Sustainability West Midlands

The Potential Impacts of Climate Change in the West Midlands

Technical Report

December 2003

Entec UK Limited

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Report for

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Foreword

Sustainability West Midlands (SWM) is leading the preparation of the West Midlands response to adapting to climate change on behalf of regional stakeholders.

As a first step, SWM commissioned Entec to conduct a regional Climate Change Impact Study which sets out the overall picture of issues, challenges and priorities in the West Midlands for the first time. This Summary Report reflects the main findings of a more detailed Technical Report. The Impact Study captures a key moment in time for the region and is drawn from a wealth of more detailed and specific research studies. The study has also engaged with specialist climate change interests around the United Kingdom as well as regional organisations, agencies, partnerships and networks, individually and collectively, to develop regional knowledge and produce these findings and recommendations.

This study provides a good foundation for the next stage of the process – the development of ways of raising awareness and planning responses within the West Midlands. Discussions are already underway with the West Midlands Regional Concordat partners (comprising eleven regional decision making bodies including SWM) and a range of sector representatives and partners who are developing responses to the climate change challenge. These policy setters and decision makers will declare commitments to the need to give greater prominence to climate change in their own policies, programmes and projects delivering their core business.

The climate change study and outcomes are feeding into the current Review of the West Midlands Regional Sustainable Development Framework and other key regional strategies such as Regional Economic Strategy, Regional Planning Guidance, Regional Housing Strategy, Regional Energy Strategy, West Midlands European Framework.

The clear message emerging out of this first stage is that no one person, organisation or community of interest can shape and deliver commitments to climate change alone. The Region is collectively determined to work together to make change happen for the better and ensure that the issues raised are addressed as part of its plans for a more sustainable future.

Bernard Doyle **Chair, Sustainability West Midlands**
January 200

Executive Summary

This scoping study examines the evidence for climate change in the West Midlands and outlines possible future climates. From this, the study considers the possible impacts of these changes on a range of issues, building on a pre-scoping study for the region completed in 2001. The report also puts forward a number of possible adaptation options.

The study aims to encourage policy responses to climate change that are appropriate to the West Midlands as it has included significant consultation with individuals and organisations across the region. It is also intended to raise awareness of the implications of climate change and to encourage an increased understanding of the common issues faced by the entire region in the event of various climate change outcomes.

Climate change is happening in the West Midlands

The climate of the region changed significantly in the last century. The key changes are given in the following table.

Climate indicators	Recent trend
Air temperature	Annual average temperature has risen by +0.6ºC since the 1900s
	Several of the warmest years on record have occurred since 1989
	Growing season has increased by 30 days since the 1900s
	Nocturnal urban heat island intensifying
Rainfall	Decreasing summer rainfall since the 1880s
	Increasing winter rainfall over last 150-200 years
	More winter rain days and longer wet-spells since the 1960s
	Heavy storms have contributed more to winter rainfall totals since the 1960s
Snowfall	Fewer snowfall events and smaller snowfalls since the 1960s
Gales	Record wind speeds in 1987 and 1990
	No long-term trend but cluster of severe gales in the 1990s

So climate change is happening but what about the future?

The future climate of the West Midlands

Models of the future climate suggest that the region’s climate could change in the following ways:

- The average annual mean temperature in Birmingham between 1961 and 1990 was 9.4^{o}C. This is expected to increase by between 0.5^{o}C and 1.5^{o}C by the 2020s and between 1.0^{o}C and 2.5^{o}C by the 2050s;

- Most of the warming is expected to take place in summer although winters are also expected to be significantly warmer. Warwickshire and the south east of the region are expected to warm up more than Shropshire and the north west of the region;
- The mean annual precipitation is expected to change by less than 10% by the 2050s. However, this hides a dramatic change in seasonal precipitation. Winter precipitation might increase by between 0% and 10% by the 2020s and up to 20% by the 2050s. On the other hand, summer precipitation might decrease by between 0% and 20% by the 2020s and up to 30% by the 2050s;
- Cloud cover is expected to decline slightly overall (between 2% and 6% by the 2050s) with a small increase of up to 2% in winter and a larger reduction of up to 10% in summer by the 2050s;
- Overall the mean relative humidity (the amount of water vapour in the air in comparison to the maximum saturation) is likely to decline by a small amount in winter (up to -2%) and decline much more in summer (-2% to -4% by the 2020s and -2% to -8% by the 2050s) as the air temperature is expected to increase. This may lead to a reduction in the number of days with fog;
- The mean daily wind speed is not expected to change very much over the year (0% to +1%) but winter mean wind speed is expected to increase by up to 4% in the south east of the region by the 2050s. Summer mean wind speed is likely to stay the same (+/- 1%). However, there are low levels of confidence in the modelled wind speeds; and
- The potential changes in soil moisture are quite dramatic. Soil moisture is a function of temperature, precipitation, humidity, sunshine and wind speed. Overall in summer the region would be drier and warmer and hence soil moisture could fall by between 5% in the north west of the region and 35% in the south east by the 2050s. In winter however, the increased precipitation could lead to higher soil moisture levels and the increased probability of flooding.

As well as the changes in average climate conditions outlined above, the occurrence of extreme climate events is also expected to change. This could be in the daily extremes of temperature or precipitation for example, or in the occurrence of extreme years. The figures in the following table indicate the percentage of years in which various extreme events could occur. For example, a 1995-type summer could occur 20% of the time, one in every 5 years, by the 2050s.

Percentage of years in which England and Wales could experience extreme climate events

Climate event	Difference relative to the 1961-90 average	2020s	2050s	2080s
A hot '1995-type' August	3.4ºC warmer	1	20	63
A warm '1999-type' year	1.2ºC warmer	28	73	100
A dry '1995-type' summer	37% drier	10	29	50
A wet '1994/95-type' winter	66% wetter	1	3	7

Source: Hulme et al. (2002)

Climate change impacts and opportunities

The pre-scoping report (included as **Appendix G**) considered fifteen sectors and issues in the West Midlands. However, in order to consider the potential impacts in more detail, this study focuses on five 'hot issues' identified at a regional workshop as being of most importance from a climate change perspective. They are as follows:

- Water Management;
- Agriculture;
- Energy;
- Land Use and the Built Environment; and
- Transport.

The potential impacts of climate change on the 'hot issues' were identified based on information on the current situation in the West Midlands, and possible future economic and social changes. Assessment of these impacts was developed through consultation with people and organisations across the region.

In summary the general potential climate change impacts for the region include the following:

- Increased temperatures and different patterns of rainfall could lead to changes in the demand for, and availability of, water. A significant proportion of the region's water is supplied from reservoirs in Wales, which has a wetter climate. Drier summers could result in lower flows in the region's rivers, with negative impacts on biodiversity and water quality, and an increase in the demand for water for irrigation, garden watering, industry (especially food and drink) and the public. However, whether these impacts actually occur will depend on the success of implementing an effective regional water strategy and measures to address supply and demand issues;
- Increased temperature could change the demand for energy, with a reduction in demand for winter space heating and an increase in the demand for cooling in the summer. Reduction in winter space heating demand could help to reduce incidences of fuel poverty in the region, although this will depend on future energy costs and housing conditions. Use of natural ventilation, shading, and green spaces for cooling may be able to meet any increased demand for cooling but these measures will need to be incorporated into building design;
- There are plans to expand the amount of energy produced from renewable sources in the region. Reduced cloud cover and hence increased sunshine may increase the opportunities for certain renewable energy e.g. solar based technologies;
- Increased temperatures and less cloud might encourage people to spend more time outdoors, with possible health benefits from increased physical activity but risks of skin damage or heat exhaustion on very hot or bright days. People may decide to take more local holidays rather than travel abroad, especially if other destinations such as Southern Spain and France experience more negative climate change impacts e.g. reduced water availability and increased fires. The West Midlands has

many attractive destinations and these may need to be developed and extended to attract visitors and respond to increased demand;

- Increased temperatures and carbon dioxide levels and a longer growing season could benefit certain agricultural and horticultural crops and trees. This could benefit agriculture but potential opportunities are closely linked to consumer demand. Forestry and woodland could be extended in the region. This may have benefits for related activities e.g. the renewable energy and leisure sectors;
- Higher temperatures could increase the urban heat island effect in Birmingham. Policies in the draft Regional Planning Guidance aim to concentrate development in existing urban areas and develop Birmingham as a 'World City'. Denser development may exacerbate the urban heat island effect and require adaptive measures for development layout to be built into the spatial development process in the region. If these adaptive measures are not taken then comfort in buildings could be adversely affected leading to a reduction in productivity amongst office based workers and discomfort in domestic dwellings;
- Wetter winters could lead to increased recharge of regional water supplies e.g. aquifers and hence increased availability of water and also provide the opportunity for providing enhancement of certain habitats e.g. wetlands, that are under-represented in the region; and
- Wetter winters and extreme precipitation events could also increase the risk of flooding and hence economic and social disruption in the region. Flood risk is dependent on a number of factors e.g. land use (transport, housing, agriculture etc.), soil type, availability of drainage and level of flood protection. Flood risk can be reduced through a number of actions e.g. reducing development in the floodplains, water storage and flood management. Urban areas may experience flooding from drainage systems that are inundated during extreme events. A focus of the draft Regional Planning Guidance is to concentrate development in previously developed urban areas. Capacity of existing drainage systems may need to be increased to take into account possible future climate.

Adaptation to Climate Change

There are a number of ways in which individuals, organisations and policy makers in the West Midlands can adapt to the potential impacts of climate change outlined in this study. These have been suggested for each of the 'hot issues', but can be broadly categorised as follows:

- Share loss, e.g. insure business against weather losses;
- Bear loss, e.g. accept that some land will flood in winter;
- Structural or technological change, e.g. strengthen building foundations to cope with increased subsidence risk;
- Legislation or institutional change, e.g. strengthen planning guidance on developments in flood risk areas;
- Avoid risk, e.g. grow new agricultural crops better suited to new climate;
- Research, e.g. use research to better understand the climate risk; and
- Education, e.g. increase public awareness about coping with flooding at home.

Recommendations

The possibilities for adaptation have led to a number of specific recommendations for the 'hot issues'. These suggest ways in which to encourage appropriate adaptation responses and support adaptation in the policy making process. More general recommendations are outlined here. These cover the need for policy proofing, further specific research, provision of sectoral information and further sector involvement.

