sheltered. Gales from the north or north east are more troublesome especially towards the coast, but are relatively rare. The combination of strong north winds and low pressure tracking down the North Sea tends to raise sea levels on the coast as a 'storm surge' with sea flooding on Teesside and Holderness.

4.3 Rising Temperatures

The modelled changes in temperature are shown in Table 4-1. Annual temperature is expected to be between 0.5 and 1.0 °C warmer by the 2020s and between 3.0 and 3.5 °C warmer by the 2080s, compared with the 1961-1990 reference period. The variability in winter temperature is expected to
decrease, while summer variability is expected to increase. In summer, the smallest temperature increase is likely to be on the North Sea Coast, with the largest increases in South Yorkshire.

The low climate change scenario produces a smaller temperature rise, between a half and one third of the medium-high change for annual, winter and summer. The high scenario has increases larger by 0.2 to 0.5 °C than the medium-high.

Table 4-1 UKCIP02 30-Year Mean Annual, Winter and Summer Temperature Increase (°C), relative to 1961-1990 for the Low Emissions and High Emissions scenarios

<table>
<thead>
<tr>
<th>Period</th>
<th>Annual</th>
<th>Winter (DJF)</th>
<th>Summer (JJA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020s</td>
<td>L 0.5 to 1.0</td>
<td>0.5 to 1.0</td>
<td>0.5 to 1.1</td>
</tr>
<tr>
<td></td>
<td>H 0.5 to 1.0</td>
<td>0.5 to 1.0</td>
<td>1.5 to 1.8</td>
</tr>
<tr>
<td>2050s</td>
<td>L 1.0 to 1.4</td>
<td>1.0 to 1.4</td>
<td>1.6 to 1.8</td>
</tr>
<tr>
<td></td>
<td>H 2.1 to 2.3</td>
<td>1.6 to 1.8</td>
<td>1.8 to 2.0</td>
</tr>
<tr>
<td>2080s</td>
<td>L 1.6 to 2.0</td>
<td>1.4 to 1.6</td>
<td>2.3 to 2.6</td>
</tr>
<tr>
<td></td>
<td>H 3.5 to 3.9</td>
<td>2.7 to 3.0</td>
<td>2.3 to 2.6</td>
</tr>
</tbody>
</table>

Note: L – Low Emissions scenario; H – High Emissions scenario.
These data are for the following periods: 2020s – 2011 to 2040, 2050s – 2041 to 2070, 2080s – 2071 to 2100 AD

Daily mean temperature range is expected to increase by between 0.5 and 4.9 °C by the 2080s in all seasons.

Figure 4-1 shows the pattern of warming produced in the UKCIP02 scenarios. The sea has a moderating influence on the temperature rise on the coast while inland areas have the greatest rise.

An increase in the mean temperature implies that the numbers of occasions above or below temperature limits also change. For example, as conditions become warmer then the number of frosts (temperature below 0 °C) will become less. Table 4-2 shows the change in the numbers of frosts, the number of warm summer nights (night minimum temperature above 15 °C) and warm summer days (day maximum temperature above 25 °C). This has been carried out for Bradford and Sheffield using the historic temperature records shifted up by the temperature increase expected for those two places by the 2080s using the UKCIP02 High Emissions scenario in winter and the Medium-Low Emissions scenario in summer. The numbers in the table are the average occasions per year.

Table 4-2 Changes in the Frequency of High and Low Temperatures at Sheffield and Bradford

<table>
<thead>
<tr>
<th>Place</th>
<th>Frost Nights (High Emissions)</th>
<th>Warm Summer Nights (ML Emissions)</th>
<th>Warm Summer Days (ML Emissions)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Past 2080s</td>
<td>Past 2080s</td>
<td>Past 2080s</td>
</tr>
<tr>
<td>Sheffield</td>
<td>40 8</td>
<td>8 34</td>
<td>9 22</td>
</tr>
<tr>
<td>Bradford</td>
<td>55 13</td>
<td>5 28</td>
<td>5 14</td>
</tr>
</tbody>
</table>
Figure 4-1 Changes in annual mean temperature in the Yorkshire and Humber region

© Crown Copyright 2002. The UKCIP02 climate scenarios data have been made available by the Department for Environment, Food and Rural Affairs (DEFRA). DEFRA accepts no responsibility for any inaccuracies or omissions in the data nor for any loss or damage directly or indirectly caused to any person or body by reason of, or arising out of any use of, this data.
4.4 Changing precipitation patterns

The modelled changes in precipitation are shown in Table 4-3. Annual rainfall is expected to decrease slightly by up to 20% (High Emissions scenario) in some parts of the region by the 2080s, compared with the 1961-1990 reference period. The low scenario has no change, while high scenario has similar changes.

The annual changes mask considerable seasonal variation in rainfall. In winter the rainfall is expected to increase by between 13% (Low Emissions) and 32% (High Emissions) by the 2080s. The smallest percentage increase is in Pennine areas. Variability in winter rainfall increases.

Summer rainfall could fall by 10 (Low Emissions) to 15% (High Emissions) by the 2020s, and by as much as 52% (High Emissions) by the 2080s. The variability of summer rainfall decreases. The UKCIP02 report emphasises that the decreases in summer rainfall are at the top end of the results from a range of models. The full range of figures are given in the Table 4-3.

<table>
<thead>
<tr>
<th>Period</th>
<th>Annual (DJF)</th>
<th>Winter (DJF)</th>
<th>Summer (JJA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020s</td>
<td>L 0 to -5</td>
<td>0 to 5</td>
<td>-10 to –15</td>
</tr>
<tr>
<td></td>
<td>H 0 to -5</td>
<td>2 to 6</td>
<td>-12 to -15</td>
</tr>
<tr>
<td>2050s</td>
<td>L 0 to -5</td>
<td>8 to 12</td>
<td>-13 to –17</td>
</tr>
<tr>
<td></td>
<td>H 0 to -5</td>
<td>15 to 20</td>
<td>-27 to -32</td>
</tr>
<tr>
<td>2080s</td>
<td>L 0 to -5</td>
<td>13 to 17</td>
<td>-23 to –26</td>
</tr>
<tr>
<td></td>
<td>H –5 to -20</td>
<td>25 to 32</td>
<td>-47 to -52</td>
</tr>
</tbody>
</table>

Changes in winter rainfall from the UKCIP02 scenarios are shown in Figure 4-2. Most areas have increased rainfall in winter. In summer the changes are small on the coast, but there is a decrease especially in south west Yorkshire.

The increase in winter rainfall is mainly due to an increase in the number of days with heavy rainfall. Figure 4-3 shows some typical results from the RCM near Leeds (medium-high scenario) and compares the present climate with the 2080s. For daily rainfall amounts up to 10 mm there is little difference. However, for daily rainfalls above 15 mm there is generally an increased number of days by the 2080s. Figure 4-4 shows that or summer rainfall there is a decrease in the number of the heaviest rainfall events.
Figure 4-2 Changes in mean winter rainfall in the Yorkshire and Humber region

Winter precipitation change
(percentage change with respect to the 1961 - 90 mean climate)

-15 to -10
-10 to -5
-5 to 0
0 to 5
5 to 10
10 to 15
15 to 20
20 to 25
25 to 30
30 to 36
36 to 46

© Crown Copyright 2002. The UKCIP02 climate scenario data have been made available by the Department for Environment, Food and Rural Affairs (DEFRA). DEFRA accepts no responsibility for any inaccuracies or omissions in the data nor for any loss or damage directly or indirectly caused to any person or body by reason of, or arising out of, any use of, this data.
Figure 4-3 Daily Rainfall Distribution near Leeds in Winter for the Present Climate and the 2080s

Figure 4-4 Daily Rainfall Distribution near Leeds in Summer for the Present Climate and the 2080s
4.5 Temperature and Rainfall Anomalies

Table 4-4 shows the return period (years) for temperature and rainfall values for locations within the Yorkshire and Humber region, which are unusual in the present climate. The anomalies are with respect to the 1961-90 mean and results are for the A2 (medium-high) scenario except where indicated. Warm months, seasons or years are expected to become much more common. Very wet winters or very dry summers also increase in frequency.

Table 4-4 Changes in the Frequency (and percentage probability) of Monthly, Seasonal and Annual Temperature and Rainfall Anomalies for selected scenarios (Low, Medium Low and Medium High)

<table>
<thead>
<tr>
<th>RETURN PERIOD (YEARS)</th>
<th>PRESENT CLIMATE (1961-90)</th>
<th>2020s</th>
<th>2050s</th>
<th>2080s</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TEMPERATURE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANNUAL: anomaly +1.4 °C as in 1999</td>
<td>230 (0.4%)</td>
<td>2 (50%)</td>
<td>Exceeded 2 out of 3 years (66%)</td>
<td>Nearly every year exceeds (almost 100%)</td>
</tr>
<tr>
<td>SEASONAL: anomaly +1.8 °C as in summer 1995</td>
<td>100 (1%)</td>
<td>3 (33%)</td>
<td>2 (50%)</td>
<td>Exceeded 2 out of 3 years (66%) (Low)</td>
</tr>
<tr>
<td>MONTHLY: anomaly +2.7 °C as in August 1997</td>
<td>100 (1%)</td>
<td>7 (14%)</td>
<td>3 (33%)</td>
<td>2 (50%) (M Low)</td>
</tr>
<tr>
<td><strong>RAINFALL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WET WINTER: more than 160% of normal</td>
<td>13 (8%)</td>
<td>11 (9%)</td>
<td>4 (25%)</td>
<td>3 (33%)</td>
</tr>
<tr>
<td>DRY SUMMER: Less than 50% of normal</td>
<td>18 (6%)</td>
<td>4 (25%)</td>
<td>4 (25%) (Low)</td>
<td>4 (25%) (Low)</td>
</tr>
</tbody>
</table>

4.6 Changing Wind Speeds

Mean wind speeds are little changed except for an increase (3 to 5%) in winter by the 2080s. This is likely to be due to an increase in the number of occasions of strong winds. However, the confidence in the wind changes is low.
4.7 Other Climate Variables

There is little change in mean cloud cover except for a small (3 to 12%) fall in summer and autumn by the 2080s, with a corresponding small increase in sunshine.

As temperatures rise the air is capable of holding more water vapour at all seasons. However, the air humidity relative to saturation, the relative humidity, will change little from current values except for a reduction of 10% in summer by the 2080s.

4.8 Derived Climate Variables

The mean increase in potential evaporation from water, or from crops growing in moist soil, for summer and autumn combined is 11% by the 2020s, 17% by the 2050s and 20% or more by the 2080s, relative to the 1961-90 period. The winter and spring increase is rather less.

Some applications of temperature data such as the estimation of building heating need and the growth of crops depend on the sum of temperatures over time above a base temperature. Space heating is related to the number of day degrees below 15.5 °C and the growth of crops such as grass has been related to day degrees above 5.5 °C. A warming climate reduces the day degrees below 15.5 °C, but increases it above 5.5 °C. For the Yorkshire and Humber region the number of day degrees below 15.5 °C could drop by 20 to 40% by the 2080s. The period above 5.5 °C could increase by 50 to 90 days by the 2080s. This suggests that space heating needs will decrease in future and that crops such as grass in moist soil will be growing for a greater proportion of the year.
4.9 Future Changes in the Context of Historical Data

Historical trends in temperature and rainfall are examined for a few sites in relation to the expected future changes. Temperatures are available from Bradford (1908-2001) and Sheffield (1883-2001) while rainfall is available from sites around Hull from 1871 to 2001. Figures 4-5 to 4-8 show the mean for the season in each year and also a 30 year running mean which is plotted at the final year of each 30 period.

Figure 4-5 shows the winter temperature at Sheffield. Projections, using the UKCIP02 medium-high scenario, for the next 100 years are shown as averages for 30 year periods centred on the 2020s, 2050s and 2080s. Winter temperatures were at a peak from about 1920 to 1940, but declined in the following decades. Temperatures have risen smartly in the past decade. The future projection shows that the temperature rise during the past decade is expected to be maintained.

Figure 4-5 Mean Winter (Dec-Feb) Temperature at Sheffield (1883-2001) with estimates for the 2020s, 2050s and 2080s for the Low, Medium High and High Emissions scenarios
In the summer the temperatures showed a broad peak for the 30 years ending in the 1960s (Figure 4-6). Temperatures for 30 year periods ending in the 1990s were at an all-time high. The recent rising trend is expected to continue over the next 100 years under the medium-high scenario.

Figure 4-6 Mean Summer (June-August) Temperature at Sheffield (1883-2001) with estimates for the 2020s, 2050s and 2080s for the Low, Medium High and High Emissions scenarios

The 30 year means of winter rainfall at Hull (Figure 4-7) have shown small variations over the past 60 years, but a steady rise in the 30 year mean is expected for the next 100 years under the medium-high scenario. In contrast, summer rainfall (Figure 4-8) has generally declined from around 1910, and in future a further decline is likely.
Figure 4-7 Winter Rainfall at Hull (1872-2001) with mean 30-year estimates for the 2020s, 2050s and 2080s for the Low, Medium High and High Emissions scenarios

Figure 4-8 Summer Rainfall at Hull (1871-2001) with mean 30-year estimates for the 2020s, 2050s and 2080s for the Low, Medium High and High Emissions scenarios
4.10 Sea Level Rise

Sea level change is controlled by two main factors. Eustatic change relates to the expansion or contraction of sea water plus the changes in the volume of water stored on land as ice sheets and glaciers. Isostatic change relates to the movement of land in response to the effect of glaciers on the earth’s crust. Recent and future sea level change in the region is dominated by the eustatic component resulting from global warming. The isostatic component is small around the Humber because this area is on the axis between uplift in the north and subsidence in the south. Local changes, for example in geomorphology, modify these broader changes and have a significant effect on the actual sea level rise experienced along the region’s coastline.

Long term average tidal level data for the Humber are shown in Figure 4-9. These records show that mean tide levels have risen at rates between 1.5 and 3.6 mm per year over the last 80 years.

Extreme water levels are caused by a combination of factors and are normally divided into two components, a tidal level and a surge level. The UKCIP02 scenarios suggest relative net sea level rise of between 15 and 75 cm for Yorkshire by the 2080s for the Low Emissions and High Emissions Scenarios respectively (Hulme, et al., 2002; Table 12). However, changes in storminess, in particular changes to windspeed and direction, will influence the magnitude and frequency of the surge component of extreme sea levels. For the Medium High Emissions scenario the surge component is expected to increase water levels by a further 20cm with the effect of increasing the frequency of extreme levels by at least 10-fold.

An example presented in the UKCIP02 technical report using the Medium High Emissions scenario suggests that extreme water level of 1.5m at Immingham, with a return period of 1 in 120 years, would occur once every seven years by the 2080s, a 17-fold increase in frequency (Hulme, et al., 2002; Fig. 74).

Figure 4-9 Annual Mean Water Level at Blacktoft, Immingham and Spurn
5 The impacts of climate change in the Yorkshire and Humber region

This section describes the potential impacts of climate change based on a review of the baseline information, climate scenarios, expert opinion and outputs from the stakeholder consultation.

The impacts assessment is divided into 8 sub-sections:

- Section 5.1 The Coastal Zone
- Section 5.2 Drainage, Rivers and Floodplains
- Section 5.3 Water Resources
- Section 5.4 Agriculture and Forestry
- Section 5.5 The Natural Environment
- Section 5.6 Industry and Commerce
- Section 5.7 Services
- Section 5.8 Transport

Further analysis of 2nd order and above impacts and the interactions between these sectors/themes is presented in Section 6.

5.1 The Coastal Zone

5.1.1 Introduction

The coastal zone is an important area for Yorkshire and the Humber. It includes the major ports of Hull and Grimsby, the smaller towns of Scarborough, Bridlington, Cleethorpes and Whitby and the proposed Humber Trade Zone. The coast is particularly vulnerable to a changing climate in terms of rising sea levels, changing patterns of tidal flooding and coastal erosion and the warming of sea waters.

Rising sea levels are one of the most certain aspects of a changing climate. With the exception of the low lying fens in Norfolk, the region has the largest area at risk from tidal flooding in the country. It also has the greatest value of assets at risk from flooding due to the lower standard of protection in the Humber compared to the Thames Estuary.

This section describes the potential impacts of climate change on the coastline including changes to flood frequency, coastal erosion and changing maritime conditions. Flood risks associated with inland environments are discussed in Section 5.1.2. Fisheries are discussed in detail in the Agri-food sector case study.

5.1.2 Background

In the Yorkshire and Humber region, the coastline is eroding fast, with parts of the Holderness coastline retreating at a rate of over 1 m per year. There are also large areas of low lying land within the tidal floodplain including a large proportion of the land allocated for development over the next 26 years. In the Regional Planning Guidance for Yorkshire and the Humber (RPG12) almost the entire coastline was identified as a “second priority regeneration area”.

The coastal zone of the Yorkshire and Humber region is one of great diversity and importance. North of Flamborough Head the coastline is dominated by limestone and sandstone cliffs, with some smaller stretches composed of boulder clay. The high chalk cliffs of Flamborough Head itself are home to important breeding populations of seabirds, while the wave-cut platforms provide excellent habitats for algal species, some at their southern limit5. The North Yorkshire coast is lightly populated, with small villages and the sea-side towns of Whitby, Scarborough and Filey.

The Holderness coastline is largely composed of boulder clay cliffs, which are being eroded at a rate of 120 m per century, one of the fastest erosion rates in Europe (Goudie and Brunsden, 1994). Small towns and villages lie along the coastline, but many others have been washed away by the sea as the coastline has retreated. The eroded sediment has an important effect on the geomorphology of the Humber Estuary and the coastline further south.

The Humber Estuary (Trent Falls to Spurn Head) is 62 km long, up to 14 km wide and drains about 20 per cent of England’s surface. The Estuary is an internationally important habitat for migratory birds, which feed on the rich inter-tidal invertebrate communities and seagrass beds1. The estuary is significant for its fish habitats and also provides passage for ships to the ports of Hull, Goole, Immingham and Grimsby.

5 Information from the English Nature website (www.english-nature.gov.uk).
The coastal zone and the habitats within it are protected by many designations, of both national and international importance (Table 5-1). Some 82 per cent of the region’s coastline is designated as Heritage Coast and particularly important areas covered by conservation designations include the North York Moors coastline, Flamborough Head and the Humber Estuary.

Coastal Zone Management

Coastal zone management in England and Wales is the policy responsibility of DEFRA and the operational responsibility of the Environment Agency (flood defence) and maritime local authorities (coast protection works).

The Strategy for Flood and Coastal Defence in England and Wales (MAFF/WO, 1993) established the strategic approach for coastal management and encouraged the establishment of regional coastal defence groups and the development of Shoreline Management Plans (SMPs). SMPs are designed to establish a strategy for coastal defence taking into account natural processes as well as human and environmental influences and needs (MAFF, 1995). SMPs are based on natural sediment cells and sub-cells.

Four main options are considered at the level of smaller management units:

1. Do nothing
2. Hold the existing defence line
3. Advance the existing defence line
4. Retreat the existing defence line

It is now widely recognised that flood defence schemes need to consider a full range of issues and involve coastal stakeholders in decision making. In the Humber Estuary there is a target of no net reduction on inter-tidal habitat and consequently the flood defence strategy, outlined in the Humber Estuary SMP (Environment Agency, 2000), has three main features:

1. Hold the line of existing defences where there is no justification for moving them;
2. Identify sites where moving the defences will provide direct and indirect flood defence benefits, taking into social, environmental and economic issues into account; and
3. Support the creation of new inter-tidal habitat to maintain the estuary’s conservation status.

<table>
<thead>
<tr>
<th>Designation Type</th>
<th>Designation</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landscape designation</td>
<td>National Park</td>
<td>North York Moors</td>
</tr>
<tr>
<td></td>
<td>Heritage Coast</td>
<td>North Yorkshire and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cleveland</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flamborough Head</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spurn</td>
</tr>
<tr>
<td></td>
<td>National Nature</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reserve (NNR)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sites of Special</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scientific Interest</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(SSSIs)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conservation designation</td>
<td>Special Areas of</td>
<td>Beast Cliffs</td>
</tr>
<tr>
<td></td>
<td>Conservation (SACs)</td>
<td>(Robin Hood’s Bay)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(candidate)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flamborough Head</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(candidate)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Humber Estuary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(proposed)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>North York Moors</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(candidate)</td>
</tr>
<tr>
<td></td>
<td>Marine SACs¹</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flamborough Head</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(candidate)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Humber Estuary</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(proposed)</td>
</tr>
<tr>
<td></td>
<td>Special Protection</td>
<td>Flamborough Head</td>
</tr>
<tr>
<td></td>
<td>Areas (SPAs)²</td>
<td>and Bempton Cliffs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hornsea Mere</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Humber Flats, Marshes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and Coasts (phase 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Humber Flats, Marshes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and Coasts (phase 2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>North York Moors</td>
</tr>
<tr>
<td></td>
<td>Ramsar sites³</td>
<td>Humber Flats, Marshes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and Coasts (phase 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Humber Flats, Marshes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and Coasts (phase 2)</td>
</tr>
</tbody>
</table>

International designations: *Designated under EC Habitats and Species Directive; †designated under the EC Directive on the Conservation of Wild Birds; ‡designated under the International Convention on Wetlands of International Importance.

Coastal erosion is a major problem in parts of the region. Historical erosion rates are shown in Table 5-2.
Table 5-2 Cliff Erosion Rates

<table>
<thead>
<tr>
<th>Coastline</th>
<th>Geology</th>
<th>Erosion Rates (m/century or cm/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Yorkshire</td>
<td>Shale</td>
<td>9</td>
</tr>
<tr>
<td>North Yorkshire</td>
<td>Glacial Drift</td>
<td>28</td>
</tr>
<tr>
<td>Holderness</td>
<td>Glacial Drift</td>
<td>120</td>
</tr>
</tbody>
</table>

Source: Goudie and Brunsden, 1994.

5.1.3 Impacts

Sea level rise, storm surges and extreme water levels

The UKCIP02 scenarios suggest relative net sea level rise of between 15 and 75 cm for Yorkshire by the 2080s for the Low Emissions and High Emissions Scenarios respectively (Hulme, et al., 2002; Table 12). DEFRA recommends that for planning purposes, a relative rise of 6 mm per year is taken into account for the coast south of Flamborough Head with a 4 mm per year allowance north of this (MAFF, 2000a). Given the results of the Medium High scenario the DEFRA allowances are an adequate response to the potential impacts of sea level rise. The new defences around Hull’s Humber frontage have been designed to meet an annual average rise of 6mm per year up to 2050.

Not all of the tidal flood defences on the Yorkshire and Humber coast were built since the DEFRA guidance was introduced in 1993 so, by inference, the remainder are not protected against sea level rise. Therefore the coastal area is likely to be at increased flood risks in future without further investment in defences or retreat from the coast. Flood gates designed to protect Hull from flooding will require modifications to either their operational rules or their design to provide continued protection over the next 50 years.

Surge heights are expected to increase and Hulme et al. (2002) have reported a seventeen fold increase in the frequency of a 1 in 120 year water level (1.5 m) for Immingham based on the Medium High Emissions scenario. However, future scenarios of changing storminess are particularly uncertain and these results have not yet been adequately validated. A reasonable starting point for estimating future coastal flood risks is to take historic “port diagrams”, i.e. plots of recorded extreme sea levels versus return periods or probabilities, and simply adding the scenario mean sea level rises. Dixon and Tawn (1995) have analysed port diagrams around the UK including Immingham in the Humber Estuary. Adding the DEFRA Sea Level Rise (SLR) guidance figures suggest that the frequency of current 1 in 200 year levels will at least double over the next 50 years and that smaller flood events may occur 5 to 10 times more frequently than in the past.
Table 5.3 Example calculation of future extreme levels for Immingham

<table>
<thead>
<tr>
<th>Current Return Period 1 in X</th>
<th>Extreme level m</th>
<th>Return Period for + 30cm (50 yrs at 6 mm per year)</th>
<th>Return Period for + 20cm (50 yrs at 4 mm per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>8.3</td>
<td>1.5</td>
<td>2</td>
</tr>
<tr>
<td>100</td>
<td>8.8</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>200</td>
<td>9.0</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>1000</td>
<td>9.5</td>
<td>250</td>
<td>400</td>
</tr>
</tbody>
</table>

(Source: Based on Dixon and Tawn, 1995 Fig. 16.6)

Therefore, depending on the assumptions that are incorporated in the analysis, extreme sea levels along the Yorkshire and Lincolnshire coast and within the Humber Estuary are expected to at least double in frequency over the next 50 years and may even increase up to seventeen fold over 80 years.

Overall this will mean more frequent tidal flooding, a larger area of land at risk from flooding and larger areas of valuable inter-tidal habitat lost due to processes of coastal squeeze. In summary the main impacts of rising sea levels will be:-

- “Coastal squeeze.” Inter-tidal habitats that are important for birds and other species could be lost to the sea as they are trapped between rising sea waters and hard coastal defences.
- Increased risk of tidal flooding including the overtopping, bypassing and breaching of coastal defences due to sea level rise and possibly changes in storminess. Tidal gates will have to be operated more frequently with possible knock-on effects for estuarine and river ecology.
- A larger area of land within the 1 in 200 year tidal indicative floodplain map. This area is defined as “high” flood risk in Planning Policy Guidance note 25 (PPG25)
- An increase in urban drainage problems because drains into the Humber estuary will be “tide-locked” more frequently due to higher sea levels. There will be a greater need for pumping of drainage water from low lying land into the estuary with the knock-on effect of increased energy use.
- Disruption to coastal transport corridors due to increased frequency of flooding, particularly alongside the Humber Estuary.
- Increased rates of coastal erosion and land sliding leading to losses in agricultural land and property.
- Growing concern regarding tidal flood risks potentially leading to “insurance blight” for businesses and households and a reduction in inward investment into these priority areas due to the high risk of flooding.

Rising sea levels have many other impacts on the coastal environment and on river water quality, for example:-

- Changing sea temperatures that will affect the type and quantity of fish stocks. The area has already seen a reduction in cod stocks and an increase in red mullet due partly to warming waters (see Section 6.1.2).
- A possible increase in the likelihood of algal growth in coastal waters.
- More difficult maritime conditions affecting shipping.

Coastal Erosion

The rise in sea levels may increase erosion rates at the coast. Slumping on the soft glacial drift cliffs will also increase due to greater rainfall in winter and during storms.

The loss of salt mashes and mudflats in the Humber Estuary due to future sea level rise is identified in the Humber Estuary SMP, and the creation of replacement areas is highlighted as a priority. This process will be considered in a Coastal Habitat Management Plan (CHaMP). The creation of replacement habitat is also essential in meeting the Regional Sustainable Development Framework Aim for a biodiverse and attractive natural environment. Two of the targets for this aim are ‘zero loss to areas of priority habitat’ and ‘no decrease in wild bird populations’. Managed realignment schemes addressing these issues are in progress at Paull (Thorngumbold) and in the planning stage at a number of other sites including Alkborough.

5.1.4 Opportunities

There are potential “wins” for the coastal zone, such as the development of new forms of tourism and recreation to take advantage of the warmer climatic conditions. The main business
opportunities relate to increasing the tourism potential of the coastal areas and providing services to mitigate against climate extremes for example:-

- Development of new forms of low impact tourism along the Yorkshire coast.
- Development of new flood proofing and flood protection products.
- Specialist services to reduce the risks of supply chain or utility disruption due to flooding and specialist insurance products and schemes to insure property in the tidal floodplain.
- Opportunities to create new habitats as part of the policy of managed retreat, e.g. the Environment Agency has is in the process of identifying suitable coastal sites for the managed realignment of embankments to create approximately 1000 hectares of intertidal habitat on former agricultural land.
- Relocation of industry and business away from the coast to green field sites as part of “roll-back” policies.

- Increase coastal erosion and landsliding.
- Increase rates of coastal squeeze of important intertidal habitats.
- Potential benefits of increased temperatures on the tourist industry that may help towards the regeneration of the coastal zone. However other changes are needed, e.g. public perceptions about the reliability of the region’s weather will need to improve and the region needs to be marketed to attract visitors.

5.1.5 Conclusions

The coastal zone of the Yorkshire and Humber region is diverse, in terms of geology, ecology and human-use. It is an important area for industry and has been designated as an area for regeneration in the RPG.

Impacts of climate change

The main impacts of climate change across the full range of scenarios are:-

- Sea level rise at average rates of up to 9 mm per year along the region’s coastline (High Emissions scenario = 75 cm by 2080s). Local changes in geomorphology may accentuate these relative sea level changes.
- Increased risks of tidal flooding including the overtopping, bypassing and breaching of coastal defences due to a combination of sea level rise and changing patterns of storminess.
- Increased flood risks will affect many coastal industries.
- A larger area of land within the tidal floodplain, specifically a larger area of land within the 1 in 200 year tidal floodplain that will be defined at risk following PPG25 guidelines.
- Local authorities have serious concerns relating to the conflict between the Indicative Floodplain, the existing use of this land and future development. The development of Strategic Flood Risk Assessments by local authorities should be an opportunity to resolve differences between flood and coastal defence management and planning. The East Riding of Yorkshire Council is one of the first to produce a Strategic Flood Risk Assessment. They see this as a first attempt, which highlights the areas most at risk, but which will require ongoing refinement. In North East Lincolnshire the influence of embanked roads and railways has not been considered in defining the Indicative Floodplain. Refinement is therefore critical, not only for decision-making concerning insurance and development, but also in assessing the impacts of climate change.