Policy proofing

In order to assess the potential impacts of climate change on key regional policies and strategies they should undergo a climate change appraisal to highlight the key issues and responses. There could be a number of stages to this appraisal process:

- An initial scoping, objectives led, qualitative assessment to highlight key issues;
- A more detailed assessment, if required for specific strategies, could include application of UKCIP tools and techniques e.g. risk, uncertainty and decision making, economic evaluation and scenarios; and
- The most detailed assessment might require the use of higher resolution climate modelling and use of downscaling e.g. flood risk assessment and management, water resource availability, agricultural production and air quality.

A methodology, with accompanying guidance, should be developed that specifies when to apply these three levels of assessment for developing policy. This could help to address a concern voiced at the third workshop that fully considering every local policy from scratch would waste significant resources.

Further specific research for the West Midlands

Data and information on current and potential climate change could improve the understanding of the nature of potential climate change and its impacts and hence the effectiveness of planning. A number of actions could assist this:

- Development of a set of climate change indicators to assess whether, and if so to what extent, climate change is happening;
- Improved observations and data for higher resolution modelling of future climate conditions; and
- Measurement of climate change impacts.

The climate change indicators could include key climate variables such as temperature, precipitation, wind speed and humidity. Impact areas to be measured could include the following:

- flooding occurrences;
- low river flows;
- changes in habitats and species;
- changes in agriculture e.g. growing season, type of crops grown, yields and pests;

- changes in water demand and availability;
- changes in energy demand;
- costs associated with climate change, not only losses due to flooding and storms but also opportunities e.g. changes in tourism and leisure patterns;
- change in building and development design and implementation; and
- climate change related health impacts.

Further research should be considered into the requirement for the development of higher resolution models to assess more detailed changes and impacts. Additional sectoral assessment on potential climate change impacts should be carried out using more detailed modelling techniques to assess crop yields, water resources and quality, increase in flood risk, energy demand, impacts of transport infrastructure and changes to land use and spatial development for example.

Provision of sectoral information

In a number of the workshops, a need for further information was identified. This would involve specific information for the particular sector on the expected changes in climate, possible ways in which to respond to these changes and sources of information and support. This could encourage individuals and organisations to take action as their understanding of options improved.

Further sector involvement

This study has engaged a wide range of individuals and organisations in developing this report. The choice of 'hot issues' was made during this consultation, but there were a number of other issues that were not included as 'hot topics'. These sectors are also important in the region, and may benefit from discussion of potential climate change impacts.

- The finance sector should be engaged for a view on the potential market in the West Midlands for the possibility of water trading and on the potential costs to business of increased flood risk in the region (including insurance);
- Biodiversity and the impact of climate change has been a cause of particular concern nationally, and it would be useful to consider in more detail the threats, opportunities and changes possible in this sector in the West Midlands;
- The heritage sector should be consulted for key concerns and policies on the impact of climate change on key heritage features; and
- Information on the potential impacts of climate change on health should be considered to improve understanding of effects at an individual level and facilitate planning in the health sector.

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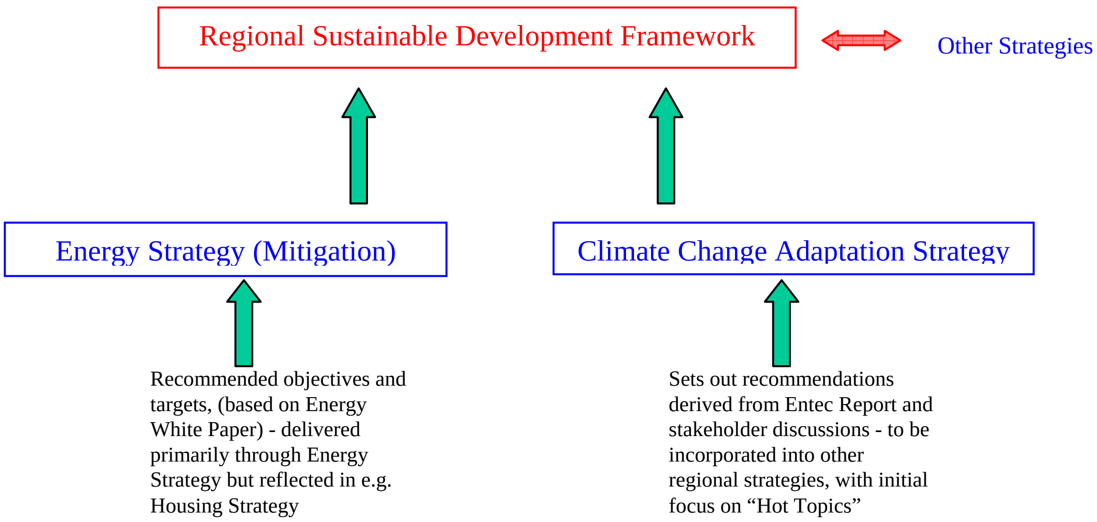
1. Introduction

1.1 Objectives of the Scoping Study

This study was commissioned by Sustainability West Midlands, a consortium of organisations from the region convened to improve the consideration of sustainable development issues within the West Midlands. Sustainability West Midlands (SWM) seeks to communicate, promote and champion the principles of sustainable development and good corporate governance across the region. SWM is an independent partnership between 25 members of business, community, voluntary, non-governmental and public sector organisations which represent wider networks of economic, environmental and social interests. It is regional and strategic in its outlook, whether responding to international, national, regional or local sustainability concerns. SWM is a partner of the West Midlands Concordat (comprising major regional bodies) to advance individual and collective commitments to sustainable development principles and actions in all policies, programmes and projects for the region. The study was undertaken by Entec UK Ltd, the School of Geography, Earth and Environmental Sciences at the University of Birmingham and Metroeconomica.

This study will be one of the key foundations for the development of the Climate Change Adaptation Strategy for the West Midlands, which SWM is leading and co-ordinating on behalf of regional organisations. The strategy will indicate the commitments of different sectors in the region, and formulate an action plan to respond to risks and opportunities. This study will also be used as a component of the Regional Sustainable Development Framework, which offers a regional interpretation of national and local sustainability priorities, including climate change. This is illustrated in **Figure 1.1** (Source: Sustainability West Midlands).

Figure 1.1 Regional Sustainable Development Framework and Strategies



The requirement for this study was identified in the pre-scoping project undertaken by the West Midlands Climate Change Impacts Study (March 2001) which provided a baseline from which a formal climate impacts scoping study could be undertaken. The pre-scoping work was a valuable first step in understanding climate change in the West Midlands, and the mitigation and adaptation measures needed. Following the publication of more detailed climate change scenarios in 2002 (UKCIP02 scenarios), a need was identified to revisit this analysis and help focus on the key issues that require a more in-depth evaluation.

This study considers some of the potential impacts of climate change on specific issues to help to develop the understanding of the possible effects in the West Midlands. Although climate change could have wide-ranging effects across the economy, society and environment of the region, this scoping study focuses on five issues of regional importance. While activities and sectors across the West Midlands might affect the degree to which climate change occurs, this study does not focus on how to minimise our contribution to climate change. Instead it focuses on the potential range of impacts of climate change and the possible threats and opportunities these may pose for individuals and organisations in the West Midlands in order to inform an approach to adaptation.

This study has involved significant consultation with individuals and organisations across the West Midlands in order to focus on those issues most important to the region. The study aims to encourage those responsible for making policy to respond to the potential impacts of climate change in a way that is appropriate to the region. It is also intended to raise awareness of the implications of climate change across the West Midlands and to encourage a better understanding of the issues in the event of various climate change outcomes.

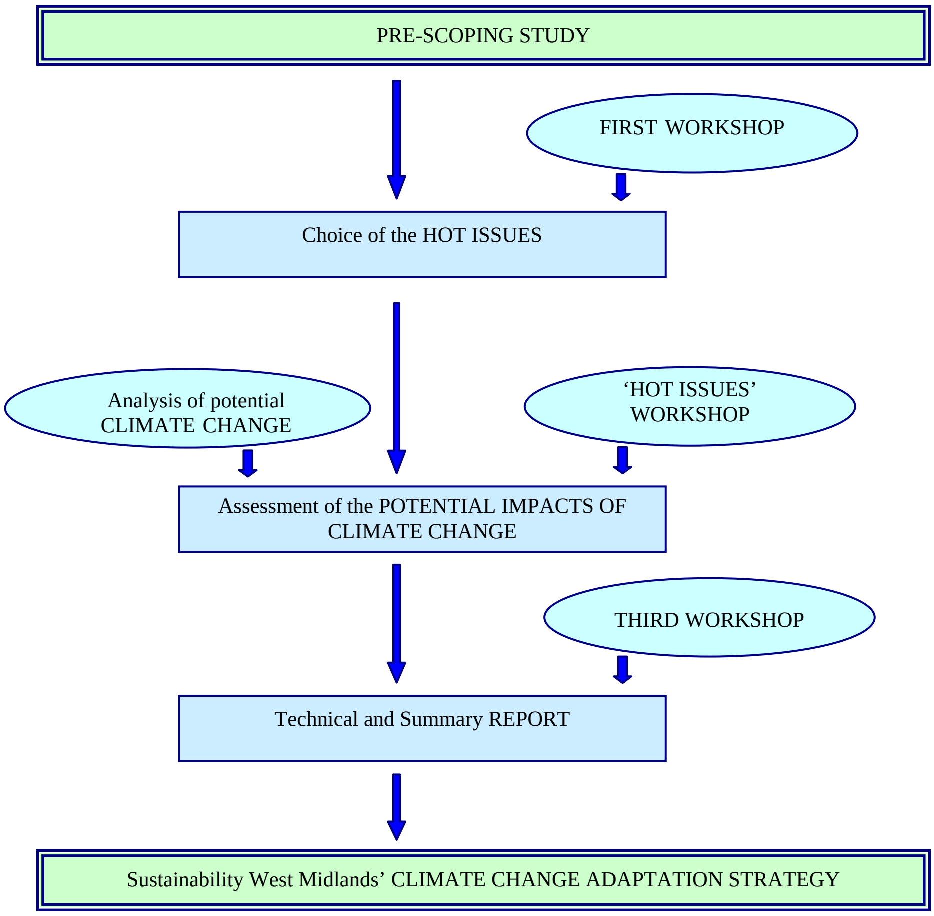
Specifically the study aims to meet the following strategic objectives:

- To establish an overview of the region's baseline position with regard to climate change;
- To predict the likely impact of climate change within the region and identify potential adaptation strategies;
- To raise awareness of climate change in the region; and
- To identify key information gaps and uncertainties in assessing the impacts and recommend ways to respond.

1.2 The Scoping Study

The scoping study was conducted as part of a broader assessment of climate change in the West Midlands. As indicated above, it built on the pre-scoping study, and will inform the regional climate change strategy. Within this study, there were a number of stages of research and activity. These are shown in **Figure 1.2**.

Figure 1.2 The Scoping Study



1.3 Report Structure

Two reports have been produced as part of this study. This report, the Technical Report, describes in detail the study's findings and contains more information for specialists and those involved in detailed planning. A Summary Report has also been produced.

Following on from this introduction, the document is in two main parts. The first part of the report provides a broad characterisation of the West Midlands. While it is not comprehensive, it aims to consider a range of economic, social and environmental features of the region to provide a context for the analysis of climate change that follows. The following sections consider the climate of the West Midlands. This develops from an assessment of the current and historic climate of the region, focusing particularly on Birmingham, which has one of the longest instrumental temperature series. From this baseline, the report considers the potential future climate changes in the region based on the scenarios developed by the UK Climate Impacts Programme.

The second part of the report considers the potential impacts of these climate changes on the five 'hot issues' identified as particularly important to the region. These were identified at a workshop in March 2003 involving individuals and organisations from across the region. The discussion of these issues - water management, agriculture, energy, land use and the built environment, and transport - considers the possible future social and economic changes in order to provide a context for considering the potential impacts of climate change. In each case, the opportunities and threats for the sector are highlighted in order to encourage their consideration in planning for the future. From these potential impacts, some possible adaptation responses are suggested, and those areas that need considering more fully are highlighted.

Two further sections of the report are more specialised. The first considers the potential costs associated with extreme climate events. In this case, the costs of the floods experienced in Autumn 2000 are considered for agriculture, property and transport. The second specialised chapter considers the potential impacts of climate change at a European level. This is important for the West Midlands, since whether the region will win or lose because of climate change impacts will depend in part on the nature of the competition with other European regions.

Finally, there is a summary that aims to bring together some of the generic issues for the West Midlands. This includes information about the climatic changes as well as the implications that this could have for the key regional policies.

At the end of each chapter is a bibliography indicating those documents used during the study.

2. Characterisation of the West Midlands

2.1 Overview

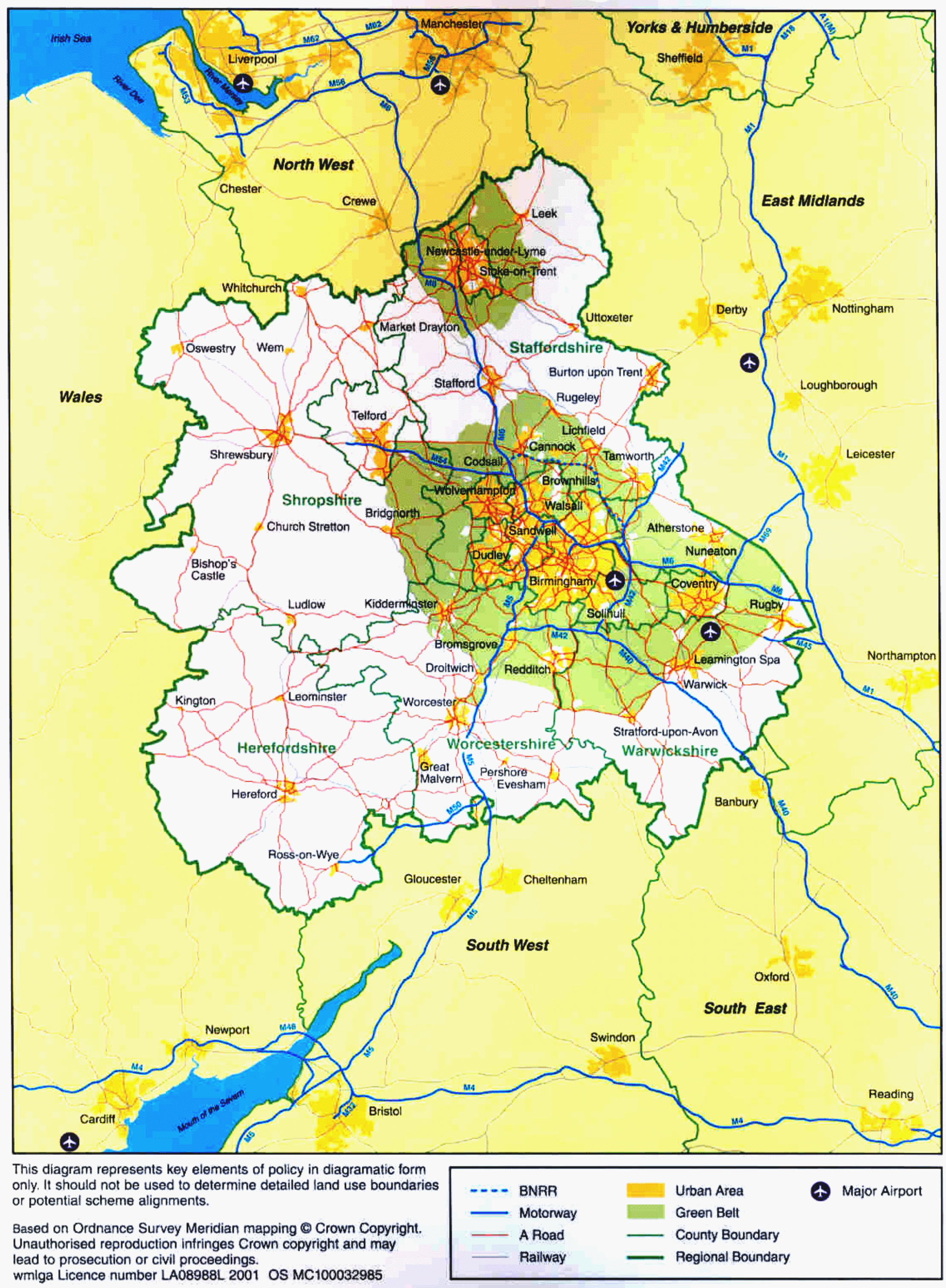
In order to provide a context for the discussion of climate change that follows in the rest of the document, this section presents a characterisation of the West Midlands. There is also some more detailed information on the environment of the region, to inform later sections of the report.

The West Midlands, shown overleaf in **Figure 2.1**, consists of just over 13,000 square kilometres in the heart of the United Kingdom, and includes Herefordshire, Worcestershire, Shropshire, Staffordshire and Warwickshire, as well as seven metropolitan boroughs (Birmingham, Coventry, Dudley, Sandwell, Solihull, Walsall and Wolverhampton).

The environment of the region varies significantly. There are a number of major valleys comprising the Severn, Trent and Avon rivers with the upland area called the Birmingham Plateau between them. The edges of the region are bounded by the Welsh Marches to the west, the hills of the Staffordshire moorlands to the north and the Cotswolds to the south east. The region resembles a shallow bowl with a subdued central dome. This varied physiography has important implications for the climate, which are assessed in Sections 3 and 4.

The west of the region is largely rural, with services and facilities focused around the market towns. Much of the land in this area is farmland, with agriculture accounting for 70% of the region's land use. In contrast, urban development is concentrated on the central Birmingham Plateau, with the conurbation extending from Wolverhampton in the north, through Birmingham to Coventry to the southeast. The seven metropolitan boroughs in the east of the region are the second most populated conurbation after Greater London, and are home to around 2.6 million of the 5.3 million people living in the West Midlands. The population in the region is growing at around 2% per annum, although this also differs significantly between the urban areas, where population has fallen by 5.7% over the last decade, and rural areas, where there has been a growth of 20%. Economically, the manufacturing industries, traditionally in the automotive sector, have a significant presence in the urban areas and the West Midlands is still the UK's main manufacturing centre, with over one fifth of all employees working in the sector.

Figure 2.1 Map of the West Midlands



2.2 Economy

According to European Union (EU) figures (Eurostat, 2003), the regional gross domestic product (GDP) for the West Midlands, was 23,919 Euro per capita, compared to a UK average of 26,096 Euro (the exchange rate averaged around 1.63 Euro to the pound over the period). Within the West Midlands, Shropshire and Staffordshire were lowest with 19,461 Euro per capita, and Herefordshire, Worcestershire and Warwickshire were highest (25,290 Euro). However, the figures do not give more detail on the differences within these categories. When considering GDP in a European context, it is more relevant to consider figures adjusted for purchasing power (how much one Euro can buy). An index of these figures indicates that the UK average GDP per capita is 1% greater than the EU average. The West Midlands is 7% less than the EU average, varying from 13% less in Shropshire and Staffordshire to 2% less in Herefordshire, Worcestershire and Warwickshire. Within Europe, other regions with a similar average GDP include Este (Spain), Est (France), South West (UK), Bassin Parisien (France), East Midlands (UK) and Oost-Nederland (Netherlands).

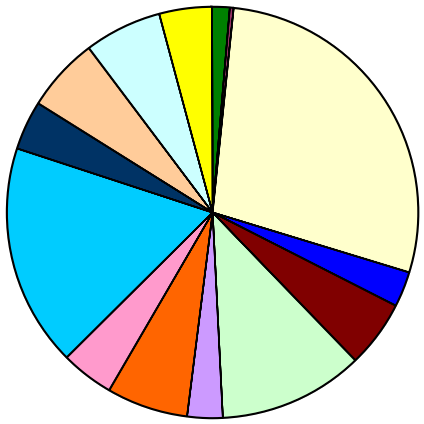
2.2.1 Industrial sectors

The industrial structure of the region is illustrated in **Table 2.1 and Figure 2.2** (National Statistics, 2002), which show the percentage of the total gross value added by industry. This gives an indication of the relative importance of different sectors to the economy of the West Midlands.

Table 2.1 Gross value added by industry groups at current prices, 1998

	West Midlands (%)	United Kingdom (%)
Manufacturing	28.9	20.3
Real estate, renting and business activities	17.9	21.4
Wholesale and retail trade (including motor trade)	11.9	12.3
Transport, storage and communication	6.7	8.4
Health and social work	6.5	6.7
Education	5.8	5.5
Construction	5.3	5.2
Financial intermediation	4.3	6.2
Other services	4.2	5.1
Public administration and defence	4.1	5.2
Electricity, gas, and water supply	2.8	2.1
Hotels and restaurants	2.7	3.3
Agriculture, hunting, forestry and fishing	1.5	1.3
Other mining and quarrying	0.2	0.2
Mining, quarrying of energy producing materials	0.1	0.3
Financial Intermediation Services Indirectly Measured (FISIM)	-2.9	-3.7

Figure 2.2 Gross value added by industry



These percentages do not add up to 100% because there is a negative figure of 2.9% for Financial Intermediation Services Indirectly Measured.