One area where flood and coastal defence and land planning has been considered more holistically relates to coastal squeeze and potential habitat loss. Initiatives such as CHaMPs and action by landowners such as ABP should ensure that the internationally important wetlands of the Humber Estuary are managed in a sustainable way.

Significance to/for stakeholders and adaptation responses

In contrast to the situation in other sectors, organisations with an interest in the coastal zone are well aware of the impacts of climate change. In SMPs there now exists a good system to assess the nature of the coastal environment down to the local scale and to recommend future management options that take into account the effects of climate change. Adequate funding will be needed to ensure that vulnerable areas receive adequate protection.
Yorkshire and Humber Climate Change Impact Scoping Study
Draft Final Report

Scarborough Borough Council are actively involved in flood defence improvement schemes in Scarborough and have just submitted a Strategic Flood Risk Assessment for Whitby to the Environment Agency. Their main concern is for no reduction in central government funding for flood defence schemes, the cost of which cannot be borne locally. For example, a current project to improve defences along a 2.1 km stretch between East Pier and North Bay cost £28 million. The Council use visual and geotechnical monitoring to detect changes in cliff geomorphology. This kind of monitoring will greatly assist in planning appropriate responses.

Following a review of the first generation of SMPs (MAFF, 2000b), improved guidance for Operating Authorities has been issued (MAFF, 2000c). Future revisions will focus on flooding and coastal erosion risks over the next 50 years, taking into account longer term implications of climate change. The review also highlighted the need to integrate SMPs more effectively with other coastal plans and the planning system in general.

MAFF (now DEFRA) have also produced a suite of Flood and Coastal Defence Project Appraisal Guidance (FCDPAG) documents, which not only advise on likely sea level rise, but also consider the impacts of climate change adaptation measures. DEFRA are also involved in the Humber CHaMP and research concerning the future of the region’s coastline.

ABP work closely with the Environment Agency to ensure that their own flood defences are able to cope with future changes in sea level and surge frequency. A survey regime checks channel markings and depths are safe. To offset the impacts of habitat loss resulting from climate change, ABP have leased land adjacent to the Humber Estuary to be managed for conservation purposes.

The North East Sea Fisheries Committee are keen to see an increased awareness of climate change as an issue. Further research into the possible impacts of climate change on fish stocks, as has been completed for cod fisheries, would be beneficial.

**Targets and Indicators**

Mean sea levels, extreme sea levels and changes in storm conditions should be monitored in light of climate change. There should be no reduction in the current monitoring network and this should be reviewed to ensure that monitoring is frequent enough to detect changes in tidal conditions over the next 20 years.

Both Scarborough Borough Council and the North East Sea Fisheries Committee are monitoring key variables relevant to their duties. This is an excellent way of assessing the nature of climate change in the region and also in planning appropriate adaptation measures.

**Information gaps and uncertainties**

There are still uncertainties concerning sea level rise, largely due to the complexities surrounding global sea level change and future ice melt. The range of mean sea level rise suggested by the UKCIP02 scenarios is subsequently very large.

Changes in storminess are also uncertain and further work is required into the combined impacts of rising sea levels, changing surge conditions and wave patterns on coastal flooding and erosion.

**Targets and Indicators**

Mean sea levels, extreme sea levels and changes in storm conditions should be monitored in light of climate change. There should be no reduction in the current monitoring network and this should be reviewed to ensure that monitoring is frequent enough to detect changes in tidal conditions over the next 20 years.

Both Scarborough Borough Council and the North East Sea Fisheries Committee are monitoring key variables relevant to their duties. This is an excellent way of assessing the nature of climate change in the region and also in planning appropriate adaptation measures.
5.2 Drainage, rivers and floodplains

5.2.1 Introduction

Increased winter rainfall, increased winter rainfall intensities, reductions in summer rainfall and increases in temperature will have impacts upon the region’s drainage systems and rivers. This section describes the potential impacts of climate change on the region’s urban and rural drainage systems, rivers and low lying river floodplains. Water quality is discussed in the following section on water resources.

5.2.2 Background

The main rivers of the region include the Esk, parts of the Tees and Ribble and those draining into the Humber Estuary: the Trent, Ouse, Aire, Don, Derwent, Wharfe, Hull and Ancholme.

Historically there has been a lot of development in the floodplain. Large areas have been drained for agriculture, industrial development and housing development. Today, the region has more assets at risk of riverine flooding than any other region with the exception of the Thames Estuary. There is a shortage of suitable building land outside the floodplain and consequently a large amount of the land allocated as regeneration areas in RPG16 is within the indicative floodplain.

Flood risks cannot be avoided but the risks can be reduced through a combination of improved flood defences, flood forecasting and warning, flood proofing and the prevention of inappropriate development within the floodplain.

Urban areas outside river floodplain also have drainage problems. Drainage systems in Leeds, Bradford and Sheffield and towns such as Huddersfield, were built largely in the 19th century. These systems were well built but they were not designed to the same standard (for flooding and water quality control) as modern systems and many drains are now falling into disrepair.

Flood defence

Flooding is potentially a huge problem in the region. Indicative floodplain maps show that 286,973 properties were at risk of flooding in 20016. Flood defence is the responsibility of the Environment Agency, DEFRA, Inland Drainage Boards (IDBs) and local authorities. The Environment Agency, which is responsible for flood forecasting, flood warning and the operation of flood defences on main rivers, maintains nearly 1,500 km of defences within the region.

DEFRA is promoting a strategic approach to catchment planning and jointly funding research into flood defence with the Agency. IDBs are responsible for managing land drainage for their members, normally farmers, and may carry out flood defence works on ‘non-main’ rivers. Local authorities may also undertake flood defence works on similar watercourses and outside IDB districts. In addition, many flood defences are privately owned and maintained for example, by the Highways Agency, Railtrack and other landowners. Therefore responsibilities and ownership of flood defences are both split between several stakeholders depending on the nature of the water course.

Following recommendations in the 1998 House of Commons Agriculture Select Committee Report on Flood and Coastal Defence, MAFF (now DEFRA) published High Level Targets for the ‘operating authorities’ (i.e. the Environment Agency, local authorities and internal drainage boards).

These took effect from April 2000

"and generally relate to the provision and collection of information, the preparation of policy statements and ensuring arrangements are in place to gather details about the status of flood defences and allow for their inspection. The aim is to encourage, share and build on best practice and achieve a greater consistency in approach by all authorities in their flood defence activities."

The targets are intended to facilitate a more certain delivery of national policy and strategy for flood and coastal defence.

---

6 Environment Agency website (www.environment-agency.gov.uk)
Following these recommendations DEFRA and the Environment Agency are promoting a more strategic approach to flood defence that involves Flood Strategy Plans and Catchment Flood Management Plans (CFMPs).

The region’s flood defences

Reports prepared prior to the floods of Autumn 2000 show that the Environment Agency’s – North East Region’s flood defences were in a worse condition than other regions of England and Wales. 65 per cent of these are classified as ‘fair’, which indicates some cause for concern and the need for careful monitoring.

Nearly a quarter of the defences on the rivers Aire, Don, Ouse, Swale, Ure, Wharfe and Nidd were classified as ‘poor’ or ‘very poor’: unsound or derelict. The Esk was the only river in the region with defences not in need of repair. The floods prompted the needed £2.5 million additional funding to repair the region’s defences. Flood defence schemes were planned in 2001-2002 for Wakefield, Calderdale, Malton and the Humber Estuary. These are in progress or due to start shortly.

Development in the floodplain

The Environment Agency generally advises against any new development on floodplains. Local authorities need to balance flooding issues with other issues, such as social and economic development, and may allow development in exceptional cases. Insurers may refuse to cover new developments in the floodplain.

Development in the floodplain is now guided by Planning Policy Guidance Note 25 (PPG25) that sets out a “sequential test” that defines the permissible development in areas with different levels of flood risks.

The Autumn 2000 floods in Yorkshire

The Autumn 2000 floods followed an unprecedented period of heavy rainfall from repeated frontal depressions passing over the UK. In Yorkshire and Humberside the normal amount of rainfall for October and November fell within a two week period between 26th October and 8th November causing widespread flooding due to the overtopping and outflanking of flood defences, river flooding in areas that were not protected and local drainage problems. These flood events cannot be linked directly to a changing climate. However they illustrate a trend of increasingly heavy long duration rainfall events and peak flows that is most likely due to a combination of changing land use, natural climate variability and climate change. The UKCIP02 scenarios suggest a continuation of this trend of increasing heavy rainfall. For the RCM grid square over York high monthly rainfall totals (equivalent to 8mm per day or the 1 in 50 year event for the present climate) are expected to increase by approximately 10% by the 2090s for the Low Emissions scenario. Flood events with return periods of 1 in 50 years and above are expected to increase in frequency 5 to 10-fold over the same period.

The region’s rivers are important for transport, amenity, water abstraction and transfer, the dilution of treated effluents and for the habitats they provide for fish and other wildlife. Changing patterns of flood risks will impacts on all these functions. The new CFMPs should provide closer integration between flood defence and other Environment Agency functions.

The region’s flood defences

Reports prepared prior to the floods of Autumn 2000 show that the Environment Agency’s – North East Region’s flood defences were in a worse condition than other regions of England and Wales. 65 per cent of these are classified as ‘fair’, which indicates some cause for concern and the need for careful monitoring.

Nearly a quarter of the defences on the rivers Aire, Don, Ouse, Swale, Ure, Wharfe and Nidd were classified as ‘poor’ or ‘very poor’: unsound or derelict. The Esk was the only river in the region with defences not in need of repair. The floods prompted the needed £2.5 million additional funding to repair the region’s defences. Flood defence schemes were planned in 2001-2002 for Wakefield, Calderdale, Malton and the Humber Estuary. These are in progress or due to start shortly.

Development in the floodplain

The Environment Agency generally advises against any new development on floodplains. Local authorities need to balance flooding issues with other issues, such as social and economic development, and may allow development in exceptional cases. Insurers may refuse to cover new developments in the floodplain.

Development in the floodplain is now guided by Planning Policy Guidance Note 25 (PPG25) that sets out a “sequential test” that defines the permissible development in areas with different levels of flood risks.

The Autumn 2000 floods in Yorkshire

The Autumn 2000 floods followed an unprecedented period of heavy rainfall from repeated frontal depressions passing over the UK. In Yorkshire and Humberside the normal amount of rainfall for October and November fell within a two week period between 26th October and 8th November causing widespread flooding due to the overtopping and outflanking of flood defences, river flooding in areas that were not protected and local drainage problems. These flood events cannot be linked directly to a changing climate. However they illustrate a trend of increasingly heavy long duration rainfall events and peak flows that is most likely due to a combination of changing land use, natural climate variability and climate change. The UKCIP02 scenarios suggest a continuation of this trend of increasing heavy rainfall. For the RCM grid square over York high monthly rainfall totals (equivalent to 8mm per day or the 1 in 50 year event for the present climate) are expected to increase by approximately 10% by the 2090s for the Low Emissions scenario. Flood events with return periods of 1 in 50 years and above are expected to increase in frequency 5 to 10-fold over the same period.

The region’s rivers are important for transport, amenity, water abstraction and transfer, the dilution of treated effluents and for the habitats they provide for fish and other wildlife. Changing patterns of flood risks will impacts on all these functions. The new CFMPs should provide closer integration between flood defence and other Environment Agency functions.

The Autumn 2000 floods in Yorkshire

The Autumn 2000 floods followed an unprecedented period of heavy rainfall from repeated frontal depressions passing over the UK. In Yorkshire and Humberside the normal amount of rainfall for October and November fell within a two week period between 26th October and 8th November causing widespread flooding due to the overtopping and outflanking of flood defences, river flooding in areas that were not protected and local drainage problems. These flood events cannot be linked directly to a changing climate. However they illustrate a trend of increasingly heavy long duration rainfall events and peak flows that is most likely due to a combination of changing land use, natural climate variability and climate change. The UKCIP02 scenarios suggest a continuation of this trend of increasing heavy rainfall. For the RCM grid square over York high monthly rainfall totals (equivalent to 8mm per day or the 1 in 50 year event for the present climate) are expected to increase by approximately 10% by the 2090s for the Low Emissions scenario. Flood events with return periods of 1 in 50 years and above are expected to increase in frequency 5 to 10-fold over the same period.

The region’s rivers are important for transport, amenity, water abstraction and transfer, the dilution of treated effluents and for the habitats they provide for fish and other wildlife. Changing patterns of flood risks will impacts on all these functions. The new CFMPs should provide closer integration between flood defence and other Environment Agency functions.

Development in the floodplain

The Environment Agency generally advises against any new development on floodplains. Local authorities need to balance flooding issues with other issues, such as social and economic development, and may allow development in exceptional cases. Insurers may refuse to cover new developments in the floodplain.

Development in the floodplain is now guided by Planning Policy Guidance Note 25 (PPG25) that sets out a “sequential test” that defines the permissible development in areas with different levels of flood risks.

The Autumn 2000 floods in Yorkshire

The Autumn 2000 floods followed an unprecedented period of heavy rainfall from repeated frontal depressions passing over the UK. In Yorkshire and Humberside the normal amount of rainfall for October and November fell within a two week period between 26th October and 8th November causing widespread flooding due to the overtopping and outflanking of flood defences, river flooding in areas that were not protected and local drainage problems. These flood events cannot be linked directly to a changing climate. However they illustrate a trend of increasingly heavy long duration rainfall events and peak flows that is most likely due to a combination of changing land use, natural climate variability and climate change. The UKCIP02 scenarios suggest a continuation of this trend of increasing heavy rainfall. For the RCM grid square over York high monthly rainfall totals (equivalent to 8mm per day or the 1 in 50 year event for the present climate) are expected to increase by approximately 10% by the 2090s for the Low Emissions scenario. Flood events with return periods of 1 in 50 years and above are expected to increase in frequency 5 to 10-fold over the same period.

The region’s rivers are important for transport, amenity, water abstraction and transfer, the dilution of treated effluents and for the habitats they provide for fish and other wildlife. Changing patterns of flood risks will impacts on all these functions. The new CFMPs should provide closer integration between flood defence and other Environment Agency functions.

Development in the floodplain

The Environment Agency generally advises against any new development on floodplains. Local authorities need to balance flooding issues with other issues, such as social and economic development, and may allow development in exceptional cases. Insurers may refuse to cover new developments in the floodplain.

Development in the floodplain is now guided by Planning Policy Guidance Note 25 (PPG25) that sets out a “sequential test” that defines the permissible development in areas with different levels of flood risks.

The Autumn 2000 floods in Yorkshire

The Autumn 2000 floods followed an unprecedented period of heavy rainfall from repeated frontal depressions passing over the UK. In Yorkshire and Humberside the normal amount of rainfall for October and November fell within a two week period between 26th October and 8th November causing widespread flooding due to the overtopping and outflanking of flood defences, river flooding in areas that were not protected and local drainage problems. These flood events cannot be linked directly to a changing climate. However they illustrate a trend of increasingly heavy long duration rainfall events and peak flows that is most likely due to a combination of changing land use, natural climate variability and climate change. The UKCIP02 scenarios suggest a continuation of this trend of increasing heavy rainfall. For the RCM grid square over York high monthly rainfall totals (equivalent to 8mm per day or the 1 in 50 year event for the present climate) are expected to increase by approximately 10% by the 2090s for the Low Emissions scenario. Flood events with return periods of 1 in 50 years and above are expected to increase in frequency 5 to 10-fold over the same period.

The region’s rivers are important for transport, amenity, water abstraction and transfer, the dilution of treated effluents and for the habitats they provide for fish and other wildlife. Changing patterns of flood risks will impacts on all these functions. The new CFMPs should provide closer integration between flood defence and other Environment Agency functions.

Development in the floodplain

The Environment Agency generally advises against any new development on floodplains. Local authorities need to balance flooding issues with other issues, such as social and economic development, and may allow development in exceptional cases. Insurers may refuse to cover new developments in the floodplain.

Development in the floodplain is now guided by Planning Policy Guidance Note 25 (PPG25) that sets out a “sequential test” that defines the permissible development in areas with different levels of flood risks.

The Autumn 2000 floods in Yorkshire

The Autumn 2000 floods followed an unprecedented period of heavy rainfall from repeated frontal depressions passing over the UK. In Yorkshire and Humberside the normal amount of rainfall for October and November fell within a two week period between 26th October and 8th November causing widespread flooding due to the overtopping and outflanking of flood defences, river flooding in areas that were not protected and local drainage problems. These flood events cannot be linked directly to a changing climate. However they illustrate a trend of increasingly heavy long duration rainfall events and peak flows that is most likely due to a combination of changing land use, natural climate variability and climate change. The UKCIP02 scenarios suggest a continuation of this trend of increasing heavy rainfall. For the RCM grid square over York high monthly rainfall totals (equivalent to 8mm per day or the 1 in 50 year event for the present climate) are expected to increase by approximately 10% by the 2090s for the Low Emissions scenario. Flood events with return periods of 1 in 50 years and above are expected to increase in frequency 5 to 10-fold over the same period.

The region’s rivers are important for transport, amenity, water abstraction and transfer, the dilution of treated effluents and for the habitats they provide for fish and other wildlife. Changing patterns of flood risks will impacts on all these functions. The new CFMPs should provide closer integration between flood defence and other Environment Agency functions.
### The PPG25 sequential test classes (abridged)

1. **Little or no risk. Annual probability of flooding**: River, tidal & coastal <0.1% No constraints due to river, tidal or coastal flooding  
2. **Low to medium risk. Annual probability of flooding**: River 0.1-1.0% Tidal & coastal 0.1-0.5% Suitable for most development.  
3. **High risk. Annual probability of flooding, with defences where they exist**: River 1.0% or greater Tidal & coastal 0.5% or greater  
   a. **Developed areas**  
      These areas may be suitable for residential, commercial and industrial development provided the appropriate minimum standard of flood defence (including suitable warning and evacuation procedures) can be maintained for the lifetime of the development (see paragraph 31 below), with preference being given to those areas already defended to that standard.  
   b. **Undeveloped & sparsely developed areas**  
      These areas are generally not suitable for residential, commercial and industrial development unless a particular location is essential, e.g. for navigation and water-based recreation uses, agriculture and essential transport and utilities infrastructure, and an alternative lower-risk location is not available.  
   c. **Functional flood plains**  
      These areas may be suitable for some recreation, sport, amenity and conservation uses (provided adequate warning and evacuation procedures are in place). Built development should be wholly exceptional and limited to essential transport and utilities infrastructure that has to be there.

### Flood warning

Rivers in Yorkshire are characterised by their “flashy” response to rainfall. This means that there is only a matter of hours between the occurrence of heavy rainfall events in the Pennines and peak flows in the region’s rivers. This makes flood forecasting and warning difficult as there is insufficient time to act in response to forecasts. The region is investing in advanced flood forecasting systems and increasing the awareness of people living and working in floodplain about flood risks.

### 5.2.3 Impacts

#### Changing flood risks

The Autumn 2000 floods devastated parts of Yorkshire that were amongst the worst affected parts of the UK. While these events can’t be linked directly to climate change they were linked widely in the media. With costs in the region nationally of £1 billion the events were seen by some as “… the first bill for global warming?”

All the climate change scenarios suggest an increase the total amount of rainfall falling in winter. Currently a winter with more than 160% of normal (1961-90) rainfall is expected to occur once in every 13 years. Under the UKCIP02 **High Emissions** scenario this amount of rainfall will occur almost every year.

The main impact of climate change is likely to be increased flood risks in terms of flood magnitude (peak levels and volumes) and the frequency of flooding in winter months. Areas at risk include the Vale of York and other river floodplains as indicated in Fig 5-1. The increase in winter rainfall intensity (Fig. 4-3) will also cause increased urban flooding in areas outside the existing floodplain.

Climate change will affect flood risks in the following ways:

- Change the number of days when catchment soils are “wet” (with soil moisture deficits of less than 6mm). Soils will be much wetter all winter increasing flood risks  
- Reduce the amount of storage in catchment soils and surfaces in winter months  
- Increased baseflows throughout the year  
- Increased winter rainfall intensity will increase the “peakiness” of urban runoff and river flood hydrographs  
- Increased winter rainfall volumes will increase the volume of flood hydrographs which is a particular problem if flood defence relies on storage in washlands or behind flood defence barriers.  
- Increased frequency and prolonged inundation may weaken flood defences.  
- Increased vegetation growth due to increased temperatures may increase channel roughness and therefore flood levels

In a major departure from the UKCIP98 scenarios the UKCIP02 scenarios suggest that Autumns will be drier throughout the region and that Springs will be drier in inland areas.
This means that flood risks will change in the other seasons and that it is possible that flood risks are actually reduced for a period at the beginning of the “flood season” in September. This is the subject of an ongoing research project by DEFRA and the Environment Agency.

The Environment Agency and DEFRA are aware of the potential impacts and current guidance suggests that an increase in the volume of river flow by 20% should be used to account for impacts on peak river flows. This is implicit in PPG25 guidance and has been used as a sensitivity test in the Environment Agency’s Section 105 studies. Implementation of this guidance will place much more land within the indicative river floodplain (with climate change). For example in the case of the River Aire Section 105 Study an increase in flow by 20% was found to be equivalent to using a 1 in 200 year rather than a 1 in 100 year return period flood. The allowance amounted to an increase of 0.25m in water levels after the increased flows had been run through a hydraulic river model.

Improved guidance on how to incorporate climate change into flood risks assessment will be issued in the near future by the Environment Agency and DEFRA.

Maintaining defences

One interesting impact that has not been previously highlighted in other sub-UK scoping studies is the potential impacts on the reliability of the region’s flood defences. The traditional approach to flood defences in the region includes the construction of river banks and barrier banks and the use of washlands for storing flood water. The importance of storage areas was clear from the Autumn 2000 flooding as many of the cities identified as major “near misses”, such as Leeds and Doncaster, were saved by the storage provided in washlands.

The banks in Yorkshire have been constructed using compacted earth and were designed to hold back water during infrequent extreme flooding events. The construction standards of these defences are much lower than those for reservoirs and dams but the consequences of a breach can be just as severe. These banks were not designed to cope with regular saturation and this is a concern with climate change as more frequent flooding and the wetting and drying of these embankments may decrease their stability and increase the risk of dramatic bank failure.

New and improved flood defence schemes will be required in some areas, while in those areas where reducing the risk of flooding through defences is not viable (economically or otherwise) it will be necessary to improve flood warning schemes and emergency response.

Urban drainage problems

Increased intensity of urban rainfall will lead to more urban flooding problems. For example, the frequency of days in Leeds with more than 30mm of rain falling in one day will double by the 2080s. This has implications for drainage in urban areas, where stormwater systems may require upgrading. Modern urban drainage systems are designed to store excess storm water in tanks, tunnels and ponds to ensure that large pulses of urban runoff are released at a controlled rate. Changes in the frequency of extreme rainfall events will mean that these in-built safety mechanisms will be used more often and become less effective leading to more flooding in urban areas.

In response to concerns about flood risks and water quality issues there is an increasing interest in Sustainable Urban Drainage Systems (SUDS). PPG25 promotes the use of SUDS and all new development should now consider implementing SUDS as part of the planning process. SUDS can also be retro-
fitted and this has happened with local authority housing in Leeds.

However there are some problems with SUDS that need to be resolved. For example, there are issues relating to maintenance and health and safety responsibilities. One well known concern is for children’s safety when new housing is located alongside ponds and open grass channels.

**Perceptions of flood risk**

Local authorities need better delineation of flood risks that that provided in the IFPM. There also needs to be guidance on criteria that can be used to help decision makers rule of development proposals in the floodplain.

Some stakeholders believe that the stance of no development in the floodplain is simply untenable in the region and would compromise the region’s development objectives.

“My husband lost his business and our home was uninhabitable for eight months. The Government promised an extra £51 million but we haven’t seen a penny. They have put a temporary piling on the river bank, but we are still living in fear.” Resident of Barlby, N. Yorks.

The Environment Agency recognises that flood defences need to be sustainable and they are not just considering increasing the levels of flood defences throughout the region. Improved catchment management can contribute significantly to reducing flood risks. Changes in land management practices in the headwater catchments can provide additional storage so that more rainfall is stored in soils and more flood water is stored in natural floodplains in the upper reaches. Both these processes will reduce flood levels downstream in more urban areas.

There have been concerns that flood defence schemes have been planned in an ad-hoc way to provide local protection while possibly increasing flood risks downstream. Climate change provides a driver to finally developed integrated catchment plans and to address the problems at source i.e. in headwater catchments where runoff is generated, often due to poor land husbandry.

The sequential test approach of PPG25 places most development land in the high risk classes and a more detailed delineation of flood risks is required to inform planners on where the development could go ahead with appropriate safeguards in place, like flood proofing, flood warning and evacuation procedures. Within high risk areas, variations in ground elevations, locations of flood flow paths and other factors mean that there is, in fact, a range of different levels of flood risk. It is important for any new development to be located in the relatively low risks areas, with appropriate engineering measures on-site and possibly compensation works to control flooding at source, to reduce flood risks. For example developers could restore wetlands upstream of sites in the same way that compensation managed retreat sites are required for coastal development.

**5.2.4 Opportunities**

Increased flood risks provide few direct opportunities with the exception of:-

- Development of new flood proofing and flood protection products, such as steel flood gates
- Specialist services to reduce the risks of supply chain or utility disruption due to flooding and specialist insurance products and schemes to insure property in the tidal floodplain

However, climate change provides an added incentive to develop more sustainable drainage in urban and rural areas, change land use practices and to develop “win-win” situations that reduce flood risks and create new wetland habitats.

In urban areas SUDS schemes can be developed with multi-purpose aims, such as reduction in flooding, improving water quality, water conservation and providing urban green space. An example of a SUDS is illustrated in Figure 5-2. SUDS require more space that traditional drainage systems, water can be encouraged to infiltrate rather than runoff and be drained slowly in gravel trenches; trees can be planted that will use the drainage water, rather than requiring watering, and provide shade during the hotter summer months.
Figure 5.2 Permeable pavement, gravel drains and tree catch pits designed to slow rates of urban runoff and improve water quality

In rural areas, changes in land use policy mean that set-aside land could be targeted in headwater catchment floodplains to provide flood water storage and create wetland habitats.

5.2.5 Conclusions

Impacts of climate change

Increased and more intense winter rainfall is suggested under all the scenarios (UKCIP02 figures). In terms of fluvial flood risks this will mean that:

- Flooding events are likely to occur more frequently due to a combination of factors, such as increase catchment wetness, rainfall intensity and rainfall depth.
- The area at risk from flooding, defined in the IFPM as areas that flood with an annual probability of 1%, will grow. Levels of the 1% probability flood will increase of the order of 0.25 m.
- Flood banks designed for infrequent use will be in use more often, leading to a higher risk of breach and the need for much more regular monitoring and maintenance.
- Urban drainage systems will not be able to cope with the increase intensity of winter rainfall events leading to more urban flooding and the disruption of urban transport systems.

Significance to/for stakeholders and adaptation responses

The changing nature of flooding has important implications for the Environment Agency, local authorities, Yorkshire Forward, the RDA, nature conservation groups and anyone living and working in areas at risk.

One of the Environment Agency’s stated long term objectives is to reduce flood risks: “Flood warnings and sustainable defences will continue to prevent deaths from flooding. Property damage and distress will be minimised. The role of wetlands in reducing flood risks will be recognised and all the environmental benefits from natural floods will be maximised.” (Environment Agency, 2000).

Specific Environment Agency responses to the Autumn 2000 floods included:

1. Monitoring of the stability of flood banks to minimise the risk of breaches. This can be achieved using a range of non-invasive survey techniques such as ground penetrating radar;
2. Research into the factors affecting bank stability with the aim of producing models that can quantify the affect of increasing inundation frequency on bank stability and subsequent flood risks;
3. Improved management of washlands, for example optimisation of washland operations;
4. Examine the feasibility of reclaiming agricultural land through set-aside and other schemes to create more washlands for flood defence and environmental benefits.
Local authorities have made some progress in strategic flood risks assessment and the Yorkshire and Humber Assembly have welcomed and promoted a more strategic regional approach to flood risks.

Next steps

Further work within the region is required in several areas. For example, the role of land use change and its influence on flood risks has not been considered in detail and further research may be required in addition to the CFMPs.

A greater understanding and development of the region’s implementation of PPG25 is required. For example the high risk class of the “sequential test” needs to be mapped in more detail based upon the outputs of Section 105 studies and further work. Workshops between planning authorities, developers, the Environment Agency and their consultants may play a useful part in this process.

Targets and Indicators

As well as contributing to DEFRA’s high level targets for flood defence in England and Wales, there are other potential targets and indicators relevant to Yorkshire and the Humber, for example:-

- The percentage of agricultural land restored to washlands
- The number of households refused flood insurance as part of homes and contents insurance
- A reduction in length of flood defence classified as “poor” or “very poor”

Information gaps and uncertainties

There are still some uncertainties, for example:-

- There is a requirement for further guidance on considering climate change and fluvial flood defence (Underway nationally DEFRA/EA project)
- Water companies require guidance on the impacts on urban drainage and sewerage systems. (Underway as a UKWIR Ltd. Project)
- Interactions between changes to fluvial and tidal flood risks including combined probability analysis that considers the impacts of UKCIP02 scenarios on the Humber Estuary

5.3 Water Resources

5.3.1 Introduction

Water resources will be affected by a changing climate in terms of the overall quantity of water in rivers and groundwater, the seasonality or timing of recharge and runoff and water quality. The overall balance between the demand for water for household use, industry and agriculture and the supply depends on changing social and economic conditions as well as the variation in climate conditions.

5.3.2 Background

In simple terms the amount of water in rivers and groundwater depends upon the “effective rainfall” or balance between rainfall and evapotranspiration. The region has a variable distribution of annual rainfall with over 1400 mm per year falling in the Pennines and approximately half this amount falling in the south east areas around Hull. In average years the effective rainfall that reaches rivers and groundwater is around 350 mm. Parts of the region are as “dry” as the south east and are vulnerable to drought.

Water resource planning

The Water Resources Planning Guideline published by the Environment Agency in February 1998 sets out the way in which the Agency required water companies to prepare and present their Water Resource Plans; these plans cover the period up to 2024/25. The Guideline recommended standard methodologies to be followed in the assessment of various components of the supply/demand balance, and how these should be brought together to take account of uncertainties. In the context of climate change the most important of these methodologies are:


The first study found that the annual average recharge to aquifers and the average winter river flow would increase under all climate scenarios in the north east. There were
reductions in average summer flow in late summer for rivers dominated by groundwater and throughout the summer for rivers with low groundwater inputs. These results suggest that hydrological yields will not be adversely affected by climate change and that the only problem will be related to particular summer abstractions that rely on reasonable summer flows.

In parallel with the Water Resources Plans, water companies have also prepared Business Plans for OFWAT that were submitted at the beginning of April 1999. The Business Plans cover the much shorter period up to 2009/10. Each of these planning horizons is much shorter than the timescale often associated with climate change, and indeed those given under the UKCIP scenarios as discussed in earlier sections.

**Water supply**

The region’s water is supplied from groundwater aquifers, like the Sherwood Sandstone and Chalk of the Yorkshire Wolds; direct river abstractions from rivers like the Ouse and Derwent and groups of small reservoirs, particularly to the west of Halifax, Huddersfield and Sheffield.

The largest percentage of water abstracted is for public water supplies but other important regional uses include agricultural irrigation, electricity generation and other industrial cooling.

Some communities rely on private water supplies in both rural and urban areas, for example there are more than 600 households in the Bradford district alone.

The availability of water is affected directly by climate variation. Small reservoirs and direct river abstractions are most at risk and may suffer following a single dry winter. Groundwater sources are more robust, particularly the sandstone aquifers that respond slowly to changes in effective rainfall.

**Water demand**

The demand for water is affected directly and indirectly by climate variation. For domestic households, out of house uses, such as garden watering and car washing, are most affected by climate conditions with large increases in water consumed during hot, dry periods. For agriculture, there is a direct relationship between climate and the amount of water used on irrigated crops. This is particularly the case for main crop potatoes, and one recent case study of potatoes in the Vale of York suggested an increase in water use of between 10% and 19% (Environment Agency, 2001). The economics of potato production is such that farmers would consider paying for water from public supply if direct abstractions were unavailable due to license constraints or insufficient river flows or groundwater levels.

For industrial uses of water the relationship between climate and demand is more complex. In some sectors, such as tourism, there is a distinct seasonal pattern of water use that is partly due to climate and partly due to other factors, such as an increase in visitor numbers and outdoor recreation during the summer period. In manufacturing, water use is mostly related to production rates rather than climate conditions.

**The 1995-1996 Drought**

The 1995-1996 drought had a significant impact on the Yorkshire and Humber region. The region as a whole had suffered similar droughts in the past, for example in 1954, 1973 and 1976 but 1995-1996 was acutely severe in the western Pennines. For example at Lindley Wood reservoir the drought was the most severe on record and lasted for some 20 months (Goldsmith, *et al.*, 1997). Many communities in South Yorkshire depended upon local water supplies and when these “ran dry” the only solution was to transport water by tanker from other areas with surplus supply. Since then Yorkshire Water have invested heavily in improving their distribution system so water can be transported from areas with a surplus supply to those with a shortage of water. However, there are still many small reservoir developments in the south that supply large populations, so the south is more susceptible to drought than areas to the north of the region (Environment Agency, 2001). The Environment Agency suggests that the region has “medium” vulnerability to one dry winter and “high” vulnerability to a two year plus drought.

**Water quality**

Water pollution is derived from a range of point and diffuse sources. The impact of point sources of pollution such as sewage treatment works and manufacturing plants depends upon water treatment processes and the volume and quality of the receiving water. Water treatment processes may be affected by temperature but
water quality will be most affected by the volume of water available for dilution and within river processes affecting the oxygen balance. Diffuse sources include nutrients and pesticides derived from agriculture and sediments and other wastes derived from urban areas and drainage systems. The impact of these pollutants depends on a range of factors including rainfall-runoff relationships, land management practices, soil processes and drainage characteristics.

Water quality in the region has improved considerably over the last 20 years. However, there are still problems, particularly in urban catchments due to the combined sewer overflows.

<table>
<thead>
<tr>
<th>Table 5-4 Environment Agency Water Resource Recommendations and Alternative Actions for the north east</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>For public water supply, by 2010</strong></td>
</tr>
<tr>
<td>Water savings of up to 39 Ml/d and resource developments of up to 30 Ml/d</td>
</tr>
<tr>
<td>• Demand management options include metering and water efficiency measures</td>
</tr>
<tr>
<td>• Groundwater resource developments through aquifer artificial recharge and recovery in the Sherwood Sandstone</td>
</tr>
<tr>
<td><strong>For public water supply, by 2025</strong></td>
</tr>
<tr>
<td>Water savings (excluding current leakage control targets) of up to 85 Ml/d and resource developments of up to 90 Ml/d</td>
</tr>
<tr>
<td>• Demand management options include metering and water efficiency measures</td>
</tr>
<tr>
<td>• Surface water resource developments through a take on the River Aire upstream of Knostrop supported by bankside storage</td>
</tr>
<tr>
<td><strong>For agriculture, by 2025</strong></td>
</tr>
<tr>
<td>• Optimise use of existing licensed allocations through improved water efficiency</td>
</tr>
<tr>
<td>• Local groundwater development, where available</td>
</tr>
<tr>
<td>• Development of local winter storage reservoirs</td>
</tr>
<tr>
<td><strong>For industry and commerce, by 2025</strong></td>
</tr>
<tr>
<td>• Optimise use of existing licensed allocations through water minimisation initiatives</td>
</tr>
<tr>
<td>• Local groundwater resource developments, where available</td>
</tr>
<tr>
<td>• Utilise existing surface water resource developments</td>
</tr>
<tr>
<td><strong>For the environment</strong></td>
</tr>
<tr>
<td>• Reduction of 25 Ml/d in authorised quantities to move towards sustainable levels of abstraction</td>
</tr>
<tr>
<td><strong>Other options under consideration</strong></td>
</tr>
<tr>
<td>• A Kielder-supported transfer south into the Yorkshire Water supply system</td>
</tr>
<tr>
<td><strong>Other significant uncertainties</strong></td>
</tr>
<tr>
<td>• On-going and further investigations to confirm environmental needs</td>
</tr>
</tbody>
</table>


**Strategies**

As part of the national water resources strategy, the Environment Agency advocates a combination of minor resource development and demand management, the “twin-track” approach. Specific recommendations for the north east, including Yorkshire and the Humber, are outlined in Table 5-4.

**5.3.3 Impacts**

The climate scenarios for the Yorkshire and Humber region indicate a slight overall decrease in rainfall with large increase in winter and large reductions in summer. In a major departure from the UKCIP98 scenarios autumns are also expected to become significantly drier throughout the region.

The combination of changes in seasonal rainfall, temperature and evaporation can be expected to reduce effective rainfall while also increase the demand for water, for uses such as garden watering and personal consumption.

The main impacts on water resources include:-

- Greater average winter recharge to groundwater sources that is likely to increase the amount of water available and relieve the pressure on aquifers that are currently over-used.
- Higher river flows in the winter and much lower flows in the summer. This will provide positive benefits for water reservoirs but negative impacts on businesses that rely on abstracting from rivers in the summer months.
- Local seasonal and annual droughts may become more frequent. We need to use water more carefully during the summer months and water companies need to ensure that water can be distributed effectively throughout the region.
- Higher demands for water in the summer months from both households and some businesses, particularly in the large urban centres of Leeds and Sheffield.
- Agricultural needs for water will increase due to higher irrigation demand, particularly for potatoes, and increased demand nationally for seasonal salad products
- In urban areas “hard won” water quality improvements may be lost if increased winter rainfall intensity
leads to a greater frequency of urban sewer overflows into our rivers. Drainage systems in Bradford, Leeds and Sheffield need further investment to help improve water quality.

- In upland areas, including important drinking water reservoirs, water quality may deteriorate due to the release of organic soil materials that discolor water.
- In other areas water quality may improve due to increased river flows diluting pollution.
- Changing water quantity, quality and warming of rivers will affect fisheries. Some exotic species like Common Carp and indigenous species, like eels may benefit while other valued species, like brown trout, could be badly affected.

**Perceptions on managing water supply**

A fine balance will need to be met between maintaining reservoir levels and pumping from rivers. Water companies need to optimise water management practices to minimise the impact on the environment of pumping water from rivers like the Derwent in summer, while reducing pumping costs and consequently their greenhouse gas emissions.

The UKCIP scenarios suggest that there will be changes in the year to year variability of climate conditions as well as long term average conditions (Section 4). More recent water resources R&D has focused on the changing frequency of dry years and how this may affect minimum groundwater levels (WS Atkins, 2001). This work suggested that overall most groundwater sources in the north of England were likely to have increased minimum groundwater levels due to the increase in average winter rainfall. However, the results depended on the residence time of water within the aquifer and any systems where the groundwater drains annually were likely to suffer low levels more frequently.

**Drought frequency**

The probability of a single dry winter will increase with climate change due to changes in year to year variability.

Its unclear, how the frequency of a two year drought will change but it is most likely to occur less frequently under the climate change scenarios.

Therefore particular sources that fill and empty annually will be most at risk from climate change.

Climate change will impact on water quality in the following ways:-

- Any reduction in summer river flow will reduce the amount of water available for dilution. The overall load of pollution reaching the river will have to be reduced further to maintain current pollutant concentrations level.
- Increases in winter rainfall may increase the load of nutrients that runoff or are leached from agricultural systems.
- Increase in winter rainfall intensity will increase the frequency of CSO spills. Although the impact of these spill is greatest in summer when dilution is low.
- Changing soil processes due to increased temperature. This will lead to a release of organic minerals that will discolor water supplies.

Current pollution reduction policies such as the UWWT Directive are having a positive impact on pollution levels. In future, the main problems will be “exotic” pollutants such as endocrine disruptors that are difficult to remove from the water cycle.

**Perceptions of Fisheries**

Climate change could have both positive and negative impacts on the region’s fisheries. The life cycles of coarse and salmonid fish species are finely tuned to the seasonal fluctuation of water temperatures and river flows.

Some invasive species, such as Common Carp, need extremely warm summer conditions. A series of warm summers would allow very successful breeding of Common Carp which could out-compete valued indigenous species such as Brown Trout.

Rising temperatures could impact directly on salmonids (salmon and trout). If water temperatures rise over 20°C salmonids will suffer from heat stress, in addition, at these temperatures water quality is likely to deteriorate rapidly resulting in a deficit of dissolved oxygen.
5.3.4 Opportunities

Overall the water resources situation in the region should remain in balance with adequate water from groundwater sources. In other parts of the country, water resources will become less secure and water scarcity and pricing will begin to impact on industries in the south east of England. A more favourable water resource balance therefore presents an opportunity for Yorkshire and the Humber compared with regions with supply shortages.

Other opportunities include:-

- Improved water quality some rivers, not adversely affected by urban discharges.
- Changing chemical and physical river environments may provide opportunities for some conservation gain, for example by nurturing the spread of valued fish species that prefer warmer water conditions.
- The development of water efficient and leakage reduction technologies is an important growth area. In particular the development of technologies for industry that combine water efficiency with energy efficiency.
- The development of real-time control technologies for industrial abstractions and discharges.

5.3.5 Conclusions

Impacts of climate change

- Overall groundwater levels in Yorkshire and Humber will increase under the climate scenarios due to the increase in winter rainfall. The average hydrological output from sources in the region will remain unchanged or increase.
- Although the average situation will improve the increase variability of climate will mean that there will be increase risks of single drought years. Individual sources and water resource zones at risk and alternative emergency sources of water need to be identified as part of the water resource planning and drought contingency planning process.
- The demand for water will increase in warmer and drier summers. The impacts of these increases on water supply will depend upon water company strategies to manage demand, store excess winter available in the winter months and improvements in the water distribution network.
- Some types of agriculture, such as potato production will have a considerable increase in demand during the summer. This may be a problem where farmers rely of direct river abstraction.

Significance to/for stakeholders and adaptation responses

These impacts are important for water companies, the Environment Agency, water consumers, planners, fisheries and recreation and farmers.

The Environment Agency have already made considerable progress, stating their aims and objectives and vision for the future in their water resources strategy.

Yorkshire Water have improved the distribution network and are taking account of climate change in their long term planning.

Next steps

The UKCIP02 scenarios are significantly different in terms of their water resource impacts to the earlier ‘98 scenarios. Therefore stakeholders need to review strategies in light of these changes.

Further work is needed on secondary and tertiary impacts of changing resource base on water supply and river ecology. For example the changing seasonality of river flows will mean that the operation of water supplies will need to change to ensure that adequate water is stored in the winter to last through the drier summers.

Targets and Indicators

As well as specific Environment Agency and water company targets on leakage and water quality, further possible targets and indicators include:-
• Monitoring of reservoir levels for particularly vulnerable reservoir sites in South Yorkshire.
• Water efficiency savings due to new technology, better process management.
• Use of water for irrigating potatoes and other crops.

Information gaps and uncertainties

The impacts of changing flow regimes on water companies, other industries and the environment requires further work. National studies may address these issues but only at a national scale so further work is required to quantify the impacts on upland and lowland catchments.

5.4 Agriculture and Forestry

5.4.1 Introduction

Warming temperatures, longer growing seasons and changing water regimes could have major impacts on the region’s agricultural and forestry industries. This section describes the potential impacts of climate change on important regional crops, like potatoes and sugar beet, livestock and forestry. Further analysis of the potential impacts on the food and drinks industries is presented in section 6.0.

5.4.2 Background

Agriculture

Agriculture is, and will continue to be, a major economic sector in Yorkshire and Humber. In 1997, around 42,000 people in the region were employed in agriculture, representing around 2% of the employed workforce. Unlike the national trend for decreased employment in this sector, forecasts suggest a moderate (5%) increase in employment in agriculture in the Yorkshire and Humber region up to the year 2005\(^7\). Land use in the region is currently dominated by agriculture, with rural areas accounting for 80% of the region’s land area and accommodating about one fifth of the population\(^7\).

There are currently around 16,000 main agricultural holdings in the region, of which 9,686 are owned by the occupant. Indeed, 2,576 occupants own none of the land which they farm and there has been a trend for small farms to be subsumed into larger concerns, resulting in an overall 8% decrease in holdings since 1987. The majority of farms are between 20 and 100 ha in size, with 36% being classified as part-time and financially too small to support one full-time worker. This is particularly the case for lowland cattle and sheep farms. In general, farms over 100 ha are far less vulnerable to economic pressures.

The region of Yorkshire and Humber has particularly favourable climate conditions and good quality land for the production of cereals, vegetables and oilseed rape, with cereal farms being the most abundant farm type. The region has defied the national trend in that the numbers of lowland cattle and sheep had been increasing up until the recent foot and mouth (F&M) disease outbreak; the production of milk from the region has been stable over recent years.

Figure 5-3 shows the breakdown of the holdings in the region according to agricultural activity, with the clear dominance of cereals and general cropping; cereals actually comprise 18% of holdings. The high average acreage of cereal holdings means that over 70% of the region’s cropping land is currently under cereal production, representing an area of around 403,000 ha. Within this category wheat and barley dominate, but winter wheat is of increasing importance. Oilseed rape is another important crop, occupying around 9% of the region’s cropping land. The cereal and oilseed rape land plantings are of national significance, representing 14% and 13% of England’s total coverage of these crops. Similarly, 16% of England’s outdoor vegetables come from the region, being dominated by the production of potatoes. This is an extremely important component of the region’s agricultural production, having led to the development of local processing. In contrast, fruit production in the region is very limited, although horticulture does covers 3.5% of the cropping area, albeit largely restricted to the south-east of the Yorkshire and Humber region. However, there are opportunities for the introduction of novel crops such as soya, lupins, borage and evening primrose.

\(^7\) Cambridge Econometrics 1998
Horticulture

Horticulture is important to the region, covering a wide range of crops from brassicas through to protected salad crops and ornamentals. For example, Yorkshire produces nearly 70% of UK early rhubarb, mainly in the area around the Vale of Pickering, whilst Humberside supplies about 40% of the national cucumber crop, which is grown under glass.

Livestock

There is a marked contrast in livestock farming between the very productive lowlands of the Vale of York, Vale of Pickering and the Humber Estuary and the hill livestock farming areas of the Pennines and the North York Moors. The lowland areas have a high number of pig farms, an agricultural sector which has recently suffered substantial falls in income. However, the Yorkshire and Humber region still remains a major UK centre for pig production, accounting for nearly 30% of the English pig herd. There is also a substantial number of poultry units in the region, mainly providing broiler chickens.

Agriculture and types of agricultural holdings in the region are diverse, making generalisations difficult. For this reason, we have grouped together the major types of agriculture on a case-by-case basis. Some more general comments are provided in the ‘highlights’ at the end of this section.

Forestry

In marked contrast to the 403,000 ha of Yorkshire and Humber under cereal production, there are a total of only 92,082 ha of forest in the region, of which 90,127 ha are in areas of 2 ha or more. The managed state forest area is 20,200 ha with the remainder being privately managed. Annual production of timber is 200,000 tonnes, half of which is actually processed within the region.

Natural and managed woodland cover occurs throughout the region, covering a total of 6% of the land area, but the distribution varies widely. For example, parts of Sheffield, Rotherham and Barnsley are now designated as the South Yorkshire Forest in an attempt to improve the landscape of this urban fringe whereas, in contrast, Wakefield currently has the lowest woodland cover of any British local authority (3.5%). The national average for percentage woodland coverage is 8.4% with a range that extends from a regional minimum of 3.9% for London to a maximum of 14.1% for the south-east of England.

Perhaps surprisingly, broad-leaf woodland dominates the forest area in the Yorkshire and Humber region, with 41.5% of the afforested area falling into this category. The remainder is largely coniferous (32%) with the remainder being classified as mixed. The two dominant tree species within these main categories are oak and pine.

One particularly unusual feature of forestry in the region is the wood-fired gasification plant in South Yorkshire, at Eggborough, adjacent to the existing coal fired power station.

5.4.3 Impacts

Cereals

Cereals generally benefit from warmer weather, with more rapid crop development and earlier harvests. However, in very dry years soil moisture reserves are depleted and may lead to reduced leaf function and slower growth. In general, the beneficial effects of warmer summers tend to dominate and the dry years are the years with high yields. Indirect effects of a warmer climate on cereal growth include the beneficial reduction of competition with weeds, although there may be greater occurrence of certain insect pests. Thus, climate change has knock-on effects on herbicide, fungicide and insecticide usage.

Figure 5-3 The breakdown of holdings in the Yorkshire and Humber region according to agricultural activity

The anticipated changes in precipitation are of concern to cereal production within the region, with soil moisture deficit being the result of temperature and rainfall patterns. Under most of the predicted climate change scenarios there
will be shifts in soil wetness which will vary in importance according to the specific soil type in any specific area. Increased winter rainfall, with an associated increase in storm events, will mean that some soils are above field capacity for greater periods of the year. Well-drained soils will be little affected by this but any soils with low permeability are expected to suffer from surface ponding and increased surface flow. This will affect management and cropping, firstly, by shortening the length of the season for machine access and, secondly, through potential increased physical damage to the soils.

Raised summer temperatures, in combination with decreasing summer precipitation, may lead to soil cracking in clay-rich soils, with associated by-pass flow of pesticides and fertilisers and attendant risk to adjacent water bodies. In contrast, crops on the sandier soils, with their limited water holding capacity, may suffer from water shortage unless irrigation is increased. Again, this has major implications for the associated aquifers and rivers. On the positive side, these sandier soils tend to be more flexible with regard to cropping and management regimes and offer potential for diversification.

Sugar beet

The agricultural management of sugar beet is very intimately linked to processing, with considerable variation in yields from farm to farm and in the contracts between individual farmers and processor. The importance of between-year variation in the contracted yields and in controlling the dates of factory openings make the industry very sensitive to climate. Additionally, world prices, overall global production and international policy make the sugar beet industry very vulnerable to a variety of changes at the local, national and global level. For example, it has been suggested that the growth of sugar beet in Italy will no longer be economically viable under future predicted climates; it is therefore almost impossible to predict the future global position of the UK sugar industry under new global climates.

With something like a 10% loss in national sugar beet production between 1980 and 1995 due to drought stress (Jaggard et al., 1998), the prospect of hotter and drier summers is a matter of concern to the industry and one such year, 1995, resulted in an estimated national lost yield potential of around 700,000 tonnes, or around £16 million pounds (Orson, 1996). It should be noted that around 5% of the UK sugar beet land area is to be found in the Yorkshire and Humber region. A significant and increasing proportion of the UK’s root and vegetable harvest is produced using irrigation and, in 1995, sugar beet accounted for 17% of the total area irrigated. The amount of water abstracted for irrigation varies annually but there is a long-term upward trend, with greater usage in dry summers such as 1995. The installation of irrigation equipment is also increasing, partly to maintain a consistent high quality product, but also no doubt in response to the more frequent occurrence of dry growing seasons. However, farmers with irrigation usually grow other crops besides sugar beet, such as potatoes or carrots, and, because of the higher value of the alternative crops and the importance of quality, sugar beet frequently has inadequate irrigation in drier years. Extra investment in equipment or water may be required, assuming an adequate water supply is available.

Other, more subtle impacts of future warmer summers on sugar beet farming include increases in insecticide and fungicide usage, increased labour bills and the inability to plant follow-on crops at the most profitable time.

Potatoes

Many of the climatic, soil and irrigation considerations that apply to sugar beet also apply to potatoes, but there are also major effects of higher air temperatures on potato storage. Current refrigeration and insulation provision for potato storage may not be adequate for warmer years when continuing warm weather, coupled to the high residual temperature in the harvested crop, may lead to insufficient curing with subsequent soft rotting during storage. Existing refrigeration facilities may be inadequate in the future and those potato farmers without any refrigeration facilities at all may face considerable investment.

Horticulture

The potential impacts of climate change are unique to each crop but there are some generalisations which can be made:

- Horticultural yields are frequently higher in the warmer, sunnier years unless water becomes limiting.
- Propagation and maturing times for certain crops will be several days faster
Higher tissue temperatures on harvesting mean increased demand for vacuum cooling
Shelf lives may be reduced at higher temperatures
Many of the existing pesticides are less effective under drier conditions
Climate strongly influences market demand – for example, *Brassica* demand is lower in hotter summers.
Extra irrigation can be a major cost to the industry
Night-time spraying may become necessary in hot years
Farms are having to invest more in irrigation equipment
Thermo-dormancy problems may be encountered because of warmer conditions.
Recruiting and motivating staff to work in hot horticultural conditions can become an important problem
Many materials used in horticulture are degraded more rapidly under dry sunny hot conditions.

Livestock

One of the primary reasons for the high numbers of intensive animal units within Yorkshire and Humber is the local supply of appropriate feed. The majority of animals are reared indoors and, in that sense, tend to be buffered from the immediate climate. However, a critical factor in maintaining the welfare of the animals and the associated high yields is that of avoiding excessive heat during the summer months. It is well known that temperature has a major influence on pig productivity, with critical temperatures at the upper and lower extremes. Under future climates upper temperatures in summer will become a very real problem which will have to be offset by changes in animal housing and other management.

Current animal housing is specifically designed to shed excess heat in the summer but problems of overheating may become unavoidable in hot years. Again, the summer of 1995 provided an example of the effects of a hot, dry year on livestock farming, with conditions in that year causing an increase in costs and/or reduced profits across all livestock sectors. Pigs growing under hot conditions eat less, resulting in reduced growth rates and lower selling weights, whilst breeding sows may be less fertile. There are a range of management alternatives available to the farmer to deal with excess heat, which includes providing increased ventilation and shade, reducing stocking densities or using water as a coolant. The latter approaches range from permitting wallowing, through to the specific construction of sprinklers and water-cooling systems. Similarly, poultry are vulnerable to excessive heat, with reduced feeding and declines in growth rates and egg production. Actions taken in the past to reduce the problem have included use of recirculation fans, roof water sprinkling, increased ventilation and, more usually, simply thinning the broiler crop.

It is clear from the foregoing that these problems can be tolerated by the farmer on an occasional basis but a step-change in climate would require investment in appropriate technology or acceptance of reduced stocking densities. Changes in regional animal feed supply could also affect the financial viability of these holdings which, in turn, will be influenced by climate change (see above).

Sheep, dairy cattle and beef herds are to be found in both the lowland and upland areas of the region, and it is convenient to consider these areas separately because of the contrasting effects which climate change would have. Prior to the Foot and Mouth epidemic there were over 2 million ewes and lambs, with a breeding flock of over 900,000, in the upland farms of North Yorkshire. Most of these are hardy sheep, bred to withstand the harsh climate and limited grazing conditions. One major problem with upland sheep is maintenance of good health, which is very closely linked to rainfall and temperatures. Whilst the increases in winter temperatures are something to be generally welcomed by this sector, more winter rainfall may lead to a number of disease problems. Additionally, the relatively low market value of sheep may encourage farmers towards dairy, beef or arable farming where possible. Experiments in which the temperature in upland systems grazed by sheep have been artificially increased have shown marked increases in the growth of upland grasses, which may lead to an increased sheep herd or alternative livestock.

The potential impacts of climate change on lowland sheep are far more difficult to analyse, since the range of summer and autumn lamb patterns are complex and interact strongly with alternative feed availability and quality. For example, in hot dry years, drought may result in the need for supplementary feeding at a time when conserved grass is in short supply and
the high additional costs may result in high culling rates. The resulting changes in flock structure means that alternative patterns of productivity may have to be followed in the next year. MAFF (now DEFRA) have suggested that more information is needed on the range of summer and autumn lamb growth patterns and the effects this has on yield and quality.

The functioning of the dairy industry is equally strongly linked to forage conservation and availability, although the seasonal growth patterns are somewhat less complex than for lowland sheep. The inability to turn housed cattle into the fields early in the year because of inappropriate soil conditions is a constant concern to the industry. Although the farmer gains best control over dietary intake through increased housing, this is not without significant economic cost and the associated changes in feed requirements, together with yield and quality consequences, mean that the economics of dairying may change. The growing of maize as a fodder crop under climate change increasingly becomes an option, but only on those soils where the associated management does not increase the risks of soil damage or erosion. The reductions in forage availability associated with dry years can lead to underfeeding of dairy herds and the increased housing may also lead to the prevalence of such diseases as mastitis.

**Perceptions in the agricultural industry**

- The agricultural industry already copes with very variable weather from year to year. The changes resulting from anthropogenic climatic shifts will simply be accommodated within existing practices.
- There are many opportunities in the agriculture-food processing chain where flexibility to changes in the quality and quantity of raw materials is possible.
- Climate is considered of minor consequence in comparison to legislative change resulting from adjustments within, for example, the Common Agricultural Policy.
- Specific agricultural concerns (e.g. quality turf producers) are already suffering from changing climate and are altering locations and management practices to cope with the changes.
- Specific food manufacturers dependent on local agriculture have relocated to outside the region because of direct flood damage.
- Climate change in other countries will have unpredictable impacts on raw material imports and costs for the region. For example, sugar production is a global industry with many local impacts.

**Forestry**

**Agriculture and climate change in Yorkshire and Humberside, some highlights**

- Decreased length of season for machine access to land
- Increased risk of summer droughts on certain soils
- Decreasing incidence of frost-free nights will mean more pesticides
- New crops, such as outdoor tomatoes and sunflowers, may appear
- Increased need for irrigation water, particularly for root crops
- Feed problems associated with keeping animals indoors longer could lead to more silage production
- Increased risk of excessive heat for livestock
- Root vegetable storage problems at warmer temperatures
- Erosion risk increase, particularly with crops such as maize
- Organic soils may start to mineralise and upland farms may increase headages.
- Increased autumn planting, but only on certain soils.
- Farmers may be able to survive occasional drought years but maintained climate change will require new management alternatives.

An evaluation of the likely impacts of climate change on forestry in Britain has recently been made by the UK Forestry Commission (Broadmeadow, 2002) and some important conclusions have emerged. Firstly, it seems likely that timber yields will increase across a wide range of UK sites but also for the majority of tree species which comprise existing UK woodlands and forests. Northern England is one region identified as particularly benefiting from these climatic changes, which include increasing mean temperature, changes in rainfall distributions and rising CO₂ levels. For example, Corsican pine is expected to become a higher yielding and more suitable candidate for growth in the region.