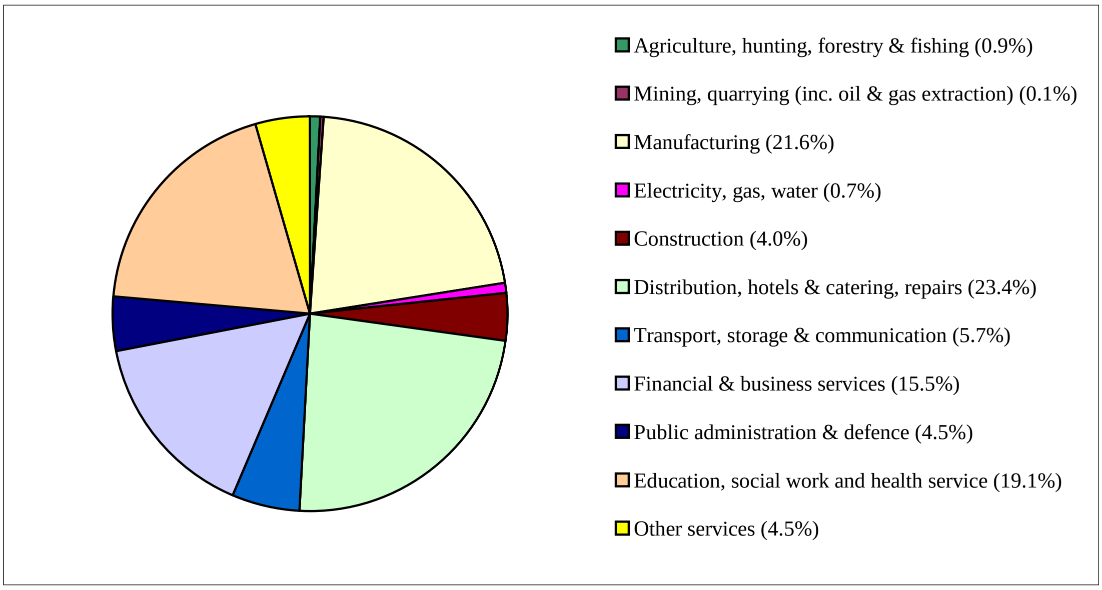
2.2.2 Employment

In the West Midlands, the greatest number of employees are working in the manufacturing, distribution, financial services and education sectors, although only in manufacturing is the percentage significantly above the national average. In all other sectors, the importance of industrial sectors is only marginally different from that for the whole of Great Britain. These are shown in **Table 2.2 and Figure 2.3** (National Statistics, 2002).

Table 2.2 Employment by industrial sector in the West Midlands (%)

	West Midlands	Great Britain
Distribution, hotels and catering, repairs	23.4	23.9
Manufacturing	21.6	15.1
Education, social work and health service	19.1	18.7
Financial and business services	15.5	19.7
Transport, storage and communication	5.7	6.1
Public administration and defence	4.5	5.3
Other services	4.5	5.0
Construction	4.0	4.5
Agriculture, hunting, forestry and fishing	0.9	1.0
Electricity, gas, water	0.7	0.4
Mining, quarrying (inc. oil and gas extraction)	0.1	0.3

Figure 2.3 Employment by industrial sector



However, there are significant differences in industrial employment within the region. The highest percentage of people employed in agriculture was in Herefordshire (5.8%), which also had a higher than average percentage of people employed in the distribution and education categories (26.8% and 12.5% respectively). Manufacturing is the largest sectoral employer in Stoke-on-Trent and Telford and Wrekin Urban Areas (30.1% and 29.3%), but only accounts for 14.2% of employment in Shropshire.

Unemployment in the West Midlands is slightly higher than in the UK as a whole, with the claimant counts averaging 3.0% and 2.6% of the population respectively. The regional breakdown of the figures are shown in **Table 2.3** (National Statistics, 2003), showing a strong trend for higher unemployment in the more urban areas of the region.

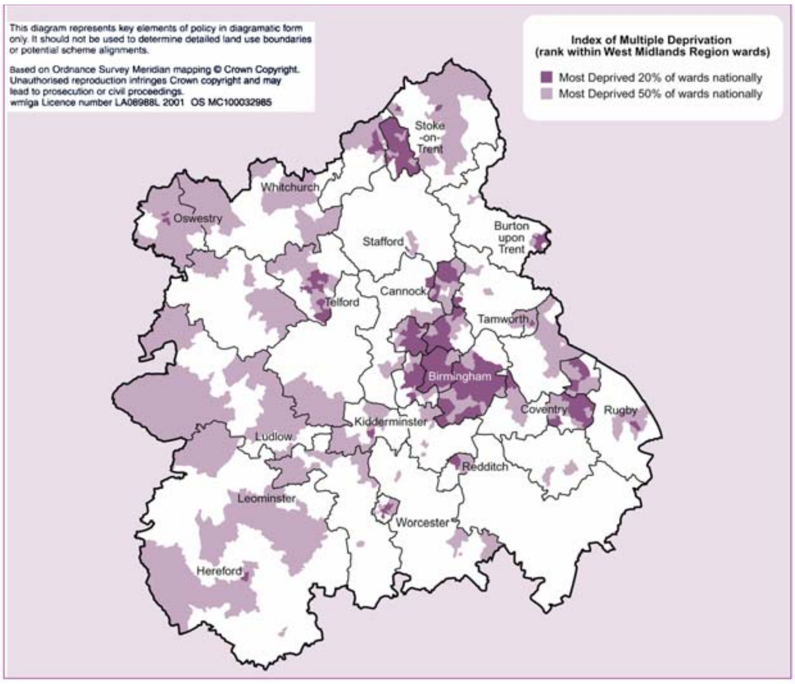
Table 2.3 Claimant count in the West Midlands

	Claimant count as % of population (as at May 2003)
United Kingdom	2.6
West Midlands	3.0
West Midlands Met. County	4.3
Stoke-on-Trent UA	3.1
Telford and Wrekin UA	2.1
Staffordshire	1.8
Warwickshire	1.7
Herefordshire, County of UA	1.6
Worcestershire	1.6
Shropshire	1.4

There is also significant variation according to ethnic origin, with an ILO (International Labour Organisation) unemployment rate of 4.6% for white groups, and 14.1% for minority ethnic groups (National Statistics, 2003).

Unemployment is one of a number of measures of the deprivation of an area, and is included as one of the six measures used to calculate the index of multiple deprivation. The other variables used in this index are income, health and disability, housing, education, skills and training, and geographical access to services, which together provide an overall picture of the deprivation in an area. However, it is interesting for this study that the index does not include any indicators of the physical environment. In the figures for 2000, only four of the hundred most deprived wards in England were in the region: Aston (Birmingham) 27th, Sparkbrook (Birmingham) 33rd, Soho and Victoria (Sandwell) 92nd, and Blakenhall (Walsall) 93rd. Areas of deprivation are shown in **Figure 2.4** (West Midlands Local Government Association, 2001).

Figure 2.4 Deprivation in the West Midlands



2.2.3 Transport

Due to its central location within the UK, as well as the high proportion of manufacturing industries, the region is a centre for travel. The M5, M6, M40 and M42 motorways all pass through the region, and the Birmingham Northern Relief Road (BNRR) is under construction. On the railways, Birmingham New Street station in the heart of the city acts as a main station for both regional and national journeys. The region has only one international airport, to the south east of Birmingham, but there is an additional airport at Coventry, and the construction of one near Rugby has not been ruled out. This is discussed further in Section 10.

The distance travelled by people in the West Midlands per year is lower than the average for Great Britain, with an average person travelling (excluding foreign travel) 175 miles by foot, 31 miles by bicycle, 5,694 miles by car or other private vehicle, and 613 miles by public transport (National Statistics, 2002).

New roads in the region have contributed to an increase in traffic of around 20% in urban areas over the last 10 years. Because of the decline in rural public transport services, 82% of journeys in the region are made by car. The region is committing itself to improving these figures in an effort to enhance a sustainable economy (West Midlands Round Table for Sustainable Development, 2000).

2.3 Society

Society includes an almost endless diversity of issues, since so many issues are interpreted in a social context. In particular, there is a strong link to some of the issues in the previous section on the economy. However, in order to facilitate the discussion here, this section focuses on some discrete descriptors of the social fabric of the West Midlands.

2.3.1 Ethnicity and language

The West Midlands is one of the most ethnically mixed areas of Great Britain, with minority ethnic groups composing over 10% of the population (**Table 2.4**, National Statistics, 2002). This compares to 29.3% in London, 6.3% in Yorkshire and the Humber, and 1.7% in the North East.

Table 2.4 Ethnicity in the West Midlands

	West Midlands	England	Great Britain
	%	%	%
White	89.3	91.2	92.9
Indian	3.2	1.9	1.6
Pakistani	3.1	1.4	1.2
Mixed	1.1	1.0	0.8
Black Caribbean	1.6	1.2	0.9
Bangladeshi	0.5	0.5	0.5
Black African	0.4	1.1	0.8
Chinese	0.3	0.3	0.3
Other	0.3	0.6	0.5
Other Asian	0.2	0.5	0.4
Black Other	*	0.1	0.1
All minority ethnic groups	10.7	8.8	7.1

* sample size too small for reliable estimate

This mirrors the frequency of linguistic diversity but to a lesser extent religious diversity. There is evidence that different communities are integrated but also that they maintain distinctiveness. This diversity was highlighted as one of the key aspects of the region in the bid by Birmingham to become European Capital of Culture 2008.

2.3.2 Crime

Recorded crimes in the West Midlands are slightly higher than the average for England and Wales for all categories of crime. However, there is also a higher detection rate in all named categories. These figures are shown in **Table 2.5** below (National Statistics, 2002).

Table 2.5 Recorded crime and detection in the West Midlands

	Recorded crimes per 100,000 population		Percentage detected	
	West Midlands	**England and Wales**	**West Midlands**	**England and Wales**
Theft and handling stolen goods	4,422	4,282	19	17
Criminal damage	2,197	2,011	15	13
Burglary	1,972	1,659	14	12
Violence against the person	1,751	1,228	66	58
Fraud and forgery	725	600	31	28
Robbery	287	229	21	17
Drug offences	236	229	97	94
Other	198	123	68	71
Sexual offences	93	78	51	49
All recorded crime	11,881	10,440	28	23

2.3.3 Education

The West Midlands has a comprehensive and integrated education and training system. The region has eight universities, four other higher education establishments, and 50 further education colleges. However, it also has some of the most difficult problems in the country. At present, around 18% of young people over 16 are not in education or training of any kind, one of the highest figures in England. There are also differences between the urban and rural areas. In 2002, just over 45% of those of working age in rural districts of the region had qualifications at NVQ level 3 or above. This is 7% higher than for those in urban areas and above average for England as a whole.