However, these positives must be balanced against the less predictable impacts which warmer winters may have on a variety of pests and pathogens, including not just fungal pathogens and insect pests, but also mammals such as red squirrels and deer. Increases in food supply for these latter two pests may well
lead to increased populations, with associated increased damage. Although the only certain prediction is that the distribution of UK forest pests will change (Evans et al, 2002) a northward movement of southern species and a contraction in range of the more northerly species is almost inevitable. One pest which may benefit from warmer winters and more frost-free days is the green spruce aphid, a species which can cause defoliation in Sitka spruce. Additionally, some non-indigenous pests currently restricted by low mean summer temperatures or frosts may well become a greater potential threat. One example of a fungal pest which is climate responsive is Phytophthora cinnamomi, a pathogen of trees which causes root rot and appears to be on the increase nationally (Brazier, 1999).

It is therefore clear that climate may exert a strong influence on tree health, but it is often difficult to disentangle the impacts of climate from other contributory factors. There are, however, some clear exceptions to this, with drought damage to beech being often specific and well correlated with drought years (see DETR, 1999). Beech is a native broadleaf, important for recreation, wildlife and timber, and currently occupying 7.1% of the total woodland/forest area of the Yorkshire and Humber region (Forestry Commission, 2002).

The inability of the climate models to produce accurate regional estimates of future wind patterns means that we are currently unable to say, with any confidence, whether forests in the region will be subjected to increased windthrow in the future; models suggest little change in wind-throw hazard risk within the region. However, the predicted increases in storm events will have overall negative influences on woodlands in the region; there will be increased damage to trees in riparian zones; waterlogging may lead to root damage and recent plantings may be particularly vulnerable to extremes in drought or flooding.

### Forestry and climate change in Yorkshire and Humberside, some highlights

- Higher growth rates but timber quality may be compromised
- Increased risk of loss from drought, e.g. urban beech
- Increased risk of fire damage
- Greater storm damage risk, particularly in riparian zone
- Potential increase in pests, pathogens and disease
- Change in competitive mix of species
- Future role of forests as energy crops
- Higher tree line

### Perceptions in the forestry industry

- The opportunities for the forestry industry arising from climate change will primarily relate to increased yields. The high proportion of processing of timber from the region within the region would suggest a yield associated rise in employment in the timber sector.
- Drought impacts to beech trees have already been some cause for concern, for example in Harrogate over the last few years, and we can expect that drought sensitive trees in the Yorkshire and Humber region will become less healthy in the future, with increased incidences of dieback.
- Phytophthora pathogens of trees appear to be on the increase within the region, following the national trend.
- Any international or national initiatives to encourage carbon uptake and the production of renewable energy may be of considerable benefit to this region, which is currently committed to increasing afforestation, community forestry and the use of forest products in power generation.
- Trees have a clear role in reducing storm water runoff extremes, and afforestation may have local mitigation value in this respect.
- Flood related losses of trees from riparian zones have been locally recorded. This has considerable amenity impact but can also lead to expensive damage to bridges and footpaths.
- Notwithstanding these considerations, the problems seem too distant to have driven any current changes in planting strategies to anticipate future climate problems.

#### 5.5 Semi-Natural Habitats and Biodiversity

##### 5.5.1 Introduction

This section describes the potential impacts of climate change on the region’s habitats and biodiversity. Semi-natural habitats of Yorkshire and Humberside play a major role in the region’s economy, having importance in contributing to the high tourism income (£1,391 m in 1997) of the region. Any changes to natural habitats will have secondary and tertiary impacts on tourism, agriculture and water quality.
5.5.2 Background

The vulnerability of rural industries in general was recently highlighted by the Foot and Mouth epidemic. It is estimated that the outbreak cost the region more than £10m per week in lost tourist revenue. Tourism is the biggest industry in the region, providing over 135,000 jobs and generating 20% of new employment.

The Yorkshire and Humber region is large, with a diverse range of habitats and, whilst containing areas of great natural beauty, it also shows the legacy of the heavy concentration of industry, particularly around Sheffield and West Yorkshire. The region contains areas of extremely high environmental quality and value including, entirely within its boundaries, two National Parks (North York Moors National Park; Yorkshire Dales) and two Areas of Natural Outstanding Beauty (AONB). It also overlaps with two other AONB areas, whilst boasting extensive stretches of Heritage coast and 26 sites of national and international biodiversity importance. With this diversity of habitats it is not really surprising that the region hosts over a quarter of the priority species identified in the UK Biodiversity Action Plan.

Additionally, there are 433 Sites of Special Scientific Interest (SSSIs) in the region ranging from disused chalk quarries to extensive areas of peat bog. Indeed, large blocks of land within the Dales, North York Moors and the Peak District National Parks are also designated as SSSIs, along with the many much smaller areas dotted throughout the region.

At the species level, there are 105 national priority species which have been recently recorded in Yorkshire and Humber but, regrettably, a further 67 species which were once recorded but are now no longer present. Particular noteworthy plant species are *Riccia huebeneriana* (violet crystalwort), *Carex muricata* (prickly sedge), *Galium sterneri* (Sterner’s bedstraw), and beds of water-crowfoot. The region contains the critically endangered *Cypripedium calceolus* (lady’s slipper orchid) and the endangered *Thamnobyrum cataractarum* (Yorkshire feather moss). Important animal species include the corncrake, with the only regular breeding site in England, and there is one particular beetle, *Bembidion humerale*, for which the region is the only known habitat in Britain. Surprisingly, many of the important species in the region are not necessarily located in the designated sites.

![Figure 5-4 Percentage of the UK (or England*) total area of a particular habitat type located in the Yorkshire and Humber region.](image-url)
The region is also internationally recognised for coastline and estuarine environments, with the Humber being of international importance for its winter populations of geese, ducks and waders. It contains two Ramsar sites, i.e. wetland sites designated under the Ramsar Convention on the Conservation of Wetlands of International Importance. Flamborough Head and Spurn Point are also noted regions of Heritage Coast, as are large tracts of the North Yorkshire coastline. Flamborough Head is included as a Special Protection Area within the region, as are the Derwent Ings, Hatfield and Thorne Moors, Hornsea Mere and the South Pennines.

Within the context of climate change it is worth noting that the region is at the northern and southern climate limit of a range of organisms. For example, the northern edge of the core breeding range for turtle doves lies in Yorkshire and Humber, whilst black grouse is at its’ southern extreme. The distribution of these species will inevitably change under a changing climate.

5.5.3 Impacts

Impacts on habitats and biodiversity refer to all parts of the Yorkshire and Humber region, and not just designated areas, such as National Parks, AONBs and SSSIs. It refers to the impacts on landscape, ecosystems (woodland, wetlands etc.), individual species and species diversity.

Water availability seems to be one of the most important climatic changes that may affect habitats. It is important to know the distribution of potential increases in rainfall both temporally (related to droughts or floods) and spatially (related to the status of aquifers, lakes and other habitats). The predicted changes will, in general, be a slight decrease in annual rainfall by the 2080s, but this annual figure masks the anticipated large winter rainfall increases and summer decreases. Changing amounts or patterns of rainfall will mean that some species will be at an advantage over others and there will be ‘winners’ and ‘losers’; generally it will be easier to identify the losers. With regard to individual species, losers will include remnant arctic/northern European species at the southerly limit of their range. All ground-nesting birds (e.g. black grouse) are very vulnerable to high rainfall and the timing and intensity of rainfall in the spring is probably the most important climatic feature. Tree nesting birds are also at risk from extreme weather in the spring, either due to wind damage, or excess chilling of eggs or nestling birds in wet conditions. The reductions in nights with frosts may be of benefit to certain species but the predicted increased frequency of heavy rainfall events will disadvantage others. For example, the song thrush is disadvantaged by severe winter weather and dry soil conditions whilst some species, such as the bittern may be indirectly affected through habitat loss due to changes in abstraction.

The exact seasonal timing of the changes in precipitation are key for many habitats. For example, for woodlands a high spring rainfall is beneficial to the growth of young trees since spring drought may be very harmful. In contrast, it is well known that excess spring flooding in flood meadows causes a decline in habitat quality, with winter flooding being largely irrelevant in these habitats. It is clear that understanding many of the impacts will require detail of the seasonal changes in climate for specific locations, and not just broad seasonal and regional projections. Cumulative aspects are important and a build up or decline in water over a number of years will lead to some areas being increasingly waterlogged or droughty.

Many of the important impacts of climate change will be secondary in nature. For example, changes in the vegetation of National Parks may affect tourism. The national parks, SPAs and SSSIs often contain large areas of uniform habitat and it will be important to know how these vegetation types alter as a consequence of climate change. If warming does lead to a shift from heather moorland to grassland, then this may impact on the tourist value of the National Parks or impact on grouse shooting. The exact impact of such changes on tourism in the future is difficult to predict and the most important feature will be an ability to adapt to, and manage, change. For example, the activities of hill farmers will be a key factor, with their role in altering drainage, amongst other management tasks. It would be possible to develop different landscapes that are attractive to tourists. Some changes, such as a ten per cent increase in woodland, are unlikely to greatly affect the behaviour of tourists. The effect of other secondary issues includes food chain effects where a shift in abundance of one species will have effects all along the food chain. Important in such aspects is whether temporal responses of prey and predator species occurrence to changes in
Nationally, one of the most sensitive habitats to climate change is the montane heathland, which is strongly represented in the region in the North York Moors and southern Pennines. Under all future climatic scenarios the conditions which favour these systems in the UK will reduce and they are considered at severe risk. Indeed, the anticipated species losses of such things as dwarf willow and trailing azalea are so extreme that it is anticipated these species will be progressively lost from the region by 2020 (Cook & Harrison, 2001). Equally rare and threatened are the peat bogs within the region, but the question remains whether the increases in winter rainfall will be able to offset the higher evapotranspiration demands and reduced rainfall in summer. Excessive drying of organic upland soils in the summer may lead to irreversible mineralisation of the organic matter. Not only does this have implications for the organisms living in these environments but it also represents a threat to the UK carbon stores, which we are nationally obliged to maintain under the Kyoto Protocol.

In upland areas the mosaic of different habitats is particularly important, especially small areas of wetland within the landscape. These represent areas of high biodiversity and would be at risk from increased desiccation caused by climate change. Their loss would significantly affect the distribution of many bird, insect and plant species.

Although suitable climatic conditions may remain for some types of bog, the species composition may well change; indeed, analysis of the fossil remains in these systems indicates many changes in species dominance during the last 10,000 years. The dominant vegetation on the bogs is sphagnum moss, which is a collective term for a large variety of species, each with their own characteristic responses to changes in water and temperature regimes. The higher plants on these bogs are also vulnerable to change, with certain species being winners and losers under projected climates. Warming experiments performed on organic soils typical of the uplands suggest a tendency for the more primitive, water-loving plants to be replaced by more aggressive moorland grasses. These same experiments also demonstrated subtle responses in the soil animal populations to temperature increase, with certain species increasing whilst other were dramatically reduced; for example, the small ‘pin worms’ which dominate these soils migrate deeper into the peat to avoid the warmer upper layers. Another ‘loser’ under climate change in these systems is the characteristic cloudberry (Rubus chamaemorus) which could disappear altogether from the region, along with bog rosemary (Andromeda perfolia).

The lowland mires of Hatfield and Thorne Moors, near Doncaster, are of international importance containing some species found nowhere else in the world; they are particularly vulnerable to higher summer temperatures. Current management plans do not take climate change into account. Limestone pavements in Yorkshire and the Humber are also important nationally with the plant species growing at bottom of cracks in these pavements considered sensitive to drought. Additionally, the classical geological features associated with limestone regions are constantly being dissolved and recreated in a dynamic process governed by rainfall patterns and water flow. It has been suggested that there will be a reduction in the formation of new limestone features and existing features may become vulnerable and decay (Harrison et al., 2001). Other nature reserves, such as those in the lower Derwent valley, are internationally important wetland sites requiring regular flooding for their maintenance, and supporting important bird populations, such as the corncrake. It is possible that these sensitive areas may become too heavily inundated with flood water during certain times of the year, leading to a population decline, or may suffer from drought when competing with increased abstraction and evaporation throughout the catchment.

Coastal areas

The Humber Estuary is a site of international importance for various bird species with saline lagoons in the estuary representing major transit sites for migratory species. For these species it is necessary to take into account the pressures on their habitats in other countries, either due to climate change or management which will affect bird populations. Sensitive areas in the Humber estuary include Blacktoft Sands, with work currently being carried out between RSPB and the Environment Agency to assess potential coastal squeeze due to rising sea levels; it is estimated that approximately
700 hectares of habitat will be lost in the next 50 years under current rates of sea-level rise. It is the physical structure of the estuary which determines the nature of the intertidal sediments which, in turn, controls the abundance and availability of the invertebrates and the waterbirds which feed upon them (Harrison et al., 2001).

Soils

The varied geology, topography and climate in the region has led to the formation of a diverse range of soil types, represented by more than 100 soil associations. The wide range of solid geological formations, ranging from Ordovician through to Cretaceous, have shaped a varied landscape dominated by chalks in the east of the region, with Carboniferous rocks forming a single, very large central outcrop, extending the length of the region. These rocks have been crucial in the development of the local character of the region but drift geology dominates the distribution of current soil associations. These, in turn, dictate the types of agriculture to be found, through controls on water relations, texture and crop suitability.

The concept of land suitability for particular crops is based on climate, relief and soil type, modified by limited social and economic factors, such as appropriate processing facilities. However, the key drivers are really the suitability of the climate and topography for growth of a particular crop species with seasonal distribution of rainfall and accumulated temperature being critical. In particular, soil working and trafficking conditions must be adequate for crop establishment, control of weeds and harvesting and the number of machinery work days (MWD) frequently controls the length of the available growing season. The size of the water reserve, balanced against crop transpiration during the growing period, also strongly affects crop suitability. For example, accumulated temperature does not limit cereal distribution in England but the climate at a particular location may frequently be too wet. Similarly, the distribution of sugar beet is strongly influenced by MWDs but the stoniness of the soil is more important. However, both crops are excluded from land which has a strong slope because of the problems associated with operating large scale drills and harvesting machinery.

The large areas of clays (see Fig. 5-5) found in the Yorkshire and Humber region are of particular concern under a changing climate. These soils have the potential to swell when wet and shrink when dry, yet the extent of these changes are rarely seen under current climatic conditions. However, in drought years, such soils can come close to reaching shrinkage potential, resulting in subsidence. The costs of insurance claims linked to clay shrinkage rises dramatically in drought years and such shrinkage may have major economic consequences.

Clearly, from Fig. 5-5, large areas of western and northern GB are not at risk from such changes but areas within the Yorkshire and Humber region are.

Figure 5-4 Distribution of clayey soils in Great Britain

Additional problems linked to clay cracking are associated with ‘by-pass’ water flow, including changed water status, increased likelihood of flash floods, increased fertilizer and pesticide runoff and decreased machine access. Peat soils also show a similar problem, referred to as ‘irreversible cracking’ which occurs when peat soils become very dry and do not reseal on re-wetting. Again, the region contains important peat deposits critical to water production, upland agriculture, tourism and biodiversity.
Despite the fact that many areas of England are potentially at risk from soil erosion, this is only really currently an important problem in a few localised areas throughout the country. However, given that the climate of 2050 is predicted to match that of countries where erosion is currently a major problem, it is likely that this will become an increasing problem in areas of the UK. Again, unfortunately, large tracts of Yorkshire and Humber are considered to be at particular risk from water erosion should the climate change.

5.5.4 Conclusions

Perceptions of the natural environment

- The natural environment of Yorkshire and Humber is of vital importance to tourism in the region yet is extremely vulnerable to climate change.
- Post-Foot and Mouth it is clear that biodiversity is as economically important to the region as agriculture.
- The diversity of natural environments in Yorkshire and Humber is a key feature for tourists.
- There are areas within the region of national and international biodiversity importance
- Bracken invasion is often seen as climate related (due to warming)
- Increased fire risk will lead to more closure days on N Yorks. moors
- Farming will move up the hills and encroach on natural systems
- Heather moorland will decrease due to changing vegetation caused by climate changes
- Beech tree damage will increase due to drought
- Earthworm populations are increasing due to warming, leading to higher badger populations, with subsidence and disease implications
- Damage to riparian zones will have many consequences on animals populations such as the loss of habitat for kingfishers
- Flooding dislodges trees from river banks and causes damage downstream (to bridges etc) and this has represented an economic loss in national parks
- More footpath puddling and more flooding of footpaths will lead more wear and tear in winter
- Wild plants will tend to flower earlier
- Water bodies will tend to dry out more in summer.

Vulnerability, adaptation and robustness

The problem with climate change for many species and habitats is the pace of global climate change. The climate may change faster than species are able to adapt or invade. There is a necessity to carry out an analysis of the stock at risk in the Yorkshire and Humber region and assess the vulnerability of different areas/ landscape types/ habitats or species to potential changes in climate. Once the most sensitive elements of the environment have been identified (hot spot analysis) management plans may be identified to protect these, if possible. In general there is a need to reduce the vulnerability of the whole region to climate change with one of the main issues being to maintain habitat quality to allow species to thrive. For example, although inter-annual variation in grouse numbers is largely climate governed, the species will survive in the region as long as habitat quality is maintained.

Specific issues such as soil conservation under different climates needs to be evaluated. The diversity of the Yorkshire and Humber region (topography, habitats, climate) is beneficial in
allowing adaptation of the natural environment to changes in climate compared to other regions in England. One feature of the region is the high reliance on rivers for water abstraction and, in a more variable climate, it may be necessary to increase the amount of water storage in the region to supply needs. One of the main planning needs is to identify goals for the region and then develop plans that can achieve these. Increasing robustness in the environment will require an integrated approach with policy development for different landscape components (such as agriculture, national parks, urban areas).

Relevance to stakeholder/adaptation responses

Climate change is an issue that all conservation bodies are acutely aware of. There are some examples of integrated policies that consider climate change. For example, the loss of salt marsh and mudflat habitat in the Humber Estuary due to future sea level rise has been identified in the Humber Estuary SMP, and the creation of replacement areas highlighted as a priority. Major managed realignment schemes by the Environment Agency addressing these issues are in progress at Paull (Thorngumbald) and are in the planning stage at a number of sites, including Alkborough at the confluence of the Ouse and Trent.

However, an awareness of climate change does not always translate into action at a national or regional level. Regional activity tends to be economically driven, often by short-term demands and, in the future, under climate change there will be a need for increasingly integrated policies.

Although management agreements for individual SSSIs may include climate change (in order to maintain them in a 'favourable status'), there is no national level strategic planning which incorporate these potential changes. There may be a need for changes in SSSI legislation as with the additional stress of climate change maintaining 'favourable conditions' may require a greater number of direct interventions. This may require conversion of SSSIs to Nature Reserves with the additional financial resources that this would require. This would be particularly true of smaller SSSI sites in the Region. Approximately twelve per cent of the Yorkshire and the Humber region is designated and the vast majority of sites are managed as agricultural systems and any changes in agricultural policy will consequently have a dramatic effect. Much of this land is heather moorland grazed by sheep or maintained for grouse.

In a warming climate there will be a general encroachment of grasslands up hillsides at the expense of moorlands. Although this may be slowed through management, it is unlikely that it can be stopped, as the management of moorland only has access to a limited number of tools, such a grazing and burning. These management tools also require a skilled workforce, such as gamekeepers whose existence depends, to an extent, on the maintenance of grouse moors. There is a large economic importance attached to black grouse (a trophy bird in red grouse shoots) which is at its southerly limit in Yorkshire and its distribution has moved northwards in recent years. Without the skills of gamekeepers and others, the moors may be managed mainly for sheep grazing which would change the nature of the moors since sheep stocking rates are kept lower on grouse moors to develop the required architecture.

Next steps

Overall, there needs to be a new, more sustainable approach to socio-economic development creating a natural environment in Yorkshire and the Humber region more amenable to adaptation.

Biodiversity and climate change in Yorkshire and Humber, some highlights

- Region contains terrestrial reserves of montane heath, limestone pavements and moorland of national and international significance
- Many species at southerly limits will decrease (e.g. Black Grouse) and those at their northerly limits may increase
- Tourism increase will cause a greater pressure on National Parks
- Risks of fire increases - causing national parks/conservation areas to close down more often
- Direct effect of temperatures are minimal and drought is considered more important
- Water storage facilities will be required to cope with wetter winters and drier summers
- Species at southerly limit most at risk
5.6 Industry and Commerce

5.6.1 Introduction

This section describes the potential impacts of climate change on the region’s industry and commerce in terms of emerging opportunities, the demand for products, business location, process and building design and industrial relations. Overall, socio-economic changes will have the greatest impact on these sectors over the next 50 years. However, climate change will play a role in providing opportunities for development of particular industries and constraining the development of others.

5.6.2 Background

Parts of the Yorkshire and Humber region constitute some of the traditional industrial heartlands of the United Kingdom. However, tremendous economic changes have taken place in the last few decades. De-industrialisation and restructuring have resulted in high unemployment in some areas of the region, a per capita GDP lower than the English average and a low involvement in research and development in the more advanced technology sectors.

Manufacturing still accounts for the largest single proportion on the annual GDP in the region. This sector is likely to contract further and it is expected that there will be a 10 per cent fall in the level of employment in this sector over the next few years. Already, in employment numbers, the distributive trades, hotels and catering together, exceed manufacturing. The background to the overall structure of the economy, and the possible trends over the next few years, are illustrated in Tables 5-5 and 5-6.

### Table 5-5 GDP (1997) and forecasted GDP (1997-2005) in the Yorkshire and Humber Region.

<table>
<thead>
<tr>
<th>SECTOR</th>
<th>GDP (1997) in £ (millions)</th>
<th>% change 1997-2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>747</td>
<td>9.4</td>
</tr>
<tr>
<td>Mining and Quarrying</td>
<td>396</td>
<td>-41.4</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>10033</td>
<td>10.1</td>
</tr>
<tr>
<td>Electricity, Gas &amp; Water</td>
<td>1037</td>
<td>5.1</td>
</tr>
<tr>
<td>Construction</td>
<td>2798</td>
<td>12.5</td>
</tr>
<tr>
<td>Distribution, Hotels &amp; Catering</td>
<td>5976</td>
<td>17.9</td>
</tr>
<tr>
<td>Transport and Communications</td>
<td>3741</td>
<td>31.0</td>
</tr>
<tr>
<td>Financial &amp; Business Services</td>
<td>6135</td>
<td>30.4</td>
</tr>
<tr>
<td>Government Services</td>
<td>6450</td>
<td>15.1</td>
</tr>
<tr>
<td>Other Services</td>
<td>1647</td>
<td>28.1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>39322</td>
<td>16.6</td>
</tr>
</tbody>
</table>

Sources: LMU, 1998; Yorkshire Forward, 2001

### Table 5-6 Employment Profile, and Forecasts, of the Region

<table>
<thead>
<tr>
<th>SECTOR</th>
<th>Numbers Employed 1997 (000)</th>
<th>% Change 1997-2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>42</td>
<td>4.8</td>
</tr>
<tr>
<td>Mining and Quarrying</td>
<td>8</td>
<td>-25.0</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>433</td>
<td>-9.9</td>
</tr>
<tr>
<td>Electricity, Gas &amp; Water</td>
<td>13</td>
<td>-46.2</td>
</tr>
<tr>
<td>Construction</td>
<td>128</td>
<td>-10.2</td>
</tr>
<tr>
<td>Distribution, Hotels &amp; Catering</td>
<td>472</td>
<td>10.6</td>
</tr>
<tr>
<td>Transport and Communications</td>
<td>118</td>
<td>9.3</td>
</tr>
<tr>
<td>Financial &amp; Business Services</td>
<td>296</td>
<td>18.6</td>
</tr>
<tr>
<td>Government Services</td>
<td>505</td>
<td>1.0</td>
</tr>
<tr>
<td>Other Services</td>
<td>100</td>
<td>35.0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>2115</td>
<td>4.4</td>
</tr>
</tbody>
</table>

Sources: LMU, 1998; Yorkshire Forward, 2001

5.6.3 Impacts of climate change

**Impacts, opportunities, changes**

The main features of the climate scenarios presented in section 4 are large increases in winter rainfall and drier summers with increased temperatures all year round. The scenarios also suggest that the frequency of extreme climatic events (elevated wind speeds and storms) may also increase.

The impacts of climate change on industry and commerce are likely to be complex and interrelated. The perceptions of change and future climates may influence:-

- business location
- industrial design and process efficiency
- the design of buildings and building standards
- the form of products
- industrial relations
- elements of the general regional infrastructure
- finance, investment priorities and insurance.

The management of change in relation to such a wide spectrum of issues would constitute a considerable challenge for even the most sophisticated enterprise.

**Business location**

The relocation of an industrial site is not something that is lightly undertaken and most industrial concerns were reluctant to anticipate such a necessity. But businesses do, from time to time, relocate, not always in the same region (or, indeed, in the same country). Infrastructure problems, frequency of flooding, incidence of storm events or even the relocation of their major suppliers in response to such issues might force relocation in relation to climate change.

**Perceptions in industry**

Companies in much of the sector tend to be small and 81 per cent of the 15,300 companies in the region have less than ten employees. This structure has a considerable influence on the way in which industry and commerce sees climate change and the degree of priority it attributes to the issue.

Most industrial and commercial enterprises in the region are aware of the climate change issue and perceive it from two perspectives: the way in which their activities contribute to the problem and how the phenomenon might impinge upon their business activities in the future. Smaller companies although aware see little reason or opportunity to give the issue more than passing concern.

Many of the larger companies consider that their main concern at present should be with their contribution to the problem and how their activities can be adapted to minimise these effects (energy conservation, for example), or how their products might also contribute in this way. Few companies have anything but planning horizons that are so short as to make this view almost inevitable. On the other hand, larger, successful businesses are often adept at rapid responses to surprise events and there is no reason to suppose that they might be more sluggish in responding to climate change challenges in the future.

However, some of the larger companies, with staff that were widely read and well-informed on the issue appreciated where the climate issue fitted in the range of company priorities and responsibilities. These were generally stated as a commitment to *enhancing profitability and share value* of the company, *compliance with necessary regulations*, efficient company operation, employment responsibilities, the attainment of *methods of best practice* (or at least good practice) and a commitment to *social responsibility*. It was usually in this last category that the environment generally, and climate change specifically, was seen to be located. In the area of compliance with regulations connected to climate change, some industries, such as energy industries, experienced difficulties leading to a degree of exasperation when regulations were regarded as punitive for their industry. Certain industries regard the Climate Change Levy in this way: an instrument that is rather indiscriminate in its focus. Others, however, like the building industry, appreciated the opportunities that compliance presents: design opportunities and reasons to make improvements to a product. Such “quantum leaps” are undoubtedly rare and it was apparent that for many businesses, if any responses would be made at all they would be incremental in degree.

**Industrial design and process efficiency**

Industrial processes are subject to continuous improvement and redesign. It is likely, therefore, that changes that might be required as responses to climate change will be incorporated within this process. For example, mean monthly increases in temperature may require cooling towers of increased efficiency, or simply more cooling towers but it is envisaged that such requirements would become part and parcel of the normal design process of a new generation of power plants (rather than, say, retrofitting activities). Many other industrial enterprises mirror such an approach.

One possible exception to this is where regulation forces more rapid change. For example, reduced summer river flows may mean the industrial discharges cause greater pollution leading to a requirement for tighter legislation. In this instance, changes such as the introduction of real time discharge control, are likely to be implemented more quickly.
Building design and building standards

The requirement to improve energy intensity in buildings and improve materials use and substitution in the building industry has been the spur to design innovation in a wide range of products, fittings and the overall conception of the building. Many such goals have been incorporated into new building norms and regulations. Generally compliance with these has been welcomed by the building industry and has been a spur to much needed improvements in function and design. This process is likely to continue in response to climate change. In certain areas it may also mean radical design adaptations in relation to such features as flooding and storm damage – especially in the light of the increasing reluctance of the insurance industry to cover certain types of flood risk. There are already examples of innovation in engineering design in new developments along the Ouse in York – new flats have been fitted with “hydrophylic” seals that expand when in contact with water to prevent flood damage.

The form of products

There is discussion on whether certain products, in their present form, will be appropriate if conditions change along with the climate. An example of this is garden products (sprinklers for lawns, for example rather than pre-laid sub-surface irrigation). Clothing products are another example, along with cosmetic products. Changes are likely to be made as part of the changes made for other commercial reasons.

Industrial relations

There is acceptance in industry and commerce that with changes in the climate (and hence weather patterns) there will be pressure to adapt the work structure. The workplace may, particularly in some industries, need to be made more “climate controlled” and the use of air-conditioning or passive cooling installed. Increased use of air-conditioning systems create more energy demand and have further detrimental implications in terms of GGE. Changes in holiday arrangements may be sought, together with pressure for changes in the working week (to the level that is prevailing in the rest of Europe). Industry and commerce will wish to address such issues before it finds itself in a conflict situation.

Infrastructure

Changes in “normal climate” have effects on a whole range of infrastructure elements. The condition of roads, the stability of buildings, bridges, earth banks and dams and much else is a function of the climate in which they exist. Changes in design and the incidence of maintenance work are acknowledged to be affected.

Finance, investment priorities and insurance

There is some evidence that the full implications of the need to address many of the issues discussed above are only slowly becoming appreciated by industry and commerce. Most of the need to manage this change will utilise financial instruments to do so.

5.6.4 Conclusions

The major task for industry must be to extend the appreciation of the risks and challenges posed by potential climate change and its impacts as appreciated by a few larger industries and institutions in the region. There is a particular need for small and medium-sizes enterprises to be involved. For this to be achieved there is probably a need for some centralised “clearing house” facility that is able to give advice and encourage co-operative and complementary action.

The way forward is probably by example and the collection, from a wide trawl, of case studies of successful responses to the opportunities presented by climate change would also be encouraging.

Forward planning to allow a precautionary attitude to some of the undoubted disbenefits of climate change needs to be encouraged at the regional and local level. Local planning procedures in relation to industrial development need to have climate change implications at the forefront of their procedures. Climate change needs to be inserted in “Agendas” in the same way as more general environmental concerns were brought to the table 15 to 20 years ago in local government and industry.
5.7 Services

5.7.1 Introduction

All the main service sectors are represented in the region: tourism; financial services; insurance; local authorities; leisure and sport; cultural activities. Together, financial and business services, government services and the distribution, hotel and catering sectors account for nearly double the GDP of manufacturing and more than three times as many employed. This section describes the potential impacts on individual services including the tourism, local authority and health sectors.

5.7.2 Background

The main service sectors in the region are generally vibrant, expanding sectors of the economy. They are seen to respond vigorously to opportunities in a highly adaptable way. Their vulnerability resides chiefly in the fact that many service arms are made up of a multitude of small businesses that do not always have the resources to weather short-term setbacks.

5.7.3 Impacts of climate change

Perceptions in services

It would have to be admitted that, except within the local authority sector, there is little direct rapport at present between those urging attention to the climate change issue and the financial services sector or, somewhat surprisingly, with the insurance sector at a regional level. Tourism, local authorities, leisure and sport and cultural institutions do show evidence of response to climate change impacts.

Tourism

Tourism is a significant contributor to the region’s economy, registering £1,391m in 1997 providing over 135,000 jobs. In 1997 there were 10.4m trips made by British visitors worth around £1,084m and 1.03m trips by visitors from abroad worth £307m. The Foot and Mouth disease epidemic in 2001-2002 had a catastrophic effect on tourism during the period of the outbreak with losses of revenue in some weeks reaching £10m. Drops of up to 40 per cent in levels of visitors compared to the same period in previous years were registered. The prognosis for recovery from this kind of perturbation has not been optimistic for the smaller enterprises and this may not auger well for adaptations in relation to changes in climate.

Table 5-7 Top tourist attractions and number of visitors in the Yorkshire and the Humber region (1997)

<table>
<thead>
<tr>
<th>Admission charging</th>
<th>Free</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flamingo Land</td>
<td>1,161,000 York Minster</td>
</tr>
<tr>
<td>Jorvik Viking Centre</td>
<td>573,521 Tropical World</td>
</tr>
<tr>
<td>National Railway Museum</td>
<td>402,503 Rother Valley</td>
</tr>
<tr>
<td>Royal Armouries</td>
<td>382,000 Country Park</td>
</tr>
<tr>
<td>Castle Museum</td>
<td>376,247 Temple Newsam</td>
</tr>
<tr>
<td>Eureka, museum for Children</td>
<td>365,000 National Museum of Photography</td>
</tr>
<tr>
<td>Fountains Abbey</td>
<td>297,333 Bolton Abbey</td>
</tr>
<tr>
<td>N. Yorks Moors Railway</td>
<td>280,756 1853 Gallery</td>
</tr>
<tr>
<td>Eden Camp</td>
<td>258,773 Pugneys Country Park</td>
</tr>
<tr>
<td>Harewood House</td>
<td>254,000 Thrybergh Country Park</td>
</tr>
<tr>
<td>Leeds City Art Gallery</td>
<td>267,625</td>
</tr>
</tbody>
</table>

Source: LMU, 1998

There are continuous efforts to develop tourism in the Region that involves new initiatives regularly coming on stream. Much of this activity is concerned with special interest activities, industrial heritage interests, regional interests (such as the Grimsby Fishing Heritage Museum) and developments of more general nature such as the Earth Centre in the Dearne Valley.

Whilst there is a well-developed appreciation in the industry that there must be a nurturing and constant development of tourism there is less awareness of the potential opportunities related to climate change. For example, representatives who co-ordinate developments in the industry declined to be interviewed on the topic. This attitude will probably have to give way to a more receptive attitude as public activity is modified by changes in climate.

Leisure and Sport Activities

Bodies running leisure activities have not really developed strategies related to the potential impacts of climate change but leisure activities are very dependant on the weather and have been heavily impacted in those years with unusual weather patterns. Consequently there is a great interest in the potential for impacts and how to adapt to them.

Football and rugby represent some of the main sports in the region and for these pitches are required in a good state of repair. The sports field infrastructure is currently in a poor state
of repair and they are often poorly drained and prone to flooding. The flooding can lead to match cancellations or, if the pitches are used in a flooded condition, they are frequently damaged. The pitches are often maintained by allowing them to recover during the summer. However, this recovery is impeded by drought. Therefore wetter winters and more frequent drought in the summer will lead to a marked deterioration in pitch quality in the region. It would be possible to counteract this with investment in drainage, and watering in summer, but local authorities have scarce and inadequate funds.

There are many activities that require intensive water use including swimming pools, playing field, golf courses, cricket pitches and certain tennis court surfaces, even though there have been marked efforts to reduce water use in recent years. Many sports are affected by water scarcity resulting from hot, dry years. Water sports will obviously be affected. Sailing clubs in inland reservoirs have difficulties in operating during drought years. Many clubs in the Pennines almost went out of business in the drought years of 1995/96.

Coastal facilities will be vulnerable to sea-level rise (the Humber is extremely important for sailing, canoeing, golf courses and football pitches). Clubs may need to relocate, if they have adequate funding.

More frequent extreme weather events will have a great effect on certain sports such as air sports, including hang-gliding, paragliding and gliding as well as tennis and athletics. The need for more indoor facilities will become evident as outdoor pitches and facilities become unusable during poor weather conditions or damaged due to extended periods of extreme weather. Current indoor facilities may be affected in hot weather, and air conditioning may be required.

Some sports may be enhanced by the changes in climate, for example warmer, drier summers should benefit cricket.

**Cultural Heritage**

Very little knowledge is available generally, nationally or in the Yorkshire and Humber region on the potential impact of climate change on our cultural heritage (although English Heritage will start a research project in late 2002). However, the anticipated change in the Region's climate would be likely to have a significant effect, both directly and indirectly, upon the heritage assets of Yorkshire and the Humber.

The density of archaeological sites is surprisingly high in the Yorkshire and Humber region. One of the major concerns is over fragile, waterlogged, wetland deposits. Changes in regional climate could result in a risk to peat bogs and their deposits if rainfall is reduced in summer through drying of the organic material. These deposits contain important archaeological remains and also they have great importance due to the desire to reconstruct past economies, lifestyles and landscapes, where the evidence is mainly organic (e.g. leather, wood, plant, pollen or insect remains). The Humber wetlands are one area of concern, and upland wetlands represent very important deposits. In dry conditions tree roots are likely to grow deeper into the soil to find water and this will destroy deposits. If winters become wetter and flooding becomes more prevalent, there will be increased demands for drainage, which will lead to increased desiccation of organic deposits.

Construction of extensive flood defences to protect properties, for example, could destroy archaeological remains through piling or, if hydrology is significantly changed, deposits could dry out over time. Similarly, the dredging of the channel or the realignment of riverbanks to improve river flows could also have significant impacts. If a combination of dry summers and increased, and more intense, winter rainfall causes soil erosion, this also has the potential to destroy archaeological deposits. Coastal areas are particularly rich in archaeological deposits.

Increased rainfall will result in faster rates of erosion of the fabric of historic buildings of the Region (stone, mortar, stained glass and metals). Apart from the damage that may be caused to buildings through flooding, the construction of flood defence works can have a major impact upon the character of historic settlements.

Archaeological deposits need to be mapped and risk assessment methodologies developed to assess potential effects of climate change. Co-ordination with other bodies at local and national scales responsible for areas containing archaeological remains will be very important under a changing climate (DEFRA, DTLR, the Countryside Agency, the Environment Agency and English Nature).
Local Authorities

Local authorities have an integrative function within their areas and therefore could have a key role in assessing climate change impacts and co-ordinating plans to respond to such changes and enhance the robustness of their regions. With this in mind, three meetings were held in parts of the Yorkshire and Humber region focussed on: West Yorkshire (held in Bradford), South Yorkshire (held in Sheffield) and the Humber region (held in Hull). There were also additional interviews with other local authorities using phone calls. The perceptions and priorities outlined here are based on these consultations.

Local Authorities addressing climate change

Local authorities are in a central position to take a leading role to effect changes in the region to increase robustness in the event of climate change. However, the gap between national and local government in the UK hampers these activities. For example, initiatives such as Local Agenda 21 are not really national priorities and this therefore hampers actions at the local level.

The local authorities’ role is to implement government or EU directives and is designed to deliver results on the ground and this role would be aided by clear commitments from national government. Currently a lot of services are out-sourced (housing, schools, care of the elderly). This mean that local authorities may be left with the 'hard infrastructure' and enforcement, quality and best value functions. However, local authorities, acting together, consider that they are in the best position to knit together various sectors and provide strategic leadership and will need to develop local strategic partnerships.

It was clear that local authorities in the Yorkshire and Humber region have considered their greenhouse gas emissions and effect on global warming (with some councils adopting GHG emission reduction targets, such as 60% reduction in emissions between 2000 and 2050 in Kirklees and 20% reductions in Leeds between 1990 and 2004), but have only recently begun to consider the impacts of climate change on their region.

Although the interest is growing rapidly and strategies based on responses to the impacts of climate change are being developed, the concept of needing to respond to climate change, rather than to the causes of climate change was a relatively new one in most councils. The issue of flooding and unusual weather patterns had, however, increased awareness of potential problems and the need for climate change to be included in planning guidance was widespread throughout the region (e.g. North East Lincolnshire Council and Calderdale both cited flood risks as a major issue).

Impacts on local authority services

The local authorities considered that climate change could impact on many aspects of local life. The main areas of concern for local authorities were:-

- Increased flood risk
- Changing drought conditions
- Health impacts, particularly low ozone impacts on air quality
- Changing leisure activities and need for access to green space

Flooding

Flooding was seen as the greatest possible impact. Many regions have borne the brunt of extreme flooding, not only in the well publicised areas, such as York, but also in areas such as Rotherham (S Yorks.) or the Stockbridge area of Keighley (W Yorks.) where, in the flooding of Autumn 2001, more people were affected than anywhere else in the UK. As well as affecting existing housing stock and industries, it was perceived that the flooding would affect future development plans in flood plains. This would be particularly important in regions where the only potential development space would be in the flatlands of the region (e.g. in Bradford district), and in any brown-field sites prone to flooding (throughout the region). This could upset plans to develop brown-field in preference and lead to increased development of green-field sites (e.g. plans to develop the lower Aire valley in Leeds), developments on the Humber estuary and the Lower Don Valley.

Health impacts of warmer conditions

While the beneficial aspects of warmer winters were recognised there was concern about the potential impacts of warmer summers on health. Increased sunshine could lead to increases in skin cancers, requiring additional burdens to health authorities or information
campaigns to change habits. The hot, sunny weather, such as seen in 1995, would also give rise to increased ozone concentrations which was potentially seen as a particularly important impact of climate change on health (ozone health targets are already being exceeded in the region). Warm weather would also have food hygiene impacts, with an increase in incidents related to food being stored in warmer conditions.

Other problems that were remarked upon included the increases in numbers of rats which can breed for longer in the warmer weather and increased sightings have caused various problems for local authorities which have to deal with increased pest infestations. The warmer weather would also provide health benefits. Currently there are 44,000 fuel-poor households in Leeds and in recent years there have been approximately 800 excess winter deaths in Leeds, 400 in Kirklees and 600 in Bradford. The warmer winters would reduce the numbers of people suffering from cold household conditions and the excess deaths. Conversely, elderly people can suffer from overly warm conditions. This would necessitate the use of increased air conditioning, causing added expense and contributing further to climate change.

Climate Change and Health

Climate change will inevitably change the incidence of human diseases and thus have effects on human health, although changes are unlikely to occur rapidly and may be slow to be recognised. There will be both positive and negative effects.

Negative impacts might include:
- The impact of warmer and wetter winters could lead to the spread of mould and fungi in domestic properties. These are associated with elevated rates of respiratory disease.
- Drier summers may increase rates of walking and cycling, and thus vulnerable groups in road traffic accident terms. There will be an increase in deaths and serious injuries.
- Wetter and windier winters could force more people to use cars and to abandon public transport, walking and cycling, adding to urban air pollution.

Positive impacts will include:
- The UK has the highest rate of loss of life in Europe due to low temperatures in the homes of the elderly with inadequate heating. A reduction in this total can be expected with warmer winters.

Further impacts where it is unclear whether the impacts will be positive or negative include:
- Changes in growing conditions and the prevalence of different plant species as a result of climate change will impact on asthma and allergy.
- Higher capital and running costs in the NHS associated with increased demand for air conditioning in hotter summers may be offset by lower heating bills in winter. There may be a negative health impact due to budget reallocation away from patient care to allow adaptation to changing climatic conditions and also a negative health impact due to increased likelihood of diseases spread by air conditioning/cooling systems (e.g. Legionnaires Disease).

All of these impacts on human health (with the possible exception of malaria which may well be confined to SE England) may be expected in the Yorkshire and Humber region.

Subsidence

The dry weather of 1995/6 also caused a great deal of subsidence in housing in the Bradford area, for example. If this were to increase there may be implications to household insurance, particularly for those houses built on clay soils susceptible to shrinkage.
Park management and leisure activities

Over the last decade councils in Yorkshire have noticed a lengthening in the growing season (for example by 3 weeks in Leeds and an extension by about one month at the beginning and end of the season in Bradford). This has affected management of council run vegetation areas, such as curb-side grass which needs to be cut for a longer period, and has considerable cost implications for the councils.

It was perceived that whilst farming would be able to adapt rapidly to new conditions, trees would be more susceptible due to the longer growth periods. This would particularly affect urban trees, which are more prone to water stress.

Patterns of leisure activity would change in warmer summer conditions. Parks and green spaces would be used more, there would be a tendency for more camp fires to be lit, giving rise to fire hazards, and also socially disruptive behaviour, which tends to be more frequent on warm summer nights would increase (related to alcohol and more young children playing outside on the streets).

Canals in the region that are used for navigation, cycling and fishing have dried up in the past, e.g. Marden on the Oldham canal in 1995, and any increase in drought frequency could affect the region’s waterways.

Adaptation and Policy Needs from the Local Authority Perspective

Long term planning

In order to deal with climate change long term visions and planning are needed with 30-40 year time-scales. This is extremely difficult at the moment where there is a tendency to give in to short term needs and planning horizons are often shorter than 5 years. This is true for infrastructure changes where, in one case regarding refurbishment of schools in the Bradford district, environmentally sensitive economically efficient improvements (related to reducing water use) were not included, even where the financial pay-back periods was between 5-8 years. There therefore needs to be pressure on defining and implementing long-term solutions with designs that will be able to cope with changes in climate.

5.7.4 Opportunities

There are a number of potential opportunities for the service sector.

- Environmental technology services are a growth sector and could be encouraged in the region (such as Solar GB developing low energy use LED technology in West Yorkshire).
- The development of specialist insurance and flood-proofing services.
- Developing partnerships: There is a key role for local authorities to promote coordinated policy responses to climate change impacts.
- The development of adaptive and flexible responses. There needs to be an integrated approach to policies so that they work as a system to address: land use planning; environmental health (food hygiene etc); land management functions (playing fields, parks nature reserves and drainage) and building maintenance.
- Awareness raising. Climate change impacts assessment and adaptation provides an opportunity of raising awareness of sustainable development and environmental issues in general.

5.7.5 Conclusions

The service sector is diverse and so are the responses and opportunities in relation to potential climate change. The tourism sector probably has most to gain from a change of climate of the kind envisaged for the region but seems to be the most detached from the issue. A change in attitude would be likely to reap considerable dividends, with time.

For the insurance sector there are considerable challenges and there should be encouragement given to ensuring that for any of the responses it makes, the public is involved in the outcomes.

Sport and leisure faces a number of adverse spin-offs from climate change and it is important that the development of new and innovative facilities are planned with a change of climate in mind. Local authorities can play a key role in “vetting” developments and giving encouragement and advice.
5.8 Transport

5.8.1 Introduction

The reliability and efficient functioning of a transport system is a primary determinant of both quality of life and economic success. It is both prudent and necessary from a public and private decision making perspective to ensure that climate change impacts are fed into transport decision making at every geographical scale. The necessity is both a function of the long lived nature of transport investments and the scale of resources devoted to transport investments over the next 10 years. Transport investments are long lived (though not as long lived as housing). New roads will frequently have a 30 year design life. Major electrification projects and infrastructure renewal projects on the railway system have a 30-40 year design life. Transport projects now in the pipeline in the Yorkshire and Humber region will come to fruition well within the time horizons associated with climate change impacts (e.g. flooding, severe weather, gales, coastal erosion).

5.8.2 Background

The government's 10 Year Plan for transport "Transport 2010" estimates that £180 billion will be spent on transport projects in the period 2000-2010. This is £50 million per day for a 10 year period. £60 billion will be spent on rail projects with the intention of increasing the number of rail passengers by 50 per cent and rail freight by 80 per cent. Spending on roads will be £59 billion with the intention of reducing congestion. £56 billion out of the total of £180 billion will be from private sector organisations. Many projects that will be at an advanced stage of planning in 2009/2010 will still be delivering benefits in the year 2050. Now is the right time to make sure that these projects are "climate change compliant".

The £180 billion investment total is not broken down by regions but our estimate is that at least £10-£12 billion (and possibly more) will be spent in the Yorkshire and Humber region. The consequences of not getting this right and failing to make investments of this size climate change compliant are very significant.

The region of Yorkshire and Humber has an extensive rail system and has a substantial length of one of the three main railway lines in the UK (the East Coast Main Line (ECML)). This line is of national and European significance and its passenger and freight carrying capacity is an important regional asset.

Road infrastructure shares some of the characteristic of rail infrastructure. Yorkshire and Humber has a significant length of some of the UK's most important motorways (e.g. the M62, M18 and M1). The region also has a large trunk road network, with several nationally important roads. (e.g. the A1, A59 and A64). The Yorkshire and Humber region has a substantial network of rural roads and coastal roads that often perform vital services to small towns and villages and isolated homes.

The region’s ports are nationally important and provide an import/export route for cars, timber and other international products.

5.8.3 Impacts

Transport Infrastructure

Higher levels of precipitation, dryer summers, higher risk of flooding, subsistence and landslides as a result of climate change can have significant impacts on road and rail transport infrastructure. There is a possibility of stronger winds causing significant damage to road and rail infrastructure, though there is low confidence in the effects of climate change on wind speeds.

Transport infrastructure is very susceptible to disruption, damage and economic loss as a result of flooding, storm damage and “down time.” Nationally businesses currently lose circa £20 billion each year as result of lost time to freight and passenger movement from traffic congestion. Transport systems are already disrupted by congestion and any other source of disruption will be overlaid on the existing problem.

Railways

There are several points on the East Coast Main Line where there are flood risks and the whole length of the line is susceptible to overhead power line failure in severe weather conditions.

From 1 April 2001 to 31 March 2002 the delay to trains resulting from bad weather in Railtrack’s London North Eastern Zone, which
includes the Yorkshire and Humber area, was 30,273 minutes. In addition 2,953 trains were cancelled and 1,372 trains were part cancelled, i.e. they only completed part of the timetabled journey, as a result of bad weather. These data would include the results of flooding and increased river levels; higher wind speeds and lightning strikes.

The railway line to Hull especially in the Brough, Ferriby, Hessle area is susceptible to storm surge and flooding conditions in the Humber Estuary and the main Trans-Pennine routes, e.g. Leeds-Preston via Sowerby Bridge and Hebden Bridge and Manchester-Huddersfield via Marsden are susceptible to landslip risks and tunnel flooding. Trans-Pennine routes are early examples of impressive Victorian railway engineering but are not well placed to deal with the risks associated with increased precipitation, saturation of soil and sub-surface material and water ingress through moorland landscapes. The latter is also likely to be exacerbated by old mine workings and the likelihood that these will drain less well in the future and overload tunnel and culvert drainage systems.

Storm surges and exposure to coastal processes (erosion and deposition) are also likely to present railways with problems in the Bridlington and Filey areas.

All these problems are associated with immediate economic losses e.g. damage to infrastructure and with future consequential losses in an ever widening ripple effect e.g. economic losses as a result of disruption to logistic systems and business operation, losses to the tourism industry as a result of disrupted travel opportunities. Equally, all these risks are associated with a number of measures that will reduce the frequency and the severity of the event of in question (see Opportunities)

**Roads**

Parts of the Yorkshire and Humber motorway system are susceptible to flooding and the same responses suggested for rail infrastructure is required. The Highways Agency report "Better value from busy roads" published in 2001 makes no mention of climate change issues but a more recent national document has reviewed the potential impacts of climate change (UKCIP, pers, comm.). However consultees from the transport sector in the region had a low level of awareness of climate change issues.

In addition to the areas of motorway affected there are also substantial lengths of trunk road. Flooding risk in combination with strong winds and storm damage (falling trees) present risks which can be managed. Best practice management intervention would include wind breaks, enhanced drainage arrangements, embankments where appropriate and permaculture planting to reduce run-off. The highways system carries the additional risk of road traffic accidents and over-turned high sided vehicles. Careful attention to adaptation measures in step with climate change assessments can minimise these additional risks. Road safety issues are discussed below as a secondary effect.

Many of these road links are susceptible to flooding and are less well engineered than the trunk road and motorway system (lack of embankments, low lying stretches, long stretches very close to rivers and streams and long stretches adjacent to exposed coastlines). There are variable but significant risks associated with these physical conditions.

The coastal roads of the region present a special problem requiring a management scheme to minimise risks as climate change impacts bite deeper over the next 30-50 years. Sections of the A165 road (Filey-Scarborough), the B1242 (Hornsea-Mappeleton-Great Cowden), A174 (Sandsend) and the A1033 (Withernsea) are exposed to coastal risks (storm surge, rising sea levels). It would be prudent to have a management programme in place based on climate change assessments.

The highway system also presents a parallel problem to the trans-Pennine road crossings. The railways often share a narrow valley/hillside with a road (e.g. the A646 in the Hebden Bridge/Sowerby Bridge area) and both linear features are susceptible to the effects of landslip and flooding. This characteristic of Pennine valleys also raises the possibility of a "double jeopardy". Flooding and landslips if they occur run the risk of impacting on rail and road at the same time. This will cause severe damage to communities, severely disrupt normal life, reduce the effectiveness of emergency services increasing the likelihood of serious injuries and loss of life and increase the costs of rail repair/restitution because it would not be possible to access the damaged area by road.
Ports and airports

Ports and airports are also affected by climate change risks. For ports the impact of rising sea level, storm surges and "down time" will have serious consequences for the economic viability of the regions ports. Airports will also be affected by the increasing frequency and severity of adverse weather events. The Leeds-Bradford airport consultee identified the problem of delays as a result of strong winds and wetter weather. Strong winds can seriously disrupt airport operation and airports are very dependent on the efficient workings of the highway system to bring workers and passengers to the airport itself.

Bad weather such as fog, snow and occasionally heavy wind have disrupted flights at Leeds-Bradford Airport. In total approximately 29,000 commercial movements took place at the Airport in 2001. Of this number 79 flights (0.27 per cent) were disrupted due to weather events. In total approximately 3 days had a number of flights disrupted due to bad weather conditions.

On the positive side there may well be benefits from warmer winter weather in reducing the probabilities of disruption from snow and ice and reducing down time from de-icing operations. Once again airports and ports should embrace a climate change compliant mode of operation. Airports in the region are responding to strong growth rates in passenger and freight air transport and it is imperative that expansion plans take into account international best practice on how to minimise the risks of disruption from climate change events. Runways and terminals built in the next few years will be still be in use in 2050, well within the time frame of predicted climate change impacts.

It would also be prudent for aviation to participate more co-operatively in the search for solutions to the predicted impacts of greenhouse gas emissions (GHGs). Aviation is the fastest growing source of GHG and so far has shown very little enthusiasm for sustainable development policies e.g. transferring domestic aviation to high speed trains and European aviation for distances up to 500km to high speed trains. A prudent climate change strategy for the aviation industry would involve classic mitigation procedures to "climate change proof" the infrastructure and minimise risks and at the same time to help reduce GHG emissions. Equally a prudent climate change strategy for the region would try and transfer road freight to inland waterways and coastal shipping. Notwithstanding the threats to ports and coastal shipping there are huge reductions in GHG emission to be won from a modal transfer strategy which in its turn assist with fundamental risk reduction in the transport sector.

From a global economic competition perspective those regions which perform best in "climate change proofing" will be best placed to sustain strong economic activity and win a greater share of global inward investment. There are significant economic opportunities flowing from a climate change strategy applied specifically to the transport and business context of the Yorkshire and Humber region.

Transport use

The secondary impacts of climate change can affect transport use and mobility. For example alternatively higher levels of car use as a result of wetter winters and perceived dangers/unpleasantness of walking and cycling in wet weather or alternatively higher levels of walking and cycling as a result of warmer winters.

Transport has a very significant impact on all of the residents of the Yorkshire and Humber region. These impacts have a strong economic, social and health dimension and it is important to assess how climate change impacts already discussed might further impact on travel behaviour, road traffic accidents and health. The most significant impacts arising from transport are in the passenger sector and include (Whitelegg, 1993):

- Road traffic accidents
- Health damage from respiratory disease, lack of exercise, obesity and diabetes
- Greenhouse gas emissions

UK government policy underlines these impacts with a number of targets:

1. Increase rail passenger use by 50 per cent
2. Increase bus use by 10 per cent
3. Quadruple the number of cycling trips
4. Reduce road traffic accidents by 40 per cent
5. Reduce car commuting trips (no specific target)
6. A 20 per cent decrease in greenhouse gas emissions (not specifically applicable to transport)

7. Improvements in air quality (a variety of targets)

Secondary climate change impacts have a direct bearing on the three main impacts listed above and the seven government targets. For the sake of brevity these are only discussed here under the following two impact headings.

Road traffic accidents

The UK has a better record in this area than most European countries but at a disaggregate level is a poor performer. Pedestrians and cyclists run relatively high risks in this country compared to Germany or Scandinavian countries. Climate changes that produce warmer weather (as long as these "gains" are not offset by wetter weather) will encourage more walking and cycling. This is in line with government policy and targets, it will contribute to reducing greenhouse gases and it will increase physical fitness reducing the incidence of obesity and diabetes. It will also lead to an increase in road traffic accidents since pedestrians and cyclists are relatively vulnerable groups. Clear policy intervention will be needed to reduce road traffic accidents in anticipation of higher levels of exposure on the part of vulnerable groups. This policy intervention should be concentrated on speed reduction and on highway space reallocation (i.e. the provision of Danish and Dutch levels of fully segregated and high quality cycle track). Government will need to make the link between climate change impacts, encouraging walking and cycling and compensating for the increase in risks associated with these higher levels of walking and cycling activity. This important consideration is not reflected in the Regional Transport strategy for the Yorkshire and Humber region. In the absence of specific and targeted compensation road traffic accidents will increase in number and severity with consequential losses for the economy and increased NHS costs (not to mention the human tragedy).

Making the links – Car use and greenhouse gas emissions

Although this study is concerned with impacts rather than mitigation it is worthwhile making the links between these two areas for the transport sector.

The car is responsible for 80.9 per cent of vehicles miles travelled in Great Britain (Transport Statistics Great Britain, 2001). Reducing greenhouse gases to the level agreed by the UK government (a 23 per cent reduction by 2010 on 1990 levels) will require a highly co-ordinated and targeted programme aimed at car traffic (and to a lesser extent at lorries). Paradoxically recent work around the world in the area of travel demand management shows that this can be done relatively easily. Reductions of 15-20 per cent in vehicle kilometres have been reported in demand management projects in Perth (Western Australia), Brisbane (Queensland) and in transport plans in the UK (DTLR, 2002). Reducing GHGs from the transport sector is a high priority but not one that currently attracts enough support. Yorkshire and Humber can distinguish itself as a responsible and sustainable region by:

- doing whatever it can to reduce GHG in every sector of the economy and in every sub sector of transport (cars, lorries and aviation) and auditing new developments (roads and airports) to be very clear that they are not unnecessarily adding to GHG inventories.

The consideration of climate change impacts in Yorkshire and Humber region brings with it a responsibility to make sure we are not making the problem worse.