Outside the formal education system, 48% of employers have a training plan and 35% have a training budget. Although these figures are slightly below the average for England, 59% of employers have provided off-the-job training in the last 12 months, which is higher than the English average (National Statistics, 2002).

2.3.4 Culture and recreation

The region has 21,000 hectares of open space used for public recreation. This is supplemented with over 21,000 kilometres of public footpaths and bridleways. The region has approximately 671 kilometres of canals and waterways and around 1,700 dedicated sports fields and pitches. Several areas in the region are host to environmental recreation, including parts of the Peak District in the north, the National Forest to the east, the Shropshire Hills on the west, the Cotswolds in the south, and the Forest of Mercia in the centre.

The region has a rich theatrical heritage, in particular focused in Stratford-on-Avon, which is visited by domestic and foreign tourists all year round. This heritage continues in the many permanent theatres and theatre companies in other parts of the region. The artistic strengths of Birmingham and the region remain strong: the City of Birmingham Symphony Orchestra, the Royal Shakespeare Company and Birmingham Royal Ballet. Venues include the National Exhibition Centre (NEC), National Indoor Arena (NIA), Symphony Hall, and art galleries (such as the Barber Institute, the Ikon Gallery, and the New Art Gallery Walsall). The region is also the centre of the Asian music industry, while The Drum is one of the UK’s biggest African, Asian and Caribbean arts centres.

Artistic culture is celebrated with annual festivals of jazz, comedy, poetry, film, literature and television and the ArtsFest, an annual arts showcase with the UK’s largest concentration of free events.

2.4 Environment

The West Midlands is characterised by diverse and distinctive rural and urban landscapes, ranging from the traditional working countryside and settlements of The Marches and the estate landscapes of South Staffordshire, through to grouped urban settlement of the Potteries area and the Black Country. The following text considers a number of environmental issues, focusing particularly on water, air and biodiversity.

2.4.1 Water supply and demand

Parts of the West Midlands are among the driest areas of England and Wales with annual rainfall totals in the Vale of Evesham less than 650mm on average. In a typical year, the West Midlands receives enough rain to cover its entire area to a depth of around 720mm, significantly lower than the average for England and Wales.

The largest use of water in the West Midlands is for public supply, abstracting over 1,400 million litres of water per day (Ml/d). In addition, industries abstract around 230 Ml/d for their own direct use, and direct abstraction for spray irrigation amounts to a further 80 Ml/d. Much of the water used for public supply and industry is treated and returned to the freshwater environment and is available for re-abstraction downstream. However, the treated water is often returned some way from where it was originally abstracted.

The demand for water will change over the next 25 years for a number of reasons. In the West Midlands today, every person uses on average 145 litres of water every day. The population of the West Midlands is estimated to grow by less than 100,000 by 2025. While individually the additional households should be more water-efficient, they are likely to add to the total demand for water. Similar arguments about the effect on demand of differing water use practices apply to industry, commerce and agriculture.

2.4.2 River flows

Trends in river flows tend to be hard to detect for a number of reasons: most records tend to be short (less than 30 years duration); river flows are typically highly variable from year to year; land-use changes may amplify or conceal climate change signals; and flow regulation, surface and groundwater abstraction mean that the flow regimes of most rivers are dominated by artificial influences (McCabe and Wolock, 1997). The mean daily flow regimes for the River

Avon and River Severn (**Figures 2.5** and **2.6**, Source: Environment Agency) show that both rivers show huge variations in flow, with no discernible trends.

Figure 2.5 Leamington (Avon) Mean Daily Flow, 1989-1998

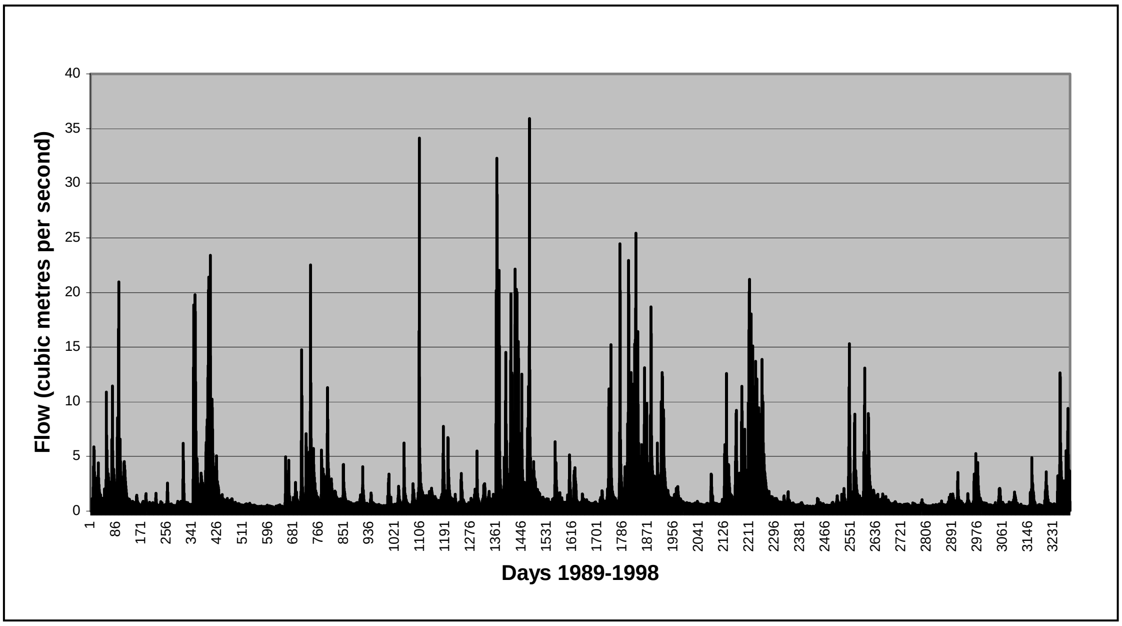
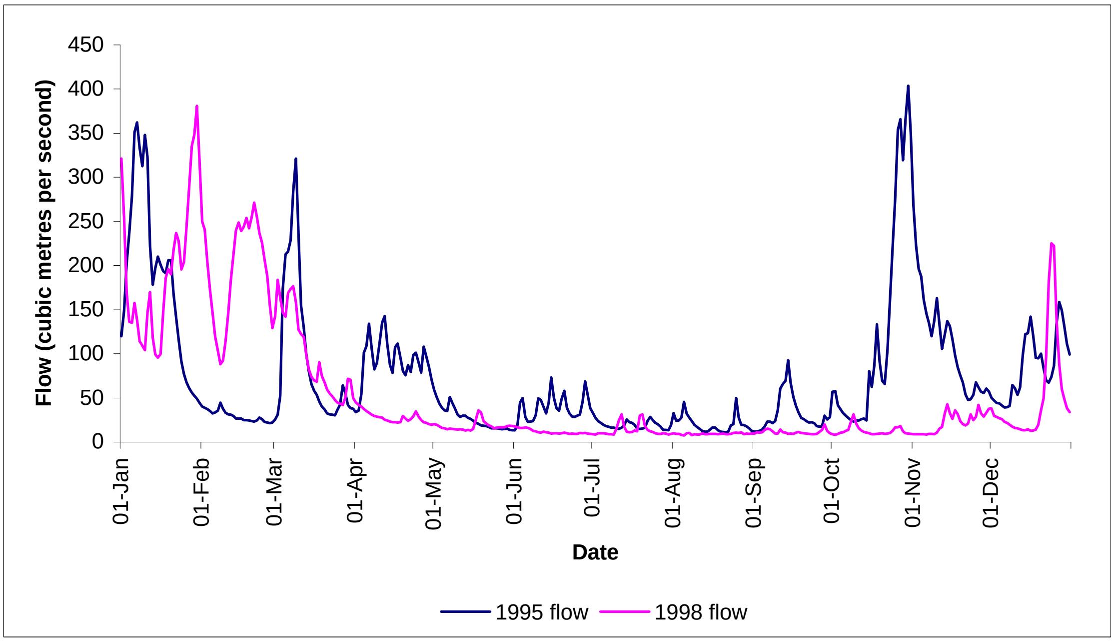