Health damage from respiratory disease, obesity and diabetes

The UK has the largest incidence of obesity amongst 14 and 15 year olds in the European Union. This is the result of lack of physical exercise and the rising incidence of car trips for the journey to school (and decline in walking and cycling). The UK Department of Health estimate that between 12,000 and 24,000 deaths each year are "brought forward" by exposure to air pollution, the majority of which has its origins in the transport sector. If climate change impacts do encourage a transfer away from the car for personal travel then there will be clear economic and health advantages and this should be encouraged (as above) by policies that compensate for the increased risk associated with increased level of exposure of pedestrians and cyclists to car traffic. The possibility of transfers in the opposite direction will also be considered. There is evidence to support the view that climate change impacts will encourage a transfer in the opposite direction (from
walking and cycling to the car). Higher temperatures will also have an impact. The main argument for car use in most Australian cities (especially Brisbane and Perth) is that air conditioned cars are a necessity and it is unacceptable to walk and cycle in those temperatures. More work is needed on the detailed geography of wetter/windier versus drier/warmer to shape a consistent approach to the probabilities of modal transfer and compensatory policy. If a transfer does take place towards the car in the built up areas of Yorkshire and Humber (especially the Leeds-Bradford area) then air and noise pollution will increase with consequential increased incidence of cardiac and respiratory diseases. Congestion will increase, economic losses associated with congestion will increase and the demands on public and private expenditures will increase to cope with congestion (i.e. more new roads and bypasses with their further effects on pollution, noise, traffic generation and greenhouse gases).

To cope with this set of contingencies very clear public transport support measures will be needed as expressed by the consultee at the South Yorkshire PTE. Public transport can "mop up" the potential shift towards the car but only if serious public transport support measures are adopted (as is the case in Zurich, Vienna and Copenhagen). There are no such policies in place in the UK at the moment and the cities of Yorkshire and Humber are in a poor position to respond to the challenges of a shift to the car over and above the other pressures already working in that direction (e.g. personal convenience and control, cost and taxation, perceptions of personal safety). Strengthening public transport infrastructure will require a co-ordinated approach to:

- Full integration on the HUR/Copenhagen model
- Priority bus lanes
- Car free areas and car free streets
- Urban logistics to keep large lorries out of cities

There are some schemes underway such as Sheffield’s super tram, guided bus lanes in Bradford and Leeds and park and ride schemes in York.

### Perceptions of Transport

- All consultees identified problems for the regional rail system of flooding, overhead power line failures as a result of high winds and speed limits leading to delays as a result of buckled track (high temperatures) and greater leaf fall (strong winds).
- Consultees from GNER, Railtrack and Arriva identified specific problems from flooding at Heck on Sea, Skelton Bridge, Selby, Malton and Church Fenton.
- The Rail Users Federation/Rail passengers Users Council were concerned about the whole York to Malton line.
- Consultees in GNER and Railtrack identified the need to strengthen embankments and increase expenditure on flood prevention.
- The Rail Users Federation identified the strengthening of catenary systems as a priority.
- The South Yorkshire PTE expressed the need for a set of clear public transport support measures.
- None of the consultees had a climate change policy that examined the implications of climate change for their business.

### 5.8.6 Opportunities

The impact of climate change on the region’s transport system has few opportunities other than ensuring that it is protected against flooding. Transport investments over the next 20-30 years should require all transport infrastructure developments to be climate change compliant. Transport investment should take on board best available evidence on:

- how to reduce the susceptibility of railway line to flooding (e.g. new drainage works, permaculture practices to reduce run-off and conserve water in biomass, embankments).
- how to reduce the susceptibility of railway overhead power lines to damage from strong winds (better design with stronger materials, wind breaks, double catenary systems, better designed catenary systems).
- how to reduce the probabilities of landslip and tunnel flooding e.g. permaculture practices to reduce run-off and absorb precipitation in suitable planting, new methods of slope stabilisation using low impact planting and embracing new technology.
- new methods of monitoring, detecting and forecasting locally specific problems and
rapid response arrangements for dealing with problems.

5.8.9 Conclusions

Impacts of climate change

The main impacts of climate change are:

- Frequent flooding which will affect particular parts of the region’s road and rail infrastructure due to the inability of drainage systems to cope with the intensity of winter rainfall events.
- Increased risk of landslips along transport routes
- General disruption of all transport operations (road, rail and air) resulting in economic losses
- A change in the transport use and consequent effects on health.

Climate change impacts present the transport system with very real threats and opportunities. The threats are physical and have a direct bearing on the economic prosperity, competitiveness and quality of life of this important region. They are also behavioural. Depending on the magnitude of climate impacts there will be behavioural adaptations leading in some cases to more walking and cycling and in others to more car use. The consequences of more car use are very worrying indeed from a health, greenhouse gas, congestion and competitiveness point of view.

Significance to/for stakeholders and adaptation response

Many of the transport stakeholders consulted were concerned about the susceptibility of the region’s infrastructure to flooding and need the for further investment in transport infrastructure to ensure it is adequately protected against the impacts of climate change. Transport operators and transport users felt that they were dependent on the providers of transport infrastructure to make this investment.

Transport is a very special case in a way that was expressed cogently by the consultee at South Yorkshire PTE.

‘Transport has the capacity to alleviate climate change problems at the same time as transport is the source (in every sense) of many of the problems from the impact of climate change’.

Many sectors of the economy have improved energy efficiency and reduced GHGs. Transport is still set on a course of year on year increases in GHG that threaten the UK’s ability to achieve Kyoto targets. The European Environment Agency in Copenhagen believes that EU GHG reduction targets will not be met due to the growth in transport sector emissions. Transport also contains the seeds of a solution. For GHGs can be reduced through a huge increase in walking and cycling (45 per cent of all trips in the UK are less than 2 miles in length). If more car users shift to public transport then this would result in a significant reduction in GHG per km travelled. If freight is transferred to waterways, trains and coastal shipping and measures taken to reduce the journey length for ordinary everyday trips to schools, shops and businesses then further GHG benefits can be gained.

As well as ensuring that the transport infrastructure is adequately protected against the impacts of climate change (e.g. flooding) the region has an opportunity to improve the provision of public transport and to reduce car use. The Yorkshire and Humber region can set a trend in this direction and the prize is a world class competitive and sustainable region.

Targets and Indicators

- Transport delays due to adverse weather conditions (i.e. road, rail and air)
- Modal shift from public transport to car due to climate change (e.g. adverse weather, reduced reliability and punctuality of transport services as a result of weather induced incidents)

Information gaps and uncertainties

- Guidance is required to inform transport stakeholders of the impacts of climate change on the provision of transport and how to make future investments in transport climate change compliant.
- Assessment of the future risk of the region’s road and rail infrastructure to flooding.
6 Analysis of impacts between sectors and case studies

This section draws together the impacts of climate change discussed in Section 5 and examines the interactions between different sectors. Impacts will rarely only affect one sector and often they have knock-on effects through supply chains and spatial scales, creating a cascade of 2nd and 3rd order impacts. This section also includes a case study of an important group of businesses in the region collectively called the “food and drinks cluster”.

The Regional Sustainable Development Framework identifies 15 aims for sustainable development in Yorkshire and the Humber. This includes the need for a managed response to the effects of climate change, which this report forms part of. However, climate change will also affect the ease to which these aims can be met. For example, the aim for minimum pollution levels may be harder to achieve if river flows are lower in summer or if more intense rainfall increases soil leaching. Table 6-1 sets out some of the potential effects of climate change, both positive and negative, on the sustainable development aims.

The region’s urban areas are still part of the UK’s industrial heartland, while supporting a growing service sector and housing around 80% of the population. The key impacts relate to the increased risk of winter flooding, a decrease in water quantity and quality, changes in the location and type of raw materials and the increased need for air conditioning (Table 6-2). There are many opportunities including a potential boost to tourism and the increased need for specialist insurance and resource management services. Adaptation responses are underway, but more action is required now to minimise impacts such as urban drainage problems and maximise the opportunities, for example those in industry.

Rural areas account for 80% of the region’s land area, which is dominated by around 16,000 main agricultural holdings. The region is also home to areas of national landscape importance such as the North York Moors and internationally important habitats, including the Humber Estuary. Key impacts include tidal flooding and erosion of agricultural land and habitats, a decrease in water quantity and quality, increase in soil erosion and change in habitats. Opportunities include a possible increase in tourism, a greater winter water resource and the growth of new crops. Adaptation measures have begun, but progress is needed, particularly to manage change in agriculture but also to realise potential benefits, for example in tourism.
Table 6-1 The Effect of Climate Change on the Fifteen Aims for Sustainable Development in Yorkshire and Humber

<table>
<thead>
<tr>
<th>Sustainable Development Aim</th>
<th>Potential Effects of Climate Change</th>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good quality employment opportunities available to everyone</td>
<td></td>
<td>Disruption to transport routes Problems with regeneration in the</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Indicative Floodplain</td>
<td></td>
</tr>
<tr>
<td>Conditions which enable business</td>
<td></td>
<td>Damage to infrastructure and loss of resources Higher insurance costs</td>
<td></td>
</tr>
<tr>
<td>success, growth and investment</td>
<td></td>
<td>Problems with regeneration in the Indicative Floodplain</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Innovations, e.g. energy generation,</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>new crops</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Growth in insurance and resource</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education and training opportunities which build the skills and</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>capacity of the population</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Climate change mitigation and</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>adaptation measures may provide</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>specific opportunities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety and security for people and property</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduction in cold and foggy</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increase in flooding, droughts and</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>storms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditions and services which</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>which engender good health</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fewer cases of hypothermia and</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>pneumonnia</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Greater opportunity for pursuit of</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>outdoor activities</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culture, leisure and recreation opportunities available to all</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Greater opportunity for pursuit of</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>outdoor activities</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vibrant communities which</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>participate in decision making</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Climate change mitigation and</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>adaptation responses require local</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>action</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local needs met locally</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adaptation measures may require</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>resources from outside the local</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>community</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A transport network which</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>maximises access whilst minimising detrimental</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>impacts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decrease in cold, icy and foggy</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased flooding, droughts and</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>landslips</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A quality built environment and efficient land use patterns that</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>make good use of derelict sites, minimise travel and promote</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>balanced development</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loss of land may encourage use of</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>brown field sites for future</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>development</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality housing available to everyone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Less fuel poverty</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Problems with flooding and subsidence</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Need for air-conditioning</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Land and insurance costs may increase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A bio-diverse and attractive natural</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>environment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adaptation policies such as washland</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>creation will have a positive benefit.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Some new species supporting</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>biodiversity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimal pollution levels</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased winter flows may dilute</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>effluent discharges</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimal greenhouse gas emissions and a managed response to the</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>effects of climate change</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Climate change impacts may encourage</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>the reduction in greenhouse gas</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>emissions and action regarding</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>adaptation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prudent and efficient use of energy and natural resources with</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>minimal production of waste</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Climate change impacts may highlight</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>need for more sustainable energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>production</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduced river flows should emphasis</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>need to minimise pollution</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A reduction in water resources will</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>necessitate more efficient use of</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>water</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Urban cross-sectoral analysis (‘landscape’ domain type analysis)

<table>
<thead>
<tr>
<th>URBAN</th>
<th>Impact</th>
<th>Opportunity</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coasts</td>
<td>Increased tidal flooding and erosion e.g. Whitby</td>
<td>Possible increase in tourism due to the warmer and drier climate e.g. Scarborough</td>
<td>SMFs already identify ‘hold the line’ option to defend against erosion and drainage systems e.g. Doncaster</td>
</tr>
<tr>
<td>Rivers &amp; drainage</td>
<td>Failure of urban drainage systems e.g. Leeds</td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
<td>Development of water resources strategies</td>
</tr>
<tr>
<td></td>
<td>Refusal of flood insurance or increased premiums for areas within the Indicative Floodplain</td>
<td>New insurance products e.g. for homes and businesses within the Indicative Floodplain</td>
<td>Development of infrastructure and processes to maximise the benefits of increased winter rainfall</td>
</tr>
<tr>
<td></td>
<td>Increase in summer demand for water e.g. Leeds</td>
<td>Development of water efficient products and processes</td>
<td>Development of water resources strategies</td>
</tr>
<tr>
<td></td>
<td>Decrease in summer water quality e.g. River Aire</td>
<td>Development of pollutant minimation products and processes</td>
<td>Development of water resources strategies</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>More water potentially available across the region in winter due to increase in rainfall</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Increase in demand for drinks, salad crops, lifestyle products and environmental technology products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>More water potentially available across the region in winter due to increase in rainfall</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Increase in demand for drinks, salad crops, lifestyle products and environmental technology products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development and installation of sustainable drainage systems, flood proofing and flood defence products</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of water efficient products and processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Development of pollutant minimation products and processes</td>
</tr>
</tbody>
</table>

Key
Impact: Major *, Moderate # and Minor &
Opportunity: Major *, Moderate # and Minor &
Response: Action underway $, action needed !!
### Rural cross-sectoral analysis ('landscape' domain type analysis)

<table>
<thead>
<tr>
<th>RURAL</th>
<th>Impact</th>
<th>Opportunity</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coasts</strong></td>
<td>Increased tidal flooding and erosion of agricultural land and habitats e.g. Humber Estuary</td>
<td>Possible increase in tourism due to the warmer and drier climate e.g. North Yorkshire Moors National Park</td>
<td>CHaMPs already identify land to be used to offset that lost through climate change! Refinement of Indicative Floodplain and resolution of conflict between flood and coastal defence management and planning through development of Strategic Flood Risk Assessments! Marketing initiatives to promote rural areas and habitats! Develop strategies to manage the change in fish species</td>
</tr>
<tr>
<td><strong>Rivers &amp; drainage</strong></td>
<td>Increased risk of flooding! Refusal of flood insurance or increased premiums for areas within the Indicative Floodplain</td>
<td>Creation of flood defence and washland schemes! New insurance products e.g. for land and businesses within the Indicative Floodplain</td>
<td>Research into climate change and flood risk! Research and monitoring concerning floodbank stability! Implementation of holistic and sustainable flood defence solutions! Need for strategy concerning insurance in Indicative Floodplain</td>
</tr>
<tr>
<td><strong>Water Resources</strong></td>
<td>Decrease in spring, summer and autumn rainfall across the region! Increase in summer demand for irrigation e.g. North Lincolnshire! Decrease in summer water quality due to low flows and possibly in winter resulting from increased leaching under more intense rainfall! Potential increase in effluent discharge standards</td>
<td>More water potentially available across the region in winter due to increase in rainfall! Development of water efficient irrigation processes! Development of pollutant minimisation practices in agriculture</td>
<td>Development of water resources strategies! Development of infrastructure and processes to maximise the benefits of increased winter rainfall and minimise the impact of decreased rainfall in other seasons e.g. winter storage reservoirs! Promotion of pollutant minimisation practices in agriculture! Drought contingency planning</td>
</tr>
<tr>
<td><strong>Agriculture &amp; Forestry</strong></td>
<td>Increase in soil erosion and damage to rural buildings due to more intense rainfall events and flooding! Increased risk of excessive heat for livestock! Decreasing incidence of frost-free nights will increase the need for pesticides! Root vegetable storage problems due to higher temperatures! Increased risk of damage or loss of trees due to pests, disease, drought, fires and storms! Loss of some species currently at their southern limit</td>
<td>Increased demand for drinks and salad crops! New crops such as outdoor tomatoes and sunflowers! Increased autumn planting, but only on certain soils! Higher timber growth rates</td>
<td>Forestry Commission, DEFRA and Country Land and Business Association beginning to address change and aim to provide advice! Need to identify any competitive advantages that may emerge for the region</td>
</tr>
<tr>
<td><strong>Habitats &amp; Biodiversity</strong></td>
<td>Loss of some species currently at their southern limit! Drying of heathlands and moorlands and increased bracken invasion! The potential increase in tourism may add pressure to National Parks and sensitive habitats! Increased risk of fire</td>
<td>Gain of some species currently at their northern limit</td>
<td>Studies undertaken by English Nature and others provided a better understanding of the region’s habitats and the likely impacts of climate change! Need flexible management plans for important habitats! Need to promote plans to provide positive conservation benefits, rather than preservation of species and habitats that will change</td>
</tr>
</tbody>
</table>
### Services

- Increased need for supply chain, energy and water management services
- Development of specialist insurance and finance products
- Possible increase in tourism due to the warmer and drier climate e.g. North Yorkshire Moors National Park
- Possible increase in tourism due to the warmer and drier climate e.g. North Yorkshire Moors National Park

### Transport

- More disruption resulting from sea level rise, winter flooding and heat stress

### Key

**Impact:** Major ⬤, Moderate ⬤ and Minor ⬤.  
**Opportunity:** Major ⬤, Moderate ⬤ and Minor ⬤.  
**Response:** Action underway ⬤, action needed ⬤.
6.1 Food and drink cluster: a case study of the reaction to climate change

6.1.1 Introduction

The food and drink sector is of major importance to the economy of the Yorkshire and Humber region, with extremely strong links between local agriculture, fisheries and subsequent processing into finished food and drink. Indeed, one unusual characteristic of the region is the major investment in food processing plants, which is a direct consequence of the local agricultural and fisheries industries. This case study assessed the vulnerability of this sector to potential climate change to anticipate and highlight any causes for concern or where opportunities may arise. There was a real need to reconcile the diverse initial perceptions from within the industry about the potential impacts of climate change which ranged from ‘there are opportunities for increased yields and profitability’ to ‘there will be minimum impact, the industry will cope as it always does’, through to concerns over the ‘severe damage to specific sectors’. To investigate these perceptions the case study focused on some of the diverse but important crops, fisheries and processing industries within the region.

6.1.2 Examples

Example 1 Impacts of climate change on the pea processing industry

One of the clearest examples of an industry which intimately links agricultural productivity and subsequent processing is the frozen pea industry. The industry is of extreme importance both regionally and nationally and Yorkshire and the Humber boasts the largest output of frozen peas of any region in the world. The demanding production process depends on an incredibly tight link between the ‘8 hour window’ in which the crop is ideal for harvest and the subsequent 3 hours after harvest during which the crop is returned to the factory and processed. The unique combination of climate, varied soil types and good transport links within the region have resulted in major plant investment and the evolution of an industry centred around a 30 mile radius of Hull.

Climate drives the production of frozen peas, with the timing of maturation of the crop being critical. It is the planned use of the varied soil types and hydrology, combined with detailed crop management, which enable the industry to thrive in the region. Problems which restrict access to the land, such as flooding or Foot and Mouth quarantines, are potentially very damaging to the industry but can be overcome by flexible management. However, at the very centre of the industry is the temperature (number of heat units) which the planted crops experience; very detailed relationships between the temperature and particular plots of land enable the exact planning of harvest. Consequently, the industry maintains an accurate historical record of past production and climate, together with careful monitoring of climate for immediate management and long-term planning. It is clear that the climate has changed and, over the last 10 years, the start date for the season has moved progressively earlier, from July into June. The industry has adapted, accordingly.

The pea processing industry is one of the major users of mains water in the region and is dependent on secure water supplies. Any assumptions about the long-term viability of the industry, therefore, assume continuity of current water supply. This will be intimately linked to the granting of abstraction rights by the Environment Agency. However, the impacts of drought years are felt by the industry through the direct effects on the crop. MAFF (1996) concluded that the drought of 1995 reduced the yields of vining peas growing on the fen and lighter soils and that problems associated with a narrower window for harvesting caused the loss of some crops. However, careful planning and micro-management within the industry reduces the impacts of such problems. The conclusion is that here is an industry that is intimately linked to climate and, consequently, knows how to cope with climate change and is already doing so. Indeed, it is the variety of soils within the region which brought the industry here and which provides, and will continue to provide, the flexibility to cope with varying weather patterns.

Example 2 Impacts of climate change on the sugar beet processing industry

The sugar beet industry has many parallels with the pea industry, in that the strong links between agronomy and processing are the key to the success of the industry. However, the two industries differ in some very important aspects, with the relative low crop value of sugar beet limiting many management options. However, the two crops do require major local processing facilities, representing a considerable level of capital investment. As for peas, climate has a tremendous effect on the sugar beet industry, with annual weather conditions dominating much of the annual cycle. This cycle starts with drilling in early
spring, the timing of which is governed primarily by temperature and condition of the soil. The predicted reduction in frosts would lead to an extended growing period with earlier drilling unless the soil is too wet. Indeed, crops may increasingly start to run into one another, which is a bonus from the aspect of yields but may result in a ‘green bridge’ for pest transfer.

Sugar beet has a very high water content and is susceptible to summer drought; it is a crop which is rarely irrigated at present because of the preference given to higher value crops, such as potatoes. However, there are opportunities here, in that the design of land preparation equipment can be modified to optimise water retention during dry summers, to provide inexpensive solutions to holding back water for the crop for as long as possible. Additionally, increased on-farm water storage facilities may become increasingly important but the necessary investment is very difficult under current farming economics. If water does not become limiting sugar beet yields may well increase under warmer conditions, but one down side is that the quality of the beet is affected by variable rainfall patterns, with more ‘even’ growth providing a better product. An increase in the within-season variability in rainfall, as predicted from the scenarios, is a negative aspect not only for this reason, but also because of the potential to cause soil erosion in the soils particularly suited for sugar beet growth.

After harvesting, the temperature at which beet is stored can affect the crop, resulting in increased respiration at higher temperatures; if ambient temperatures increase then storage prior to processing becomes more of a problem. The processing of sugar beet is dependent on a few major central processing facilities, with transport being an important cost to the industry, resulting in intensive use of strategically placed plant. In fact, a spread of sugar beet growth further north within the region is currently welcomed by the industry, to optimise return on plant investment. The processing of sugar beet and other sugar-based products is currently a strongly seasonal activity and it may be possible in future to increase the operating year for fresh beet and, consequently, to extend plant operation to 365 days.

Example 3 Impacts of climate change on protected crops

The entire concept of protecting crops is to improve the climate around those high value species that respond well to warmer growth conditions. Such crops include lettuce, cucumbers, peppers and tomatoes. The key limitation to productivity in these situations is usually the amount of light available to the crop during the growing season and, with future scenarios suggesting less cloudy days, the industry can expect higher yields, but only if water supply is not a problem. In many cases water is derived from direct abstraction and the local water authority, with the over-riding assumption that future water supplies will remain as they do today.

The modern glasshouse is specifically designed to retain and shed heat, as and when necessary, and it is anticipated that the units will maintain appropriate environments for the crops, even with temperatures raised consistently by several degrees. The major consequence will be an extension of the growing seasons, but with the associated possibility that specific pests may increase. The protected crop sector is currently undergoing a transition towards integrated crop management aimed at reducing the use of pesticides. This is achieved through a combination of biological control and manipulation of growth conditions and the industry view is that this trend will continue, largely unaffected by climate change, but with the specific nature of the pests possibly changing. A comparison of activities in this sector with that of warmer regions, such as Iberia, suggests that there will be no major problems associated with a temperature increase and that there will be no marked changes in practices or crops. If temperature conditions become extreme then there are low technology cooling systems available which could be introduced to the region but these are, at present, unnecessary even in the very much warmer climate of Iberia.

The processing of protected crops varies, with certain produce such as lettuces and leaf crops, requiring chilling after harvest whereas tomatoes, cucumbers and peppers are stored at ambient temperatures. The increased chilling costs associated with higher ambient temperatures will simply be passed on to the consumer.

Example 4 Impacts of climate change on the meat industry

Similarly, one immediate effect of increased ambient temperatures on the meat industry will be an increase in the cost of keeping the meat cool. However, these costs are minor in comparison with salary and animal costs unless new investment in additional or improved chilling facilities is needed. More important are the indirect effects of climate on animal quality and availability. For example, rainfall and stress events in Spring can alter quality of meat, which in turn affects cutting and processing. Additionally, the
inability to put animals out onto the land early in the season, due to wetter soils resulting from higher winter rainfall, may affect fat content because of the nature of the feeds provided to sheltered animals. However, it is felt that the good farmers can respond to changing weather conditions and manage the animals to keep the fat content correct. Less experienced farmers can get this wrong, leading to a product unsuitable for the supermarket. There is therefore a need for education of farmers regarding good practice under such conditions. With farmers in the region having an average age of 57, such education needs to be part-and-parcel of the general rural renaissance. Those companies which control both agronomic aspects and food processing are at an advantage as they can adapt more effectively to changing circumstance.

In terms of animal processing, the breeding cycle of the animals dictates supply and storm events can lead to animals which require cleaning and laying prior to slaughter. In general, the industry can cope with local climate change but frequently the customer will have to pay for any additional costs incurred. The major concern is maintaining competitiveness in an international market, with cost to the consumer and changes in costs and productivity overseas having a major impact on the sector. The Common Agricultural Policy is seen as the dominating influence in this sector and any effects of climate on this food sector will result in the consumer “paying the price for ‘coping’”.

**Example 5 Impacts of climate change on the Yorkshire and Humber fisheries and fish processing industries**

The fisheries processing industry is one of the main employers in the Yorkshire and Humber region when the whole chain from fishing, ports, auctioneering, processing and sales is considered.

The North Sea has a ‘mixed’ fishery where the catch can vary considerably. There is a feeling in the industry that effects of a general warming of the North Sea are already becoming apparent and there is a change in the balance of the catch. Sea temperature is one of the major factors affecting the distribution of marine organisms right up the food chain, favouring some species at the expense of others. It has been established that all marine species, from plankton upwards, are shifting their distribution in the waters around Britain and also that the temperature of the water in the North Sea has increased over recent years. However, it has also been emphasised that the main determinant of commercial fish population at the moment is the size of the catch, and climate change is an additional contributory factor, which still needs to be taken into account. There is an identifiable northwards shift of species, including important commercial fish. In the North Sea, some species at the southern limit of their range are moving northwards whilst other populations at the northern limit of their range are increasing. The most important species perceived to be moving northwards is cod since higher sea temperatures strongly affect the reproductive success of this species. Over-fishing is a major factor affecting cod numbers, but there is a perception that the effect of sea temperature increases in contributing to a general northwards movement of the population. For example, populations around Shetland and the Faeroe islands are doing much better than further south.

Some species typical of warmer seas are now becoming common in the North Sea. One main species mentioned is red mullet, a species formerly typical of the western seaboard of France and western English Channel, is now being found in sufficient numbers for there to be a development of a small red mullet fishery in the Yorkshire and Humber region. However, it was not perceived that this species, even though it is a high value fish, could replace lost cod fisheries in the region. It is believed that the population size of mullet will not become large enough to compensate for other losses, with the red mullet being largely seasonal and only present in the summer for 6-8 weeks. This contrasts with a year-long presence round the Bay of Biscay. Another high value species shifting northwards is sea bass, which is now found around the Wash. Although it is becoming possible to predict the changes in presence/absence of specific fish species under different climate change scenarios it is not possible to estimate population sizes, as yet.

Government decommissioning schemes designed to conserve fish stocks have drastically reduced the number of fisheries that remain in the Yorkshire and the Humber region and the remaining fleet consists of small or medium sized boats (usually less than sixty feet long) with a range of about 200 miles. When fishing boats have to travel over longer distances, fish quality can be compromised. Cod is the most important fish for these smaller boats and it is perceived that fisheries using these vessels will find it difficult to adapt to new circumstances with smaller cod catches. In contrast, larger fishing vessels, with a greater range, will not suffer as they can follow the cod northwards. However, most of these vessels operate from Scottish ports such as Aberdeen. The fisheries industry, generally, has had to undergo many
changes over the last thirty years, including leaving Icelandic waters and following other legislation in the Common Fisheries Policy. Therefore, the remaining industry is quite adaptable. Those fisheries relying on local catch will be most sensitive to changes in fish stocks. They can travel further to find the fish, but this will make life harder for these fishermen. If populations of new fish species rise and become viable, then there is a need to develop marketing strategies to promote the new species and change consumer preference. Alternatively there will be a need to import favoured species from farther afield.

Haddock is not perceived as being quite so sensitive to warming seas as cod. It also seems unlikely that flat fish, such as plaice, would be greatly affected one way or the other. Lobster and crab fisheries represent thirty per cent of the value of marine fisheries in the UK and Bridlington is the largest lobster landing port in the UK. Both edible crab and lobster have wide-ranging distributions in the Atlantic and it was perceived unlikely that they would decrease in abundance in a warmer sea. However, these catches are of limited number and already under pressure and it is unlikely that this fishery can increase significantly.

In the Humber estuary many fish processing industries are located close to the sea walls (such as in Hull and Grimsby) and are therefore vulnerable to increases in sea flooding unlike the processing facilities in Scarborough, Bridlington and Whitby which are not located in vulnerable locations. A general warming would entail an increased cost in chilling (cold rooms or ice production) and freezing fish in what is already a significant cost to the industry. There is a feeling that the changes in fish stocks off the Yorkshire and Humber coastline will not greatly affect large fish processing industries since more than sixty per cent of cod is already imported into the UK from abroad. The human resource and skills base, as well as the infrastructure built up in the region (especially in the Humber) would be difficult to relocate, and therefore there is a likelihood that the fish processing industry will remain, even under changing climatic conditions, even if costs of transport and storage increase. The successful companies will be those that have good responsive management, are well resourced and who can exert a significant affect on the market. One person consulted considered that smaller companies may sometimes be at an advantage in that they can adapt very quickly. In many cases it is the medium-sized industries that are most sensitive, who may have a significant investment in one type of fishery, for example. The fishery industries from the ports of Bridlington, Scarborough and Whitby are considered most sensitive to climate change as they rely more on local catches than the larger Humber ports. The fishing fleet in these ports has been reduced by 70-80 per cent already.

Both the EU and DEFRA will play an important role in assisting the fishing industry through the transitions associated with changing climate, both in developing the scientific information about fish stocks and then using this knowledge to influence decision making in Brussels. Meanwhile, the Sea Fish Industry Authority, which assists the development of the industry from the fisherman through to consumer, will play a key role in marketing and technical developing and reporting. The role national authorities can play is, in some cases being made more difficult by the increasing regionalisation of government in the UK as there is a potential for an increase in duplication of effort, e.g. training may become fragmented and duplicated. In the short term various policies affecting fisheries have a greater effect than climate changes (e.g. by setting fishing quotas). In the longer term changing sea temperatures could have a more significant effect. Currently decisions on quotas and management of fish stocks are made from year to year, but the climate change issue has highlighted the need for longer-term planning in the industry. This planning has to occur at the international, EU level, where regulations are made. There is a need to develop methods to carry out integrated studies of fishery responses to climate change and fishing, investigating the interaction between the two, with a time-scale of 20 years.

**Example 6 Impacts of climate change on the Brewing Industry**

Breweries in the Yorkshire and Humber region form a significant part of the food and drinks processing industry and have a reputation for brewing fine beers. The impacts of climate changes can have both positive and negative influences on the brewing industry, but in the main the changes in climate do not represent a threat to brewing in the Yorkshire and Humber region.

The positive impacts of warmer summers will be that more people drink larger amounts of beer. The negative impacts refer to potential impacts of flooding on sites - either flooding of the brewery themselves (such as in the case of the Tetley brewery in Leeds where the river Aire has come close to flooding the site).
Other potential impacts relate to water and barley/malt supply. Water quality is of course vital for beer quality, yet as long as the water companies can supply the water they require the breweries should not suffer. Breweries are major water users with 4 litres of water being required to make one litre of beer. The perceived main issue for the breweries with regard to the water companies was that the breweries wished to have increased prior information about changing water quality. Barley is a main ingredient in beer and much of the barley and malt is sourced locally partly due to the high cost of transportation. Additionally, breweries prefer to build up good relationships with local grain suppliers to ensure consistency of quality. However, barley is sensitive to climatic conditions, especially lack of water.

6.1.3 Impacts along the chain

Although this sector contains a variety of diverse agricultural activities and processing stages several key common features emerged:

- The agriculture and food processing industries in the region are generally adaptable to new climatic conditions, but any additional costs of production will pass to the consumer. For example, chilling is a common feature for processed foods and these costs will increase under a warmer climate.
- Those industries that exert close control both over agronomic and food processing aspects will be able to adapt more effectively to changing conditions, as they have more direct control of the supply chain.
- Growth seasons and yields for many crops will increase so that processing plants may be more efficiently used, increasing economic viability.
- Changes in growing conditions overseas will have a direct impact on the economic viability of certain crops and industries in the Yorkshire and Humber region and these changes may be both positive and negative.
- Agricultural policy is seen as a stronger driver of change than shifts in climate.
- Many of the important features that have dictated why certain industries have been established in the region (e.g. diversity of soil types for the frozen pea industry) will remain a regional strength under a changing climate.
- Low value crops are at higher risk under changing climatic conditions as costly adaptation cannot be applied as for the more valuable crops; there is therefore a need for innovative, low cost solutions to increase sustainability of these crops (e.g. water retention).
- There is a need for increased education amongst farmers about adaptation practices under changing climatic conditions. The frequent comment that the ‘best farmers’ know how to adapt suggests a need for dissemination of best practices. This needs to be part of the general renaissance of agriculture in the region.
- Warmer summers are seen as increasing demands for beers, drinks products and salads. However, maintenance of quantity and quality of water supply is frequently an issue for concern. For example, brewery operation could be compromised by flooding of premises, change in water quality and influences of water supply on barley crops in the region.
- The sector is a major water user in the region. The optimistic prognoses for the industry under a changing climate is based on an assumption that that there will continuity of water supply and this assumption needs to be verified under different climate scenarios, and the development of further water storage in the region needs to be addressed.
- Industries will be under increasing pressure to conserve water in their processes if water scarcity increases. Also, the quality of effluent from plants may need to be improved because of potential reductions in dilution on discharge.
- There is a general shift of marine species northwards in the North Sea, including commercially important species such as cod, whilst there are species typical of more southerly regions (such as red mullet) which are becoming more common.
- Major fish processing industries in the region will adapt to changing conditions as the considerable investment in processing equipment and the skills built up in the region mean that it is unlikely to relocate, but they will have to import fish stocks from further afield as required. Smaller industries reliant on local cod fisheries may find conditions more difficult.

6.1.4 Conclusion
The food and drink sector is largely very adaptable and will experience future benefits in yield, together with extended growing seasons; however, it is critical to the sector that consistency of quality and quantity of water supply is maintained. The fish processing industry will suffer from changing distributions of commercially important species, which is very much out of the control of the industry, placing specific parts of the sector at risk. However, in general, any increased costs to the food and drink industry resulting from climate change will largely be passed to the consumer.

Figure 6.1 Climate change on the Foods and Drinks cluster

- **Pressure**
  - Higher temperatures
  - Reduced summer rainfall
  - More refrigeration
  - Longer growing season
  - Higher yields
  - Increased demand for water
  - Changing fish species
  - Increased local and national demand for “summer” food products

- **Impact**
  - Less water for abstraction from rivers
  - Reduction in river flow = less dilution of food processing discharges
  - Increased risk of flooding
  - Greater soil erosion
  - Restoration of washlands for flood defence

- **Response**
  - Increase water efficiency in irrigation and processing
  - Develop alternative local water sources
  - Improve effluent quality with sustainable rural drainage systems
  - Long-term planning
  - Identification of emerging high value niche food and drink markets
  - Raise awareness of adaptation methods for farmers
  - Maximise the region’s advantages e.g. diversity of soils for pea industry
  - Plan for the changes in fish species and the adverse impact on smaller industries
  - Consider climate change in agricultural policies

- **Agricultural Policy**
  - Higher and more intense winter rainfall
  - Changes to policy must consider climate change

- **Overseas Changes**
  - Seen as more influential than climate change
  - Changes in climatic and socio-economic conditions beyond the region will affect the economic viability of the agri-food sector within the region
  - Changes in global chains of supply and demand
7 Conclusions

This study has assessed potential impacts of climate change on the Yorkshire and Humber region and identified some of the options for adaptation to those impacts. The region’s baseline position with regard to climate change was established through literature review. The likely changes in climate have been identified through analysis of historic data, UKCIP02 scenarios and the output of a Regional Climate Model. Table 7-1 summarises the main changes in temperature and rainfall over the next century.

Table 7-1 30-Year Mean Change in temperatures (degrees) and rainfall (%), relative to 1961-1990, for the Low Emissions and High Emissions scenarios

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Period</th>
<th>Annual</th>
<th>Winter (DJF)</th>
<th>Summer (JJA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>2020s</td>
<td>L 0.5 to 1.0</td>
<td>0.5 to 1.0</td>
<td>0.5 to 1.1</td>
</tr>
<tr>
<td>-</td>
<td></td>
<td>H 0.5 to 1.0</td>
<td>0.5 to 1.0</td>
<td>1.0 to 1.3</td>
</tr>
<tr>
<td>-</td>
<td>2050s</td>
<td>L 1.0 to 1.4</td>
<td>2.0 to 1.4</td>
<td>1.5 to 1.8</td>
</tr>
<tr>
<td>-</td>
<td></td>
<td>H 2.1 to 2.3</td>
<td>1.6 to 1.8</td>
<td>2.5 to 2.9</td>
</tr>
<tr>
<td>-</td>
<td>2080s</td>
<td>L 1.6 to 2.0</td>
<td>1.4 to 1.6</td>
<td>2.3 to 2.6</td>
</tr>
<tr>
<td>-</td>
<td></td>
<td>H 3.5 to 3.9</td>
<td>2.7 to 3.0</td>
<td>4.0 to 4.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rainfall</th>
<th>Period</th>
<th>Annual</th>
<th>Winter (DJF)</th>
<th>Summer (JJA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>2020s</td>
<td>L 0 to -5</td>
<td>0 to 5</td>
<td>-10 to -15</td>
</tr>
<tr>
<td>-</td>
<td></td>
<td>H 0 to -5</td>
<td>2 to 6</td>
<td>-12 to -15</td>
</tr>
<tr>
<td>-</td>
<td>2050s</td>
<td>L 0 to -5</td>
<td>8 to 12</td>
<td>-13 to -17</td>
</tr>
<tr>
<td>-</td>
<td></td>
<td>H 0 to -5</td>
<td>15 to 20</td>
<td>-27 to -32</td>
</tr>
<tr>
<td>-</td>
<td>2080s</td>
<td>L 0 to -5</td>
<td>13 to 17</td>
<td>-23 to -26</td>
</tr>
<tr>
<td>-</td>
<td></td>
<td>H -5 to -20</td>
<td>25 to 32</td>
<td>-47 to -52</td>
</tr>
</tbody>
</table>

In terms of extremes, this will mean that:

- The hot summer of 1995, an event currently expected only once in a century, will occur one year in three by the 2020s
- Summers with less than half the normal rainfall will occur once every four years by the 2020s
- Winters with more than 160% of normal rainfall will occur once every four years by the 2050s

Also:

- Sea level will rise between 15 (Low Emissions) and 75 cm (High Emissions) by the 2080s relative to the level in 1990
- The 1 in 50 year surge height will increase between 20 cm (Low Emissions) and 80 cm (High Emissions) by the 2080s

The impacts of these changes in climate, both positive and negative, and the significance of these impacts were assessed by consulting over 100 key regional stakeholders. The most significant of these impacts are:

- Changes to the risks of river and tidal flooding, with increased risks in winter months.
- Prolonged periods of flooding in the winter that will require changes to operation of flood defences, with increased emphasis on monitoring the status of barrier defences to avoid breaches, and the development and optimisation of washlands on a catchment scale.
- Drier autumns and summers leading to some local water resources problems for businesses that abstract directly from rivers in the summer. Increased average annual recharge to groundwater sources will mean the overall regional water resource balance will remain favourable compared to other regions.
- Increased short-duration drought frequency – this will affect the reliability of small surface water reservoirs that fill and empty annually.
- Changes to agricultural systems in response to the opportunities to grow different crops, such as sunflowers and outdoor tomatoes, and challenges to overcome relating changing needs for pest management, irrigation and minimising diffuse water pollution.
- Losses and gains in species with some species at their southerly limit, such as Black Grouse, migrating further north and others moving into the region from the south. Upland and coastal habitats already under stress require monitoring and sensitive management of change.
- Significant threats to road and rail as a consequence of extreme weather conditions.
The most important opportunities are related to:-

- The development of specialist services and technologies to support climate change adaptation strategies. For example, increasing water efficiency and recycling in industrial processes. There is a potential for business growth in the university/science park high technology cluster.
- Specialist insurance services that can offer competitive insurance rates due to improved information on flood risks and other climate related hazards.
- The adaptability of the food and drinks cluster. The region’s food industry has already proven that it can adapt rapidly to change. In future it should benefit from changing climate conditions.
- New forms of coastal tourism and recreation. The coastal areas have an opportunity to re-invent themselves and offer new forms of sustainable tourism activity. In future, Southern Europe may be too hot and therefore less attractive for tourism and areas in Northern Europe can benefit from these changes.
- Additional impetus for sustainable development. Climate change adaptation reinforces the need for sustainable development.

The most important indicators of change to monitor are:

- Local sea level rise, storm surge conditions and erosion rates
- Local rainfall, extreme rainfall events and droughts
- River flows, groundwater levels and soil moisture content
- Land surface and sea water temperatures
- State of key habitats and rare species
- Demand for water
- Climate related health indicators, e.g. pneumonia rates
- Future water demand, including for irrigation
- Feasibility of different crops
- Extent of refrigeration and air-conditioning required
- Vulnerability of the region’s habitats and species
- Change in type and location of raw materials
- Change in consumer preferences and behaviour
- Effect on tourism

Finally, the study sought to recommend ways in which to respond to the impacts of climate change in the region. Specific response measures are outlined in Table 7-1. Generic responses include:

- **Consensus building**. Increasing awareness of climate change impacts and encouraging smaller businesses to consider energy efficiency, water efficiency, climate risks and climate opportunities
- **Managing extremes**. Lessons learned from the 1995 drought and Autumn 2000 floods need to be incorporated into contingency plans for future more frequent flood and drought conditions
- **Risk based decision making**. Decision makers need to be informed about risks and advised on how to take account of changing conditions. Professional regional bodies and trade organisations have an important role to play in developing simple guidelines on how to take account of future risks.
- **Spatial planning**. Planners are in a unique position to support climate change adaptation. Flood risks, the potential for new crops, changing health and transport patterns can all be mapped to develop scenarios of the future with and without planning inputs. Improved mapping of the potential impacts is needed to incorporate climate change in regional plans.
- **Integration with sustainable development**. Climate variation, floods, heat-waves and droughts are not new and neither are many of the actions required to adapt to a changing climate. Climate change adaptation reinforces actions for sustainable development. Some of the region’s sustainable development targets, such as those relating to water quality, could be adversely affected by climate change over the next 50 years. Therefore, climate change makes sustainable development activities more urgent than ever before.

Information gaps should be filled to provide a better understanding of climate change within the region and to ensure that appropriate response strategies are established. Key gaps include:

- Change in storminess
- Effect on fish species
### Table 7-2 Summary of Impacts and responses

<table>
<thead>
<tr>
<th>Sector</th>
<th>Likely Impacts</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal</td>
<td>Possibility increase in tourism</td>
<td>Shoreline Management Plans and CHaMPS</td>
</tr>
<tr>
<td></td>
<td>Change in fish species</td>
<td>Refinement of Indicative Floodplain including through Strategic Flood Risk Assessments</td>
</tr>
<tr>
<td></td>
<td>Loss of land due to increased erosion rates and flooding</td>
<td>Closer integration with planning system</td>
</tr>
<tr>
<td></td>
<td>Larger area within the Indicative Floodplain causing regeneration and insurance problems</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loss of internationally important inter-tidal habitat</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased tidal flooding</td>
<td></td>
</tr>
<tr>
<td>Drainage, rivers &amp; floodplains</td>
<td>More winter flooding</td>
<td>Research into climate change and flood risk</td>
</tr>
<tr>
<td></td>
<td>Larger area within the Indicative Floodplain</td>
<td>Improvements to flood defences</td>
</tr>
<tr>
<td></td>
<td>Urban drainage problems</td>
<td>Close integration with planning system</td>
</tr>
<tr>
<td>Water resources</td>
<td>Greater winter rainfall will recharge aquifers and benefit reservoirs</td>
<td>Research by water industry and government agencies into potential impacts on supply, demand, water quality and sewerage design</td>
</tr>
<tr>
<td></td>
<td>Water quality will vary depending on flow</td>
<td>Businesses need to increase water efficiency, secure alternative water supplies and minimise pollution</td>
</tr>
<tr>
<td></td>
<td>Lower summer flows will reduce water for abstraction</td>
<td>Need to find more small scale water supplies and adopt grey water recycling</td>
</tr>
<tr>
<td></td>
<td>Greater demand for water in summer</td>
<td>Drought contingency planning</td>
</tr>
<tr>
<td>Agriculture &amp; forestry</td>
<td>Increased forest yields</td>
<td>Work underway to provide advice to farmers and rural businesses</td>
</tr>
<tr>
<td></td>
<td>Climate changes beyond the region will affect the food business</td>
<td>Opportunities presented by climate change need to be realised in policy making</td>
</tr>
<tr>
<td></td>
<td>Flooding of land or premises</td>
<td>Identification of alternative summer water resources</td>
</tr>
<tr>
<td>Habitats &amp; biodiversity</td>
<td>Potential overall increase in biodiversity</td>
<td>Studies underway identifying likely impacts</td>
</tr>
<tr>
<td></td>
<td>Species migration</td>
<td>Need for flexible management plans for species and habitats that focus on positive conservation benefits rather than preservation</td>
</tr>
<tr>
<td></td>
<td>Increased pressure on National Parks and sensitive habitats</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased fire risk</td>
<td></td>
</tr>
<tr>
<td>Industry &amp; commerce</td>
<td>Potential new products</td>
<td>Changes in building standards built into continual improvements</td>
</tr>
<tr>
<td></td>
<td>Transport affected by sea level rise, more flooding and heat stress but will benefit from less fog and cold weather problems</td>
<td>Need to identify any competitive advantages that may emerge for the region</td>
</tr>
<tr>
<td></td>
<td>Processes sensitive to environment e.g. temperature, need to adapt</td>
<td>Need to increase resource efficiency</td>
</tr>
<tr>
<td></td>
<td>Change in type and location of raw materials</td>
<td>Small and medium sized companies need to address adaptation</td>
</tr>
<tr>
<td></td>
<td>Loss or damage to infrastructure</td>
<td></td>
</tr>
<tr>
<td>Services</td>
<td>Tourism and leisure industry likely to benefit from warmer weather</td>
<td>Need to identify and promote the opportunities for tourism and recreation</td>
</tr>
<tr>
<td></td>
<td>New insurance products</td>
<td>Need to realise the potential for growth in resource management and insurance services</td>
</tr>
<tr>
<td></td>
<td>Increased need for resource management services</td>
<td>Need to monitor the condition of heritage and archaeological sites</td>
</tr>
<tr>
<td></td>
<td>Reduction in cold weather illnesses but increase in others e.g. respiratory conditions</td>
<td>Local authorities, health authorities and emergency services need to plan adaptation to changes in flooding, fire risk, transport, health, social activity and lifestyles</td>
</tr>
<tr>
<td></td>
<td>Heritage and archaeological sites vulnerable to drought, flooding and water-logging</td>
<td></td>
</tr>
</tbody>
</table>

Negative Impact: Major ★★★, Moderate ★★ and Minor ★
Positive Impact: Major ★★★, Moderate ★★ and Minor ★
Neutral Impact: ★★

Response: Action underway ✔, action needed !!
References


BMJ 1997; 315: 805-809 Anthony J McMichael and Andrew Haines Global climate change: the potential effects on health

BMJ 1997; 315: 870-874; Andrew Haines and Anthony J McMichael; Climate change and health: implications for research, monitoring, and policy

BMJ 1999; 318: 1682-1685 R Sari Kovats, Andrew Haines, Rosalind Stanwell-Smith, Pim Martens, Bettina Menne, and Roberto Bertollini: Climate change and human health in Europe


Cannell, M.G.R., Palutikof, J.P. and Sparks, T.H. 1999 Indicators of Climate Change in the UK Climatic Research Unit and the Centre for Ecology and Hydrology

CEH, Met. Office 2001 To what degree can the October/November 2000 flood events be attributed to climate change? DEFRA


Department of Health - Health effects of climate change in the UK (available from http://tap.ccta.gov.uk/doh/point.nsf) the key document for health and climate change research in this country

Department of Health 2001 Health Effects of Climate Change in the UK Dep. Of Health

DETR 2000? Climate Change: the UK Programme (Draft) DETR


English Nature, RSPB et al. Climate Change and Wildlife


Environment Agency. 1998. S. Yorks and North East Derbyshire LEAP.
Environment Agency. 1998. Swale, Ure and Ouse LEAP.
http://www.cape.ca/resources/documents/Greenhouse.html provides an overview of the relationship between climate change and health. It also contains a number of references of more depth.

http://www.scientificamerican.com/2000/0800issue/0800epstein.html Again, an overview, but this time on a global level

Hulme, M et al. 2002. Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report. Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, UK, 120pp.


IPCC 2001 Relevant sections of the Third Assessment Report (TAR)


IPPC 2001 Climate Change 2001: the scientific basis. Cambridge University Press, UK


Manson-Siddle, C (2001) Yorkshire and Humber: Health Links. ???This provides an overview of health in the region and might be useful for baselines, NHS Executive Trent ???


Parry, M.L. (ed.) 2000 Assessment of Potential Effects and Adaptations for Climate Change in Europe: The Europe ACACIA Project Jackson Environment Institute, University of East Anglia


Queens University 2002 Northern Ireland Scoping Study


Rural Development Programme


Strzepek, K.M. et al. ? Water Resources ?

Sustainability North West 1998 Everybody has an Impact - Climate Change Impacts in the North West of England: Summary Report. Sustainability North West

The variety of wildlife in Yorkshire and Humberside: A biodiversity audit of the Yorkshire and the Humber, 1999, The Yorkshire and Humber Biodiversity Forum


UKCIP. 2001. Thinking Ahead. Socio-economic scenarios for climate change impact assessment. UKCIP.


WS Atkins. 2001. Thames Climate Change Study
WWF. 2000. Keeping the Sea at Bay


GLOSSARY

AOGCM            Atmosphere-Ocean General Circulation Model
AONB             Area of Outstanding Natural Beauty
CFMP             Catchment Flood Management Plan
CHaMP            Coastal Habitat Management Plan
CFC              Chloroflourocarbon
CH₄               Methane
CO₂              Carbon dioxide
CSO              Combined Sewer Overflow
DEFRA            Department for Environment, Food and Rural Affairs. New department formed from DETR environmental divisions and MAFF
DTLR             Department for Transport, Local Government and the Regions
GCM              Global Climate Model (sometimes referred to as General Circulation Model)
GDP              Gross Domestic Product
GGE              Greenhouse Gas Emission
GHG              Greenhouse gas
HadCM2           Hadley Centre Model 2
IDB              Internal Drainage Board
IFPM             Indicative Floodplain Map
IPCC             Intergovernmental Panel on Climate Change
MAFF             The former Ministry of Agriculture, Fisheries and Food, now part of DEFRA
N₂O              Nitrous oxide
NCRAOA           The Environment Agency’s National Centre for Risk Analysis and Options Appraisal
NGO              Non-governmental Organization
NNR              National Nature Reserve
PPG25            Planning Policy Guidance Note 25 (DTLR, 2001)
RCM              Regional Circulation Model
RegIS            Regional Climate Change Impacts and Response Studies
RPG12 Regional Planning Guidance for Yorkshire and Humber (GOYH/DTLR, 2001)
RSDF Regional Sustainable Development Framework
SAC Special Area of Conservation
SAR Second Assessment Report (from IPCC)
SLR Sea-level Rise
SMP Shoreline Management Plan
SPA Special Protection Area
SRES Special Report on Emission Scenarios
SSSI Site of Special Scientific Interest
SUDS Sustainable Urban Drainage System
TAR Third Assessment Report (from IPCC)
UKCIP UK Climate Impacts Programme. This programme, funded by DEFRA, promotes stakeholder led climate impacts assessment.
UKCIP02 The latest climate change scenarios, produced for UKCIP in 2002
UKCIP98 Climate change scenarios produced for UKCIP in 1998
Appendices

Appendix A Organisations Represented on the Project Steering Group

Associated British Ports
AvestaPolarit Stainless
Business in the Community Yorkshire and Humber
Countryside Agency
East Riding of Yorkshire Council
Edison Mission Energy
English Nature
Environment Agency
Government Office for Yorkshire and the Humber
Hambleton DC
Humber Emergency Planning Services
Kingston Upon Hull City Council
Leeds Health Authority
NFU
North York Moors National Park Authority
Norwich Union
Regional Assembly
Regional Chamber
Rotherham MBC
Shepherd Building Group
South Yorkshire Passenger Transport Executive
The Forestry Authority
UK Climate Impacts Programme
University of Bradford
Yorkshire & Humber Assembly
Yorkshire Electricity
Yorkshire Forward
Yorkshire Tourist Board
Yorkshire Water Services

Appendix B

Climate Scenarios (UKCIP02 Maps)
Refer to http://www.ukcip.org.uk/climate_change/future_uk.html
## Appendix C Consultation Method

Table C-1 An example of an impacts table used by the interviewer to record consultation responses

<table>
<thead>
<tr>
<th>DOMAINS OF CLIMATE CHANGE IMPACTS</th>
<th>PRIMARY IMPACT</th>
<th>SECONDARY IMPACT</th>
<th>FURTHER IMPACTS</th>
<th>MOST VULNERABLE ASPECTS</th>
<th>ADAPTATION AND RESPONSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>CULTURAL HERITAGE, LEISURE &amp; TOURISM</td>
<td>Wetter Winters; changed rainfall patterns.</td>
<td>More frequent flooding, greater extent, longer inundation period.</td>
<td>Loss of access time; closure of facilities</td>
<td>Houses, hotels, cultural attractions and events; access.</td>
<td>More insurance; change in visitor schedules; more maintenance.</td>
</tr>
<tr>
<td></td>
<td>Drier Summers; less cloud cover.</td>
<td>Longer and more frequent periods of drought.</td>
<td>Less available water; drier soils; less stream flow.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rise in sea-level more pronounced.</td>
<td>Coastal flooding</td>
<td>Less land available for profitable use.</td>
<td>Coastal properties; road and rail links.</td>
<td>Coastal protection; improved access links.</td>
</tr>
<tr>
<td></td>
<td>Longer Summer season; fewer early and late season frosts.</td>
<td></td>
<td>More visitors; more damage to facilities</td>
<td>Wear and tear on habitats and attractions.</td>
<td>Cater for longer season; expand choice.</td>
</tr>
<tr>
<td></td>
<td>Less snowfall and shorter period of snow cover.</td>
<td>More exposure.</td>
<td>Winter events (skating and skiing)</td>
<td></td>
<td>Reduced provision for Winter sports.</td>
</tr>
</tbody>
</table>
Appendix D Workshop
### Table D-0-1 Workshop Summary

<table>
<thead>
<tr>
<th>Theme</th>
<th>Impacts of climate change</th>
<th>Opportunities of climate change</th>
<th>Climate variables &amp; scenarios presentation</th>
<th>Sustainable development aims</th>
<th>Adapting to climate change</th>
<th>Key issues</th>
</tr>
</thead>
</table>
| **Water**                         | Pressure on public water supply (households, gardens, industry, commerce)                 | Will probably be more water in total for the region (will require careful management) | Evaporation: monthly or seasonal mean temperatures  
Rainfall: monthly or seasonal mean rainfall  
Sea level rise: intra-regional variations | Link with Regional Sustainable Development Framework (RSDF) Aims No. 13 (targets relating to river water and bathing water quality) and 15 – the prudent use of water resources. | Adaptation not possible entirely within the natural environment                                   | Development of Sustainable Urban Drainage Systems (SUDDS) Water supply security               |
| **Natural Environment**           | Higher spring rainfall affect, for example, on birds, woodlands and floodplain habitats Secondary impacts e.g. on tourism, food chain | May be possible to develop different landscapes attractive to tourists | Spring rainfall: cumulative effects  
Intra-regional variations | Direct link with the targets identified in the RSDF Aim No. 12 of “zero loss to areas of priority habitats” and “no decrease in wild bird populations”. | Diversity of the region will facilitate adaptation in the natural environment | Need to consider the total environment – not just designated areas Inter-linkages between parts of the region and different habitats An integrated planning approach is essential to increase robustness Further work needed to identify vulnerable areas, landscapes, habitats and species |
| **Agriculture & Food**            | Different activities affected (dairy, sheep, pigs, vegetables/root crops) by magnitude and timing of rainfall, temperature and sunshine changes particularly on a seasonal basis | Possibility that different crops could be introduced to the region (e.g. sunflowers) | Monthly or seasonal mean temperatures  
Energy crop production: autumn  
Alternative breeds could be introduced Daily sunshine hours  
Frost free days  
Stominess (extremes in wind and rainfall)  
Soil moisture | Sustainable transport plans could be affected by climate change Land use change may reduce the areas available for landfill Water availability may be affected | Adaptation possible by switching to different crops/alternative breeds  
Husbandry can adapt to gradual change | Very specific impacts Opportunities exist for adaptation Other changes may be more significant |
| **Transport & Settlements**       | [Health] Change in annual distribution of deaths; increase in skin cancer, tropical and respiratory diseases.  
[Construction] Increase in air conditioning; change in suitable land; extremes may reduce days available for work and increase damage.  
[Transport] More travel by car; damage to infrastructure.  
[Built Environment] Changes to character of places; changes resulting from adaptation; deterioration of underground archaeological remains. | Possibility that different crops could be introduced to the region (e.g. sunflowers) | Monthly or seasonal mean temperatures  
Energy crop production: autumn  
Alternative breeds could be introduced Daily sunshine hours  
Frost free days  
Stominess (extremes in wind and rainfall)  
Soil moisture | Sustainable transport plans could be affected by climate change Land use change may reduce the areas available for landfill Water availability may be affected | Stronger role for environmental management systems within organisations e.g. NHS, local government. | Other issues: Increased potential for wind energy Need to source goods locally to reduce transport |
| **Industry & Commerce**           | Flooding – affect on development and transport  
Damage to infrastructure and goods investment problems Insurance problems | Tourism can adapt and diversify  
Building design can be a growth area A carbon tax could provide funds for initiatives that respond to climate change | Tourism can adapt and diversify  
A carbon tax could provide funds for adaptation measures | Tourism can adapt and diversify  
A carbon tax could provide funds for adaptation measures | Climate change is relevant to all industry and commerce | Climate change affects everyone Need to consider total environment and all interactions with it Integrated planning is essential |