Figure 2.6 Mean Daily Flow of the Severn at Bewdley, 1995 and 1998

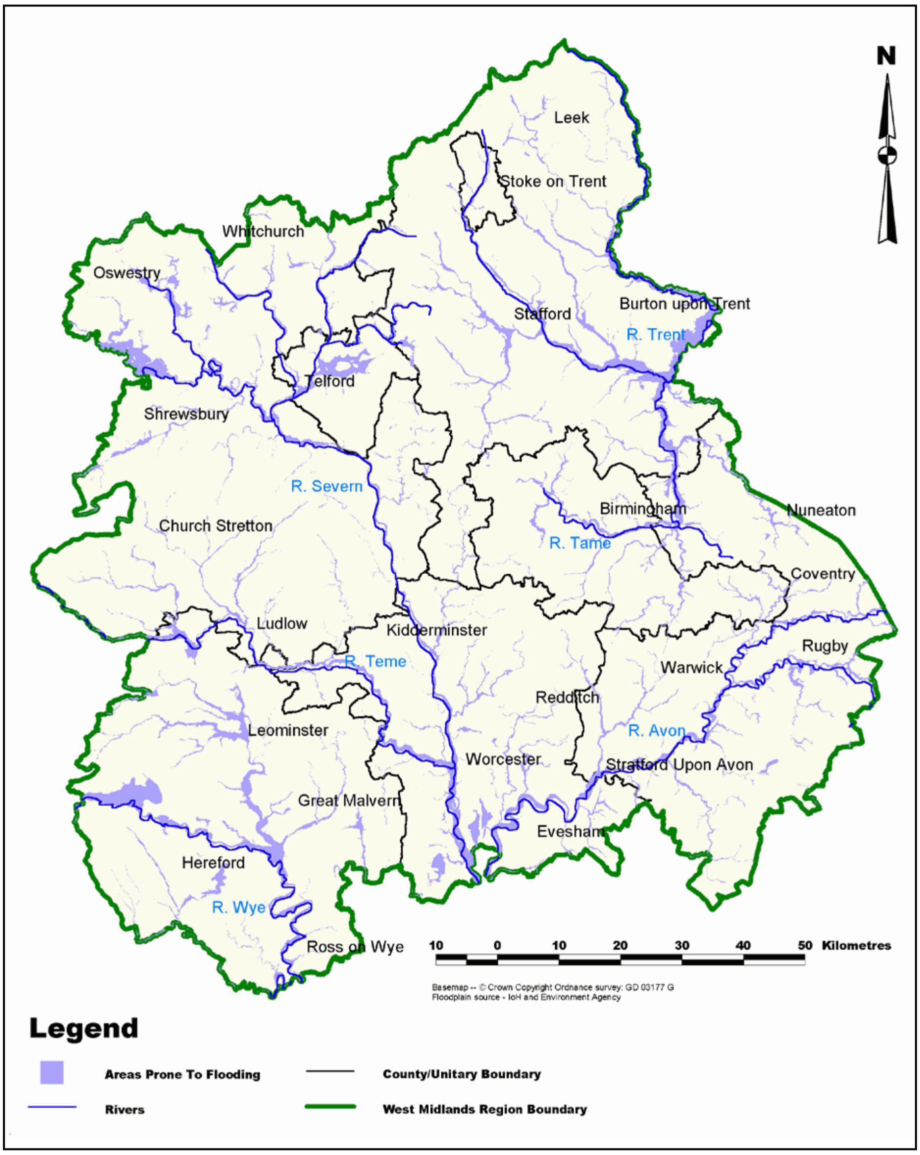


2.4.3 Flooding

Flooding has been a major issue in the West Midlands in recent years, particularly on the Rivers Avon, Leam, Severn, Sow and Trent. This was highlighted in national publicity of the review of the Easter 1998 and Autumn 2000 floods undertaken by the Department for Environment, Food and Rural Affairs (Defra). It has been estimated that 62,000 properties in the West Midlands are vulnerable to flooding (Environment Agency, 2001). New flood prevention schemes have been instigated along the Severn in Bewdley and Shrewsbury, on the Sow in Stafford and on the Trent near Stoke. A flood risk map of the region is shown in **Figure 2.7** (Environment Agency, 2001).

The River Severn is the longest river in Britain, flowing 345km from Plynlimon in the Welsh Mountains into the sea at the Severn Estuary in Gloucestershire. More than half of its journey is through Shropshire and Worcestershire in the West Midlands. The river is regulated to ensure that the flow does not fall below 650Ml/day and if the flow falls below 850Ml/day at the Bewdley gauging station then abstraction restriction warnings are issued. In the last few years flooding rather than low flow has been the major problem in attempting to regulate the river. The floods of Autumn 2000 were the highest water levels since 1947.

Figure 2.7 Flood Warning Areas in the West Midlands



Flooding has also affected urban areas away from the large river valleys. The south western suburbs of Birmingham have been affected and there have been four significant floods in Northfield between September 1998 and July 2000 (Philips 2003).

2.4.4 Groundwater

Figures 2.8 and **2.9** (Source: Environment Agency) show two different stories. Water levels have risen in Birmingham due to a reduction in abstraction as the number of industries using water in the city has declined. However, the hydrograph taken from the Check Hill borehole shows that the water level in the Wombourne (Sherwood Sandstone) groundwater unit fell to an all time low in 1997, largely due to changes in effective rainfall. Historically this unit has supported a high rate of public water abstraction, which has led to a depletion of stream baseflows with resultant environmental problems. This groundwater unit is considered to have too much water taken from it.

Figure 2.8 Rising Groundwater in the Constitution Hill Borehole in Birmingham

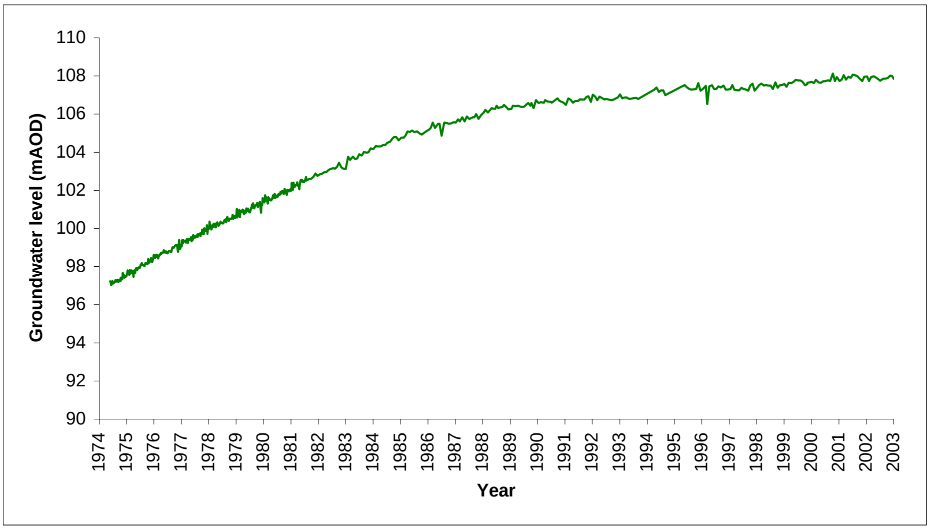
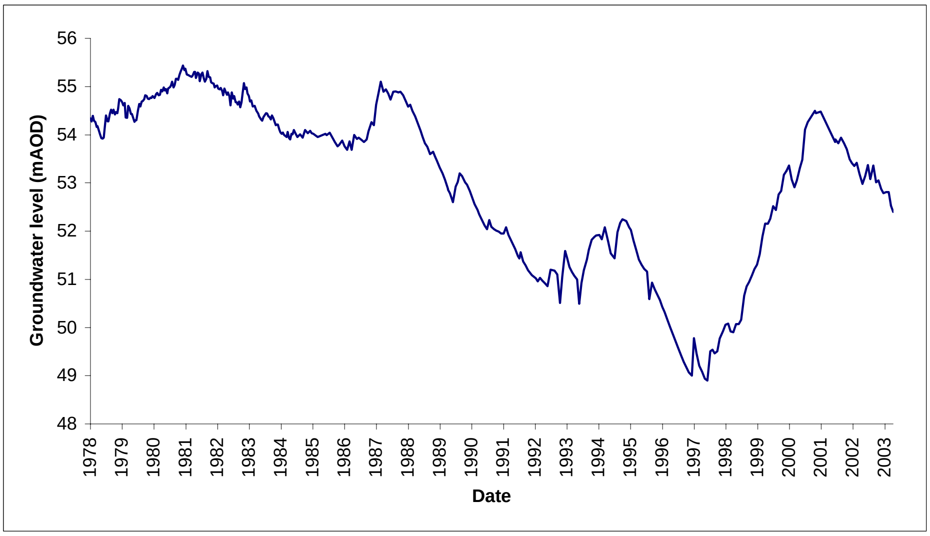


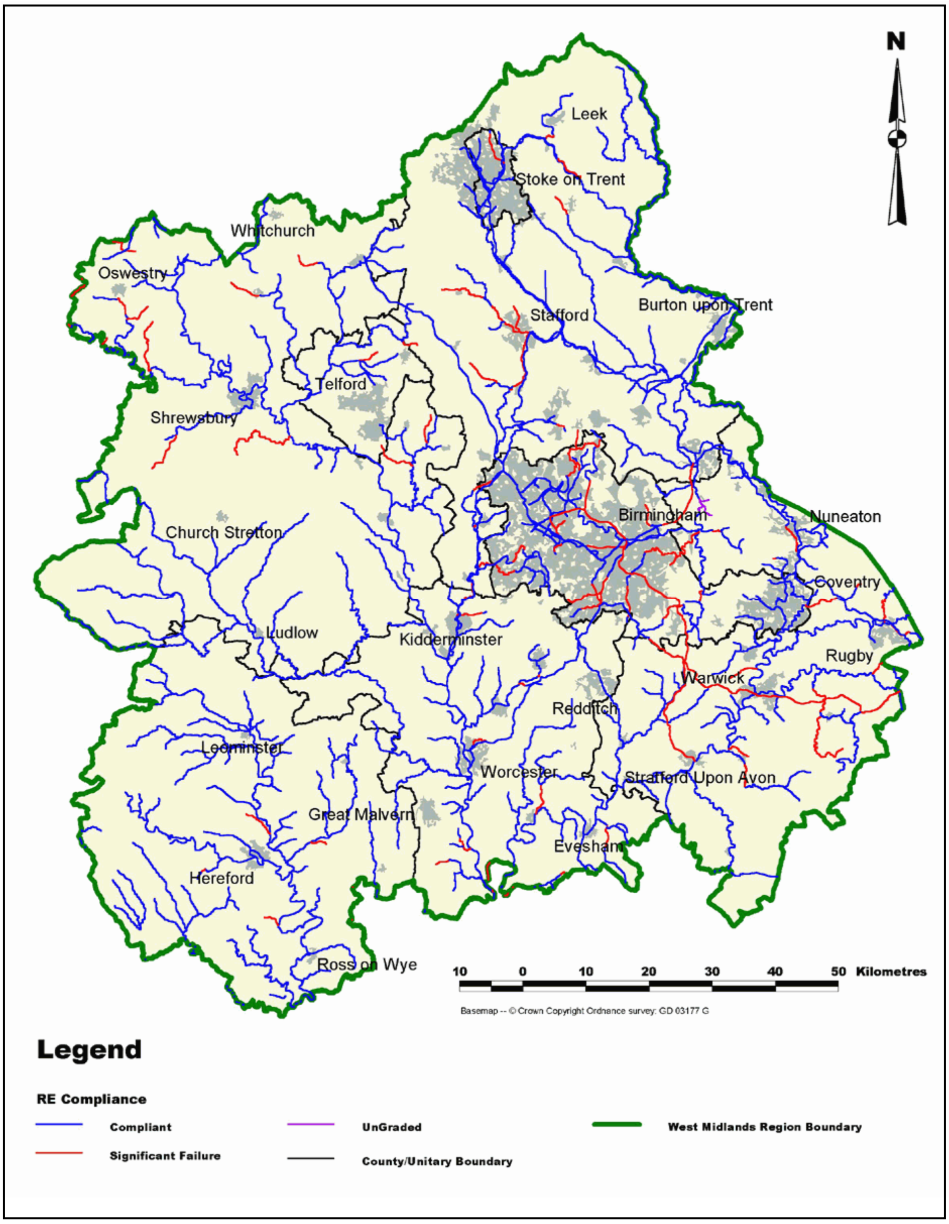
Figure 2.9 Falling Groundwater Check Hill Borehole in Kingswinford



2.4.5 Water quality

There has been an underlying trend of improvement in water quality as shown in **Figure 2.10** (Environment Agency, 2001). Since 1990, for example, the percentage of the best quality (Grade A) rivers has more than doubled (from 6% to 16%) and the percentage of the poorest (Grade E and F) quality rivers and canals has almost halved (from 18% to 10%). This improvement is due to significant improvements in the quality of discharges to rivers in the region, to tighter regulation and to better enforcement and pollution prevention by the Environment Agency.

Figure 2.10 Water Quality: River Ecosystems Compliance 1999



2.4.6 Air quality

Air quality monitoring has improved dramatically during the last ten years or so due to the setting up of the Automatic Urban and Rural Networks across the UK, which includes several sites in the West Midlands. These stations monitor hourly oxides of nitrogen, sulphur dioxide, ozone, carbon monoxide and particulate matter (PM_{10}). It can be seen from **Table 2.6** that levels of carbon monoxide and sulphur dioxide pass the required standards across the region. Although the West Midlands includes large areas of industrial activity the main air pollution problems today are caused by traffic (Environment Agency, 2001). Currently, 75% of households in the region have access to at least one car and on average, each person in the region travels 5,694 miles by car by each year (National Statistics, 2002). At motorway junctions and in urban areas levels of oxides of nitrogen, ozone, carbon monoxide and particulate matter can be high and air quality standards exceeded. As well as affecting human health, annual levels of nitrogen oxides (mainly from traffic) and sulphur dioxide (mainly from industry) cause air quality standards for the protection of vegetation and ecosystems to be exceeded.

Table 2.6 Air Quality Data for 2001

	Ozone	NO_2	CO	SO_2	PM_{10}
Birmingham Centre	7	1/34	0	0	10/22
Birmingham East	13	0/31	0	0	9/22
Coventry	14	0/19	0	0	0/15
Leamington Spa	13	0/32	0	0	4/21
Sandwell	14	0/35	0	0	NR
Stoke-on-Trent	13	0/33	0	0	8/22
Walsall Alumwell	NR	0/42	0	0	NR
Walsall Willenhall	NR	2/27	0	0	NR
Wolverhampton	NR	0/32	0	0	10/23

Notes:
NR - data not recorded
Ozone - Number of days when daily maximum of 8 hour running mean > 50 ppb
NO_2 - Number of periods when 1 hour mean > 200 $\mu g/m^3$/Annual Mean $\mu g/m^3$
CO - Number of periods when running 8 hour mean > 10 ppm
SO_2 - Number of periods when 1 hour mean > 350 $\mu g/m^3$
PM_{10} - Number of days when fixed 24 hour mean > 50 $\mu g/m^3$ /Annual Mean $\mu g/m^3$

Two of the pollutants of most concern for the future are ozone and particulates. Ozone is formed by a complex reaction between nitrogen oxides, oxygen and volatile organic compounds, and its formation is dependent on both sources and appropriate meteorological conditions. Since the reaction to form ozone takes hours or days, high concentrations are generally found away from urban centres in the rural areas downwind of sources. Studies have shown that the United Nations' targets for ozone concentration in the growing season are exceeded across the whole of the region under certain weather conditions (Environment Agency, 2001). Although this could have significant effects, for example in terms of crop yields, the transboundary nature of ozone suggests that regional actions are unlikely to mitigate these problems. Particulates exceed objectives for health standards close to all major roads in the region at some time during the year. This pollution is particularly problematic in winter, when weather conditions keep particles close to the ground (Environment Agency, 2001).

The weather influences the dispersal patterns for air pollutants. Air pollution episodes occur when the weather conditions combine to either transfer pollutants into the West Midlands from other regions or prevent them dispersing.

Figure 2.11 (Environment Agency, 2001) shows an example of a regional air pollution episode that occurred on 02 September 1998. Sulphur dioxide emitted by a number of power stations to the north east of the region was transported by north easterly winds to give elevated levels (greater than 266 $\mu g/m^3$) of sulphur dioxide in parts of the West Midlands. Thus legislation to control air pollutants has to be considered across and between regions.

Figure 2.12 (Environment Agency, 2001) shows predicted annual nitrogen dioxide levels for 2005, which correspond closely with the major roads in the West Midlands.

Figure 2.11 Model Concentrations of Hourly Sulphur Dioxide Concentrations 2300hrs, 2nd September 1998

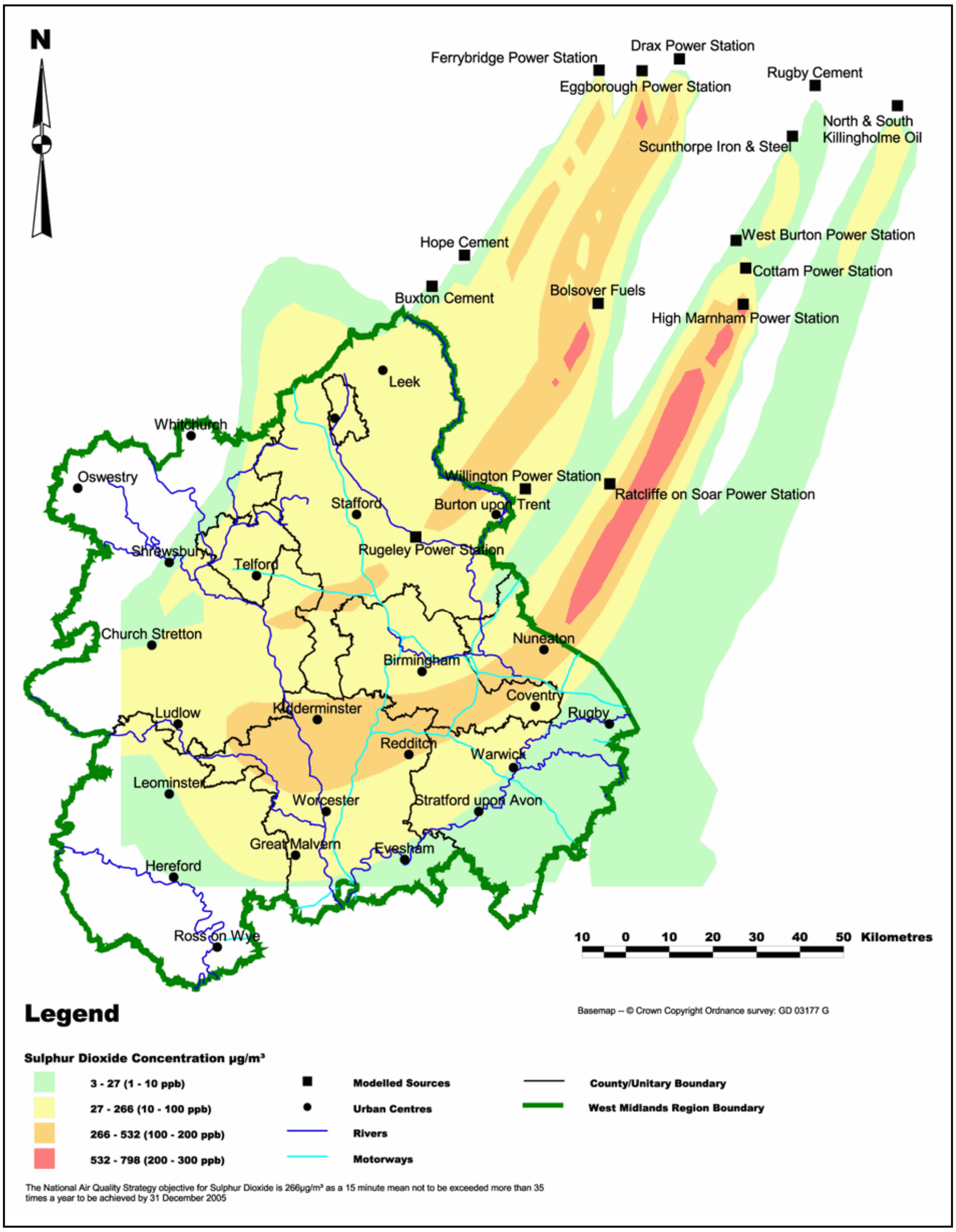
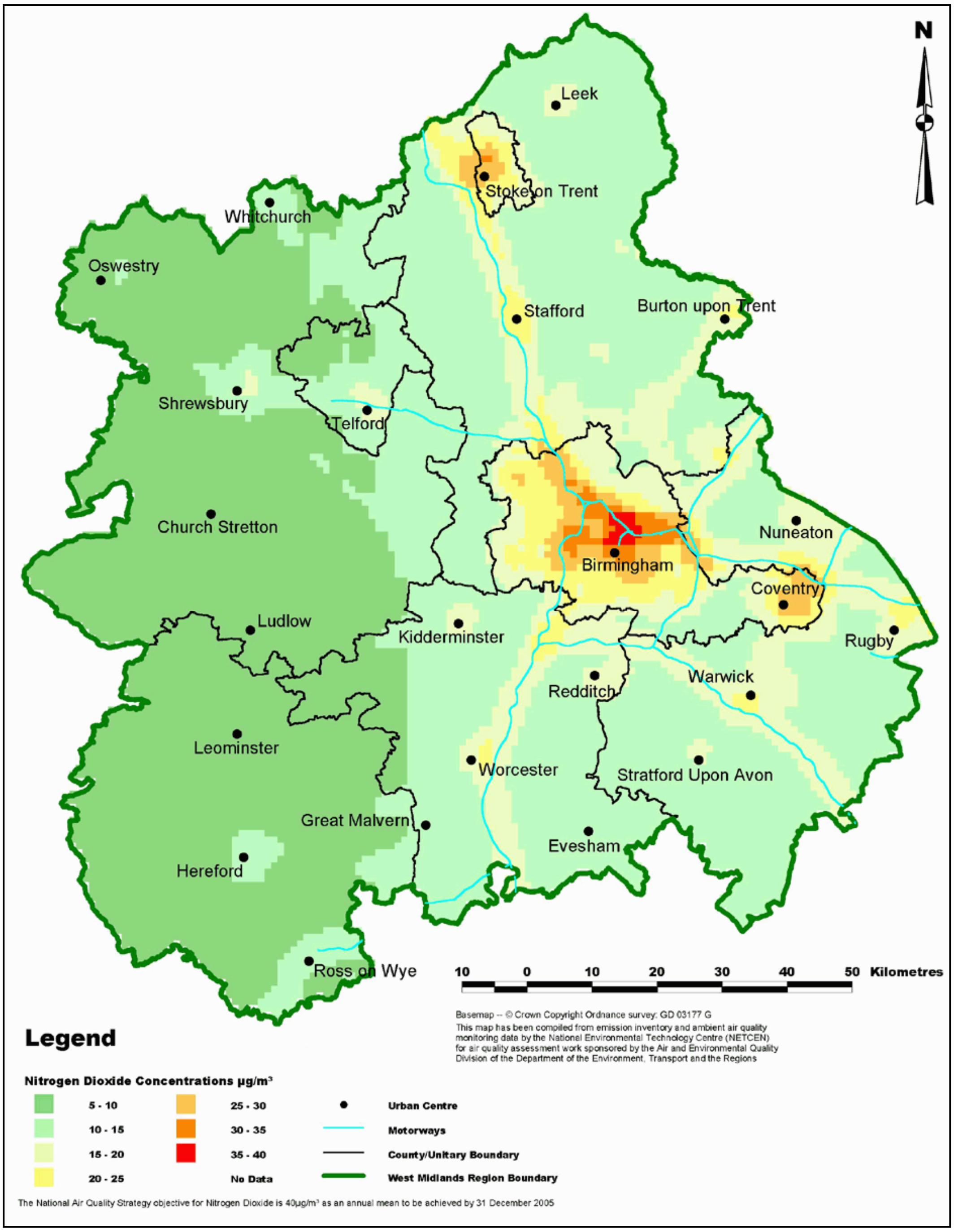


Figure 2.12 Predicted Annual Nitrogen Dioxide Concentrations in 2005



2.4.7 Land use

The majority of the West Midlands is made up of arable and horticultural land (34.6%) and improved grassland (35.4%). Other major land uses are for broadleaved, mixed and yew woodland (8.3%) and built up areas and gardens (8.7%). Both of these latter two categories are slightly higher than the English average, as shown in **Table 2.7** (National Statistics, 2002).

Table 2.7 Land cover by broad habitat

	West Midlands (%)	England (%)
Improved grassland	35.4	31.1
Arable and horticultural	34.6	35.1
Built up areas and gardens	8.7	7.1
Broadleaved, mixed and yew woodland	8.3	6.8
Acid grassland and bracken	3.0	4.3
Neutral and calcareous grassland	2.2	2.5
Coniferous woodland	2.2	2.7
(additional non-surveyed urban squares)	2.0	3.6
Dwarf shrub heath	1.5	2.7
Fen, marsh and swamp	0.6	0.7
Supralittoral rock and sediment	0.6	1.4
Standing open water and canals	0.6	0.8
Bogs	0.2	0.8
Inland rock	0.1	0.2

Within the region, 2% of land (20,000 hectares) is within designated National Park, 10% (127,000 hectares) is in Areas of Outstanding Natural Beauty, and 21% (267,000 hectares) is Green Belt land. This is lower than the national average, except in the last category (National Statistics, 2002).

2.4.8 Built environment

Increasing numbers of people are working in towns but living in the countryside. There is a wide range in the quality of housing with as much as 10% of the region's stock declared unfit for living. Of local authority owned housing, 12% is unfit with 98% of these in Birmingham, the Black Country authorities and Stoke-on-Trent. This is also correlated with housing demand, with strong housing pressure in the south and east of the region, and lack of demand in the north and west. The draft housing strategy (West Midlands Regional Assembly, 2003) aims to encourage rural and urban renaissance, and fit within the objectives of the other regional plans and policies.

2.4.9 Waste generation and disposal

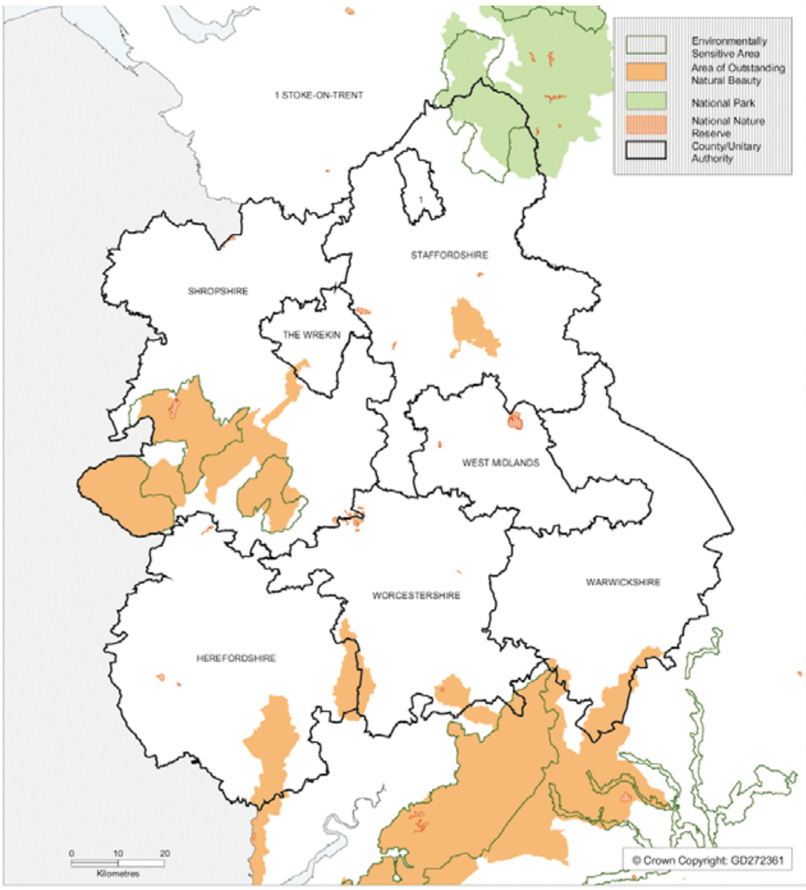
In 1995, 2.5 million tonnes of household waste was produced in the West Midlands, and it is predicted to increase to 5.3 million tonnes by 2020. Of this, less than 1 million tonnes will be able to go to landfill, while the rest will require some other form of treatment. Currently only 5%-10% of household waste is recycled (Environment Agency, 2001).

In addition, in 1998/9, the West Midlands generated 7.56 million tonnes of industrial and commercial waste, 2.76 million tonnes of municipal waste, and 6.3 million tonnes of construction and demolition waste. Of this waste, 61% was deposited in landfill, 31% was incinerated, and only 6% was recycled (Environment Agency, 2001).

2.4.10 Wildlife and biodiversity

Biodiversity is concerned with the variety of living organisms, and their different habitats and ecosystems. The West Midlands has a wide variety of wildlife, habitats and geological interest, some of which are shown in **Figure 2.13** below. There are extensive moorlands and acidic grasslands in the uplands, but lowland habitats are typically small, vulnerable and isolated. Certain localities in South Shropshire and North-East Staffordshire have greater ecological coherence due to the higher proportion of semi-natural habitats.

Figure 2.13 Areas of environmental significance in the West Midlands



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The Convention on Biodiversity was signed by more than 150 heads of Government at the Earth Summit in June 1992. The UK published four strategies in response to the Earth Summit, including a Biodiversity Action Plan (BAP) in 1994. The UK Steering Group Report of 1995 identified a number of species and habitats at a national level, each with different levels of priority. The West Midlands has nine of the thirty-nine priority species and three of the five priority habitats.

The Atlantic salmon (salmo salar) is widely recognized as an excellent indicator of environmental quality, reflecting both water quantity and quality and the physical condition of rivers within the region. Salmon spawn in the headwaters of rivers and streams and spend two years in the upper reaches before going to sea for one winter and then returning to the streams in which they were born. Some undertake a migration to the feeding grounds off the west coast of Greenland or the Faroes before returning several years later as much larger spring-run salmon.

Two prestigious salmon rivers flow through the region - the River Severn and the River Wye. The decline in salmon stocks in these rivers is illustrated in **Figures 2.14** and **2.15** (Source: Environment Agency) reflecting the national picture. The River Trent was a very important commercial salmon river with a recorded peak run of salmon in 1888 believed to be as high as 10,000 fish. The River Dove is one of the most important breeding tributaries. The rapid development of industry in Birmingham and the subsequent pollution of the River Tame had a significant effect on water quality in the River Trent and led to the disappearance of salmon. This was exacerbated by the creation of impassable structures and navigation weirs. Since the mid-1980s, the number of salmon caught or reported in the River Trent has increased, reflecting the improved water quality regime, reduced water temperature with the decline of the power stations and improvements to fish passage.

It is also possible to restock salmon from hatcheries. For example in September 2000, nearly 45,000 salmon were stocked in the Upper Severn tributaries including the Rivers Tanat, Teme and Perry and over 160, 000 salmon have been introduced into the River Dove.

There is one Special Protection Area (SPA) in the region and sixteen candidate Special Areas of Conservation (SAC). These mainly relate to the peatland sites (Fenn’s and Whixall Moss, Chartley Moss, Clarepool Moss, Brown Moss) and open water sites with key species (Fenn Pools and Lyppard Grange for great crested newts, Ensors Pool for white clawed crayfish, River Mease for spined loach).

Figure 2.14 River Severn and River Wye Salmon Catches - Rods

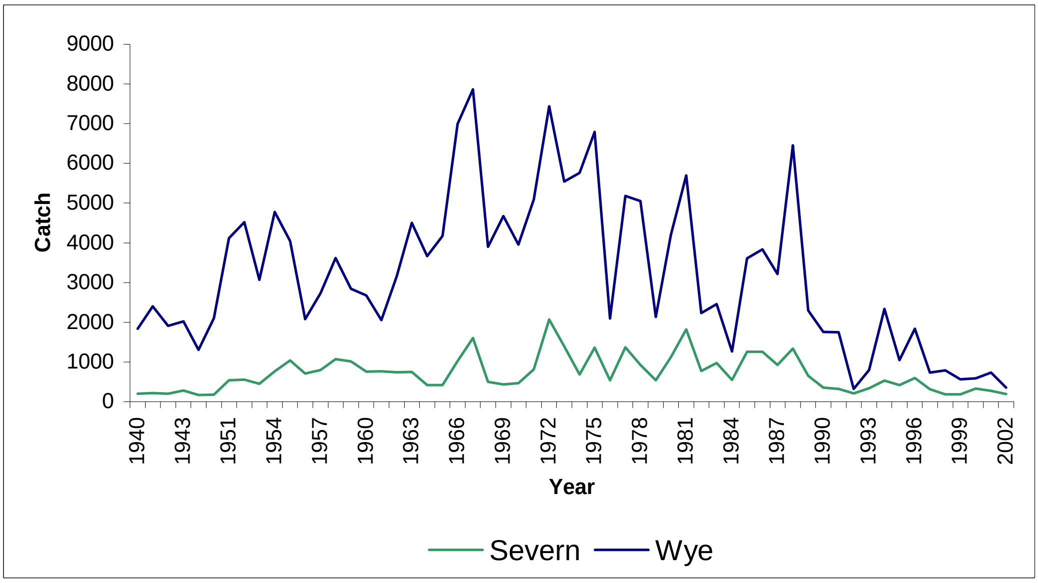