### Conclusions

- **Wide range of often specific impacts identified**
  - Opportunities exist but they are harder to identify than impacts
  - In particular, there is a need to identify intra-regional and seasonal variations
  - Aim number 14 of the RSDF is for "minimal greenhouse gas emissions and a managed response to climate change"
  - Adaptation is possible, but it will involve changes in environmental management in and between all sectors
  - Climate change affects everyone
  - Need to consider total environment and all interactions with it
  - Integrated planning is essential
Key to Figure D-1 Workshop Analysis

- Impact
- Opportunity
- Key issue
- Climate change variables
- Secondary impact
Figure D-0-1 Workshop Analysis

NATURAL ENVIRONMENT
- Integrated planning
- Consider total environment
- Effects on food chain
- Migration Extinction
- Species
- Habitat
- Landscape
- Tourism
- Different landscapes

WATER
- Supply security
- Sustainable Urban Drainage Systems
- Water supply
- Water quality
- Coastal recreation
- Flooding & erosion
- Tourism
- Effects on food chain
- Spring rainfall
- Cumulative effects
- Sub-regional variation
- Evaporation
- Rainfall variability
- Sea level rise
- Sub-regional variation

CLIMATE CHANGE
- Worst and best case scenarios
- Sub-regional variation
- Temperature
- Rainfall
- Sea level rise
- More water
- Coastal recreation
- Goods
- Infrastructure
- Tourism can diversify
- Development
- Insurance

AGRICULTURE & FOOD
- Crops
- Disease Pests
- Livestock
- Yield Quality & Quantity
- Storage & Transport
- Policy changes more significant than climate change
- Place character changes
- Environmental Management Systems
- Different crops
- Alternative breeds

TRANSPORT & SETTLEMENTS
- Work days
- Environmental Management Systems
- Redesign public transport
- Integration of transport & land-use planning
- Redesign buildings
- Building repairs
- Review energy generation & consumption
- Climate change relevant to all industry & commerce

INDUSTRY & COMMERCE
- Environmental Management Systems
- Tourism
- Development
- Insurance
- Air conditioning
- More car travel
- Air
- Conditioning
- More car travel
- Climate change
- Relevant to all industry & commerce
- Redesign buildings
- Integration of transport & land-use planning
- Building repairs
- Review energy generation & consumption
- More car travel

CONCLUSION
- More water
- Coastal recreation
- Tourism
- Effects on food chain
- Spring rainfall
- Cumulative effects
- Sub-regional variation
- Evaporation
- Rainfall variability
- Sea level rise
- Sub-regional variation
- More water
- Coastal recreation
- Goods
- Infrastructure
- Tourism can diversify
- Development
- Insurance
- Air conditioning
- More car travel
- Air
- Conditioning
- More car travel
- Climate change
- Relevant to all industry & commerce
- Redesign buildings
- Integration of transport & land-use planning
- Building repairs
- Review energy generation & consumption
- More car travel

Business in the Community
WS Atkins Report AK2535676/013
AK2535676_013_rev2_www.doc
Appendix E  Consultee List and Workshop Delegates

Consultees

Consultation method key:  Phone =  Meeting =  Letter =  

<table>
<thead>
<tr>
<th>Name</th>
<th>Organisation</th>
<th>Consultation method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terry Pearson</td>
<td>Alliance Fish Ltd</td>
<td></td>
</tr>
<tr>
<td>Graham Lee</td>
<td>Archaeologist</td>
<td></td>
</tr>
<tr>
<td>Paul Madden</td>
<td>ARLA Foods plc</td>
<td></td>
</tr>
<tr>
<td>Brian Savage</td>
<td>Arriva</td>
<td></td>
</tr>
<tr>
<td>Charlie Wood</td>
<td>Associated British Ports</td>
<td></td>
</tr>
<tr>
<td>David Hyde</td>
<td>AstraZeneca</td>
<td></td>
</tr>
<tr>
<td>Andy Hay</td>
<td>AvestaPolarit Stainless</td>
<td></td>
</tr>
<tr>
<td>David Butterfield</td>
<td>Barnes &amp; Associates Urban Forestry Consultant</td>
<td></td>
</tr>
<tr>
<td>Colin Dennis</td>
<td>Bishop Burton College</td>
<td></td>
</tr>
<tr>
<td>Andrew Marshall</td>
<td>Bradford Metropolitan District Council</td>
<td></td>
</tr>
<tr>
<td>John Bibby</td>
<td>Bradford Metropolitan District Council</td>
<td></td>
</tr>
<tr>
<td>Keith Thompson</td>
<td>Bradford Metropolitan District Council</td>
<td></td>
</tr>
<tr>
<td>Simon Fisher</td>
<td>British Sugar plc</td>
<td></td>
</tr>
<tr>
<td>Ian Smith</td>
<td>Carlsberg-Tetley Brewing Ltd</td>
<td></td>
</tr>
<tr>
<td>Jayne Johnson</td>
<td>Cattles Plc</td>
<td></td>
</tr>
<tr>
<td>Simon Jennings</td>
<td>CEFAS Lowestoft Laboratory</td>
<td></td>
</tr>
<tr>
<td>Andrew Wood</td>
<td>Council for the Protection of Rural England</td>
<td></td>
</tr>
<tr>
<td>Dorothy Fairburn</td>
<td>Country Landowners and Business Association</td>
<td></td>
</tr>
<tr>
<td>lan Deans</td>
<td>Countryside Agency</td>
<td></td>
</tr>
<tr>
<td>Stuart Pasley</td>
<td>Countryside Agency</td>
<td></td>
</tr>
<tr>
<td>Martin Aldridge</td>
<td>Dawn Carnaby</td>
<td></td>
</tr>
<tr>
<td>Jim Hutchinson</td>
<td>DEFRA</td>
<td></td>
</tr>
<tr>
<td>Anthony Hynes</td>
<td>DEFRA, Common Fisheries Policy Unit</td>
<td></td>
</tr>
<tr>
<td>Kerr Wilson</td>
<td>DEFRA, Pesticide Safety Division</td>
<td></td>
</tr>
<tr>
<td>Ivan Smithson</td>
<td>DYSON Ltd</td>
<td></td>
</tr>
<tr>
<td>Jo Wright</td>
<td>East Riding of Yorkshire Council</td>
<td></td>
</tr>
<tr>
<td>Sian Ferguson</td>
<td>East Riding of Yorkshire Council</td>
<td></td>
</tr>
<tr>
<td>Ian Panter</td>
<td>English Heritage</td>
<td></td>
</tr>
<tr>
<td>Richard Wilson</td>
<td>English Nature</td>
<td></td>
</tr>
<tr>
<td>Chris Firth</td>
<td>Environment Agency</td>
<td></td>
</tr>
<tr>
<td>Don Ridley</td>
<td>Environment Agency</td>
<td></td>
</tr>
<tr>
<td>John Aldrick</td>
<td>Environment Agency</td>
<td></td>
</tr>
<tr>
<td>John Pygott</td>
<td>Environment Agency</td>
<td></td>
</tr>
<tr>
<td>Steve Bailey</td>
<td>Environment Agency</td>
<td></td>
</tr>
<tr>
<td>Hilary Harmer</td>
<td>Food Technopole</td>
<td></td>
</tr>
<tr>
<td>Crispin Thom</td>
<td>Forest Authority</td>
<td></td>
</tr>
<tr>
<td>Anthony Rhey</td>
<td>Friends of the Earth</td>
<td></td>
</tr>
<tr>
<td>Guy Wallbanks</td>
<td>Friends of the Earth</td>
<td></td>
</tr>
<tr>
<td>Tim Sanders</td>
<td>Friends of the Earth</td>
<td></td>
</tr>
<tr>
<td>Ross Ainsbury</td>
<td>Geest Plc</td>
<td></td>
</tr>
</tbody>
</table>
Yorkshire and Humber Climate Change Impact Scoping Study
Draft Final Report

Business in the Community

Alan Hide GNER
Tim Ashelford Government Office for Yorkshire and the Humber
Tom Stanton Government Office for Yorkshire and the Humber
Richard Lodge Green Business Network
David Bentley Henry Boot Construction Ltd
Dave Brooks Hull City Council
David Simes Hull University
Bill Edridge Kirklees Council
Kam Singh Kirklees Council
Debbie Wareing Leeds Bradford International Airport
Stephen Turnbull Leeds Health Authority
Andy Nolan Leeds Metropolitan University
Mike Briggs Leeds Metropolitan University
Maltings Manager Thomas Fawcett and Sons Ltd
Bill Elders MFI UK Ltd
David Collier NFU
Adrian Coy North East Lincolnshire Council
David McCandless North Eastern Sea Fisheries Committee
Doug Robinson North Lincolnshire Council
Doug Robinson North Lincolnshire Council
Dave Walker North York Moors National Park Authority
Malcolm Hodgson North York Moors National Park Authority
Mike Welbourn North York Moors National Park Authority
Rona Charles North York Moors National Park Authority
Geo Andrews Northern Foods Plc
Ernie Preston Rail Users' Federation
Ken Buglass Railtrack
Keith Wadd Ramblers Association
Terry Perkins Ramblers Association
Karl Gerhardsen Recreation and Access Officer
Ben McCarthy Rotherham City Council
Julie Rankin / Sarah Tyler Rotherham Metropolitan District Council
Kevin Bayes RSPB
Richard Louden Rudgate Brewery Ltd
John Riby Scarborough Borough Council
John Tower Sea Fish Industries Authority
Steven Byers Sheffield City Council
Valerie Greaves Sheffield City Council
Rachel Wildman Sheffield First for the Environment
Bernard Little Sheffield Green Party
Heather Hunt Sheffield Green Party
Ron Pearson Shepherd Building Group
Robert Palmer Soil Survey York
Richard Walker South Yorkshire Forest Partnership
Teresa Hitchcock South Yorkshire Green Business Club
Mike Smith South Yorkshire Passenger Transport Executive
David Gent Sport England Yorkshire
Julian Davies Stockbridge Technology Centre
<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Richard Britton</td>
<td>The Forestry Authority</td>
</tr>
<tr>
<td>Maltings Manager</td>
<td>Thomas Fawcett and Sons Ltd</td>
</tr>
<tr>
<td>David Grantham</td>
<td>Tower Environmental Ltd</td>
</tr>
<tr>
<td>David Bolton</td>
<td>Transport and General Workers Union</td>
</tr>
<tr>
<td>Richenda Connell</td>
<td>UK Climate Impacts Programme</td>
</tr>
<tr>
<td>Brian Ricketts</td>
<td>UK Coal Mining Ltd</td>
</tr>
<tr>
<td>Mike Ashmore</td>
<td>University of Bradford</td>
</tr>
<tr>
<td>Alastair Fitter</td>
<td>York University</td>
</tr>
<tr>
<td>Owen Atkin</td>
<td>York University</td>
</tr>
<tr>
<td>Chris Martin</td>
<td>Yorkshire and Humber Assembly</td>
</tr>
<tr>
<td>Will Kemp</td>
<td>Yorkshire and Humber Assembly</td>
</tr>
<tr>
<td>Mark Warner</td>
<td>Yorkshire Electricity</td>
</tr>
<tr>
<td>Peter Glaholm</td>
<td>Yorkshire Electricity</td>
</tr>
<tr>
<td>Richard Smalley</td>
<td>Yorkshire Electricity</td>
</tr>
<tr>
<td>David Marlow</td>
<td>Yorkshire Forward</td>
</tr>
<tr>
<td>Ian Stevens</td>
<td>Yorkshire Water</td>
</tr>
<tr>
<td>Peter Myerscough</td>
<td>Yorkshire Water</td>
</tr>
<tr>
<td>Peter Kelly</td>
<td>Leeds City Council</td>
</tr>
<tr>
<td>Keith Thomson</td>
<td>Councillor, Bradford Metropolitan City Council</td>
</tr>
</tbody>
</table>
### Workshop Attendees

<table>
<thead>
<tr>
<th>Name</th>
<th>Organisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Richard Wilson</td>
<td>AEP</td>
</tr>
<tr>
<td>Paul Madden</td>
<td>ARLA Foods plc</td>
</tr>
<tr>
<td>Steven Wade</td>
<td>Atkins</td>
</tr>
<tr>
<td>Geoff Darch</td>
<td>Atkins</td>
</tr>
<tr>
<td>Iain Groark</td>
<td>Business in the Community</td>
</tr>
<tr>
<td>Dorothy Fairburn</td>
<td>Country Land &amp; Business Association</td>
</tr>
<tr>
<td>Sian Ferguson</td>
<td>East Riding of Yorkshire Council</td>
</tr>
<tr>
<td>Richard Wilson</td>
<td>English Nature</td>
</tr>
<tr>
<td>Tony Edwards</td>
<td>Environment Agency</td>
</tr>
<tr>
<td>Hilary Hamer</td>
<td>Food Technopole</td>
</tr>
<tr>
<td>Les Saunders</td>
<td>Government Office for Yorkshire and the Humber</td>
</tr>
<tr>
<td>Rhona Pringle</td>
<td>Hambleton District Council</td>
</tr>
<tr>
<td>David Brooks</td>
<td>Kingston Upon Hull City Council</td>
</tr>
<tr>
<td>Stephen Turnbull</td>
<td>Leeds Health Authority</td>
</tr>
<tr>
<td>Malcolm Hough</td>
<td>Met Office</td>
</tr>
<tr>
<td>David Collier</td>
<td>NFU</td>
</tr>
<tr>
<td>Karen Mc Kelvie</td>
<td>Norwich Union</td>
</tr>
<tr>
<td>Will Kemp</td>
<td>Regional Assembly</td>
</tr>
<tr>
<td>Kevin Bayes</td>
<td>RSPB</td>
</tr>
<tr>
<td>Steve Byers</td>
<td>Sheffield City Council</td>
</tr>
<tr>
<td>Ron Pearson</td>
<td>Shepherd Building Group</td>
</tr>
<tr>
<td>Mike Smith</td>
<td>South Yorkshire Passenger Transport Executive</td>
</tr>
<tr>
<td>Johan Kuylenstiem</td>
<td>Stockholm Environment Institute - York</td>
</tr>
<tr>
<td>Greg Haq</td>
<td>Stockholm Environment Institute - York</td>
</tr>
<tr>
<td>Michael Chadwick</td>
<td>Stockholm Environment Institute - York</td>
</tr>
<tr>
<td>Phil Ineson</td>
<td>Stockholm Environment Institute - York</td>
</tr>
<tr>
<td>Richard Britton</td>
<td>The Forestry Authority</td>
</tr>
<tr>
<td>Richenda Connell</td>
<td>UK Climate Impacts Programme</td>
</tr>
<tr>
<td>Mark Warner</td>
<td>Yorkshire Electricity</td>
</tr>
<tr>
<td>Sophie Moreton</td>
<td>Yorkshire Forward</td>
</tr>
<tr>
<td>Deborah Pedley</td>
<td>Yorkshire Water Services</td>
</tr>
</tbody>
</table>
## Appendix F  Summary of Impacts

<table>
<thead>
<tr>
<th>Sector</th>
<th>Key features</th>
<th>Key stakeholders</th>
<th>Key climate change impacts</th>
<th>Indicators to monitor</th>
<th>Information gaps &amp; uncertainties</th>
<th>Recommended responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal &amp; maritime</td>
<td>Varied coastline, much covered by landscape and conservation designations, large part earmarked for regeneration</td>
<td>DEFRA, maritime local authorities, Environment Agency, Coastal Authorities Groups, North East Sea Fisheries Committee, port operators</td>
<td>Coastal squeeze of important intertidal habitats&lt;br&gt;Saline incursion and intrusion&lt;br&gt;Increase in tidal flooding and erosion rates&lt;br&gt;Change in fish species</td>
<td>Local sea level rise&lt;br&gt;Area of key habitats in Humber Estuary&lt;br&gt;Erosion rates&lt;br&gt;Sea temperatures&lt;br&gt;Storminess</td>
<td>Change in storminess, effect on fish</td>
<td>Integrate SMPs more closely with planning system&lt;br&gt;Refine Indicative Floodplain, including through Strategic Flood Risk Assessments&lt;br&gt;Monitor change</td>
</tr>
<tr>
<td>River management</td>
<td>Rivers important for many purposes. Water quality and standard of defences vary, most rivers hydrologically ‘flashy’, historic development on floodplains</td>
<td>DEFRA, Environment Agency, local authorities, property owners/occupiers</td>
<td>Wetter winters, more intense rainfall and increase in very wet winters (&gt;160% rain) may cause more flooding and bank and soil erosion and problems with urban drainage systems&lt;br&gt;Increase in very dry summers (&lt;50% rain) and a reduction in rain in spring, summer and autumn may lead to more droughts and water quality problems</td>
<td>Local rainfall&lt;br&gt;Peak river flows&lt;br&gt;Low flows&lt;br&gt;Freshwater fisheries</td>
<td>Effect on fish</td>
<td>Research and monitor of floodbank stability; Improve washland management, including new washlands&lt;br&gt;Investment in SUDS&lt;br&gt;Development of CFMPs&lt;br&gt;Refinement of Indicative Floodplain&lt;br&gt;Better guidance for developers in relation to PPG25&lt;br&gt;Insurance strategies</td>
</tr>
<tr>
<td>Water resources</td>
<td>Water gained for public supply, agriculture, industry and power generation from reservoirs, rivers and aquifers</td>
<td>Environment Agency, water companies, OfWAT, DWI, industry, agriculture</td>
<td>Decrease in spring, summer and autumn rainfall will reduce water availability and water quality&lt;br&gt;More winter rainfall will recharge aquifers&lt;br&gt;Increased variability in rainfall will increase the risk of single drought years&lt;br&gt;Temperature rises will increase demand for water in urban and rural areas</td>
<td>Local rainfall&lt;br&gt;Peak and low river flows&lt;br&gt;Reservoir levels&lt;br&gt;Groundwater levels&lt;br&gt;Demand for water</td>
<td>Future water demand</td>
<td>Holistic water resource management and planning at catchment scale&lt;br&gt;Identification of individual sources and resource zones at risk&lt;br&gt;Drought contingency planning&lt;br&gt;Development of infrastructure and policies to maximise increase in winter rainfall and minimise impact of reduction in other seasons&lt;br&gt;Pollution minimisation</td>
</tr>
</tbody>
</table>
### Sector | Key features | Key stakeholders | Key climate change impacts | Indicators to monitor | Information gaps & uncertainties | Recommended responses
--- | --- | --- | --- | --- | --- | ---
Agriculture & forestry | Dominant land-use in region, with cereals, vegetables and oilseed rape important. Employs 2% of workforce. Woodland covers just 6% of the region. | Farmers, food processors, distributors, sellers, NFU, DEFRA, GO-YH, FWAG, Soil Survey, Soil Association, Forestry Authority, Forestry Commission, CLA | Higher temperatures may benefit crop production, but more irrigation may be required. Sugar beet production may fall under higher temperatures and potatoes may require better refrigeration. Growth of new crops possible. More winter rainfall may cause machine access and soil damage problems on soils of low permeability. Increased timber yields, but possible increases in pests and pathogens. | Seasonal rainfall, Seasonal temperatures, Sunshine hours, Frost free days, Storminess, Soil moisture | Changes in wind patterns and extremes, which will affect woodlands. Feasibility of different crops. Extent of irrigation and refrigeration potentially required. Change in competitive advantage caused by contrasting impacts of climate change in different countries. | Monitor change in indicators. Research feasibility of different crops. Examine changing need for irrigation and refrigeration. Monitor yields in relation to climatic variables. Need to identify any competitive advantage that may develop. |
Natural environment | Diverse range of landscapes and habitats. The region covers partly or entirely 3 National Parks, 4 AONBs, Heritage Coasts, 26 sites of national or international biodiversity importance and 433 SSSIs | English Nature, Wildlife Trusts, Countryside Agency, National Park authorities, GO-YH, CPRE, RSPB | Montane heathland and peat bogs are seriously threatened. Mosaic of habitats in uplands at risk from increased desiccation. Lowland mires of Hatfield and Thorne Moors, habitat for some globally unique species, at risk from higher temperatures. Lower Derwent very sensitive to water levels. Increased fire risk. Pressure on National Parks due to an increase in tourism. | State of key habitats and of rare species. Droughts. | Habitat and species vulnerability. | Compile inventory of vulnerable species and habitats. Consider climate change in management plans, particularly for priority habitats and species. More sustainable approach to socio-economic development to create a natural environment more amenable to adaptation. |
<table>
<thead>
<tr>
<th>Sector</th>
<th>Key features</th>
<th>Key stakeholders</th>
<th>Key climate change impacts</th>
<th>Indicators to monitor</th>
<th>Information gaps &amp; uncertainties</th>
<th>Recommended responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry &amp; commerce</td>
<td>Manufacturing continues to be vital to the region’s economy</td>
<td>Numerous manufacturing companies, supermarkets, utility companies</td>
<td>Relocation due to infrastructure problems, flooding or storms Changes necessary in industrial design, processes and building standards Some products may no longer be needed, while others, including new ones, may be required Increased need for air-conditioning Change in type and location of raw materials</td>
<td>Flooding Droughts Number of high temperature days</td>
<td>Change in type and location of raw materials Change in consumer preferences</td>
<td>Need to identify any competitive advantage that may develop Increase resource efficiency and minimise pollution</td>
</tr>
<tr>
<td>Services</td>
<td>Financial services, insurance, government, tourism, leisure &amp; sport and cultural activities are becoming increasingly important to the region</td>
<td>Banks, insurers, unions, local authorities, health authorities, universities, GO-YH, RAYH, Yorkshire Forward, BIC-YH, English Heritage</td>
<td>Positive and negative effects on human health Possible increase in tourism and leisure activities, although some disruption e.g. effect of droughts and floods on sports pitches Archaeological remains and historic buildings at greater risk of damage</td>
<td>Climate-related hospital admissions Number of high temperature days Droughts Flooding Groundwater levels</td>
<td>Effect on tourism</td>
<td>Need to realise the potential for growth in resource management and insurance services Produce guidelines on ways to prevent increase in health problems Promote benefits to tourism and leisure activities Mapping and risk assessments for archaeological remains</td>
</tr>
<tr>
<td>Transport</td>
<td>3 international airports, East Coast Main Line and Trans-Pennine railways, major north-south and east-west roads and four Humber ports</td>
<td>Airports, Railrack, train operators, Rail Users’ Federation, Highways Agency, local authorities, port operators</td>
<td>Wetter winters and possibly higher wind speeds will affect airport operations More disruption to rail travel due to flooding, higher temperatures and possible increase in high winds Increased damage and disruption on roads due to flooding and landslips Rising sea levels and storms could affect ports Increased temperatures will reduce cold-weather disruption</td>
<td>Flooding Storms</td>
<td>Change in human behaviour and attitudes</td>
<td>Reduce the susceptibility on railways to flooding and overhead power cable damage Identify roads at risk of disruption and damage Upgrade drainage systems Evaluate effect on ports</td>
</tr>
</tbody>
</table>
Appendix G     The Nottingham Declaration on Climate Change

Council recognises that Climate Change is likely to be one of the key drivers of change within our community this century.

We acknowledge that
- Evidence continues to mount that climate change is occurring.
- Climate change will have far reaching effects on the UK’s economy, society and environment.

We welcome the
- Social, economic and environmental benefits which will come from combating climate change.
- Recognition by many sectors, especially government and business, of the need for change.
- Emissions targets agreed by central government and the programme for delivering change as set out in the Climate Change - UK Programme.
- Opportunity for local government to lead the response at a local level and thereby play a major role in helping to deliver the national programme.
- Opportunity for us to encourage and help local residents and local businesses - to reduce their energy costs, to reduce congestion, to improve the local environment and to deal with fuel poverty in our communities.
- Additional powers to address the social, economic and environmental well-being of our communities contained within the Local Government Act 2000, which will assist in this process.

We commit our Council to
- Work with central government to contribute, at a local level, to the delivery of the UK climate change programme.
- Prepare a plan with our local communities, by December 2002, to address the causes and effects of climate change and to secure maximum benefit for our communities.
- Publicly declare, within the plan, the commitment to achieve a significant reduction of greenhouse gas emissions from our own authority’s operations especially energy sourcing and use, travel and transport, waste production and disposal and the purchasing of goods and services.
- Encourage all sectors in the local community to take the opportunity to reduce their own greenhouse gas emissions and to make public their commitment to action.
- Work with key providers, including health authorities, businesses and development organisations, to assess the potential effects of climate change on our communities, and to identify ways in which we can adapt.
- Provide opportunities for the development of renewable energy generation within our area.
- Monitor the progress of our plan against the actions needed and publish the results.

For further information see:-  http://www.nottinghamcity.gov.uk/nnp/main_index.htm
### Appendix H  Climate Change Indicators

<table>
<thead>
<tr>
<th>National Indicators of relevance</th>
<th>Climatic Variation</th>
<th>Gradual temporal trends</th>
<th>Expected future trends with global warming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea level Rise</td>
<td>Gradual increase since the early 1970’s</td>
<td>Current trends expected to continue due to global warming</td>
<td></td>
</tr>
<tr>
<td>Domestic property insurance claims for subsidence</td>
<td>Increasing due to low rainfall</td>
<td>Expected increases, but may lead to improvements to existing foundations and prevention in new buildings</td>
<td></td>
</tr>
<tr>
<td>Domestic property insurance claims for major weather perils</td>
<td>Often linked to wind storm. Increase in flooding events</td>
<td>Increase in flooding events, and dependant on future trends in storminess</td>
<td></td>
</tr>
<tr>
<td>Decreasing gas demand to households</td>
<td>No trends since 1980’s</td>
<td>Expected decreases in demand as winters become milder</td>
<td></td>
</tr>
<tr>
<td>Domestic Holiday tourism</td>
<td>None</td>
<td>Should be an increase in domestic tourism</td>
<td></td>
</tr>
<tr>
<td>Reduction of seasonal human mortality patterns</td>
<td>None</td>
<td>Should be a decline with milder winter temperatures</td>
<td></td>
</tr>
<tr>
<td>Use of irrigation for Agriculture</td>
<td>Increasing abstractions and greater yearly variability</td>
<td>Increasing usage, but only to an upper limit due to finite resource</td>
<td></td>
</tr>
<tr>
<td>Proportion of potato crop irrigated</td>
<td>Strong upward trends</td>
<td>At present up to 50% of crop is irrigated, this is expected to continue.</td>
<td></td>
</tr>
<tr>
<td>Changes to crop yields</td>
<td>Slight upward trends, maybe due to changes in agricultural practices.</td>
<td>Increases in summer droughts would depress yields. Initial increases in potato and cereal production where ample irrigation</td>
<td></td>
</tr>
<tr>
<td>Earlier leaf emergence in Spring</td>
<td>Move towards earlier emergence dates</td>
<td>Earlier leafing dates moving to more in March.</td>
<td></td>
</tr>
<tr>
<td>Earlier emergence of indicator insects</td>
<td>Move towards earlier emergence dates</td>
<td>Earlier emergence</td>
<td></td>
</tr>
<tr>
<td>Increased abundance of indicator insects</td>
<td>Increasing numbers</td>
<td>Increasing numbers, except where drought events.</td>
<td></td>
</tr>
<tr>
<td>Earlier egg laying dates of birds</td>
<td>Towards earlier laying dates</td>
<td>Continuation of earlier laying trend.</td>
<td></td>
</tr>
<tr>
<td>Higher populations of small birds</td>
<td>None since early 1970’s</td>
<td>Stabilisation at higher wren population levels</td>
<td></td>
</tr>
<tr>
<td>Marine Plankton Abundance</td>
<td>Towards greater abundance</td>
<td>Unknown effects of global warming on strength</td>
<td></td>
</tr>
<tr>
<td>Later salmonid upstream migration</td>
<td>Summer rainfall</td>
<td>More frequent summer drought would lead to later migration</td>
<td></td>
</tr>
</tbody>
</table>

### Local alternative or complimentary indicators

<table>
<thead>
<tr>
<th>Changes in soil conditions</th>
<th>Climatic Variation</th>
<th>Gradual temporal trends</th>
<th>Expected future trends with global warming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower levels of small local reservoirs</td>
<td>Lower reservoir levels in recent years</td>
<td>Increasingly low reservoir levels especially in droughts</td>
<td></td>
</tr>
<tr>
<td>Risk of tidal flooding from Humber</td>
<td>More frequent high tidal events</td>
<td>Expected to continue, some offset from lower flow levels in summer</td>
<td></td>
</tr>
<tr>
<td>Increases risk of riverine and groundwater flooding.</td>
<td>Increasing flood events and higher groundwater levels</td>
<td>Trends expected to continue</td>
<td></td>
</tr>
<tr>
<td>Decrease in domestic water use.</td>
<td>Increasing summer water use and hosepipe bans</td>
<td>Expected to continue.</td>
<td></td>
</tr>
<tr>
<td>Sports fixture cancellation</td>
<td>Increasing numbers of matches cancelled due to poor pitch state</td>
<td>Continued trend and additional summer cancellations due to drought.</td>
<td></td>
</tr>
<tr>
<td>Decreased road closures due to ice and snow</td>
<td>None</td>
<td>Decreasing with milder winters. Lower council demands for grit</td>
<td></td>
</tr>
</tbody>
</table>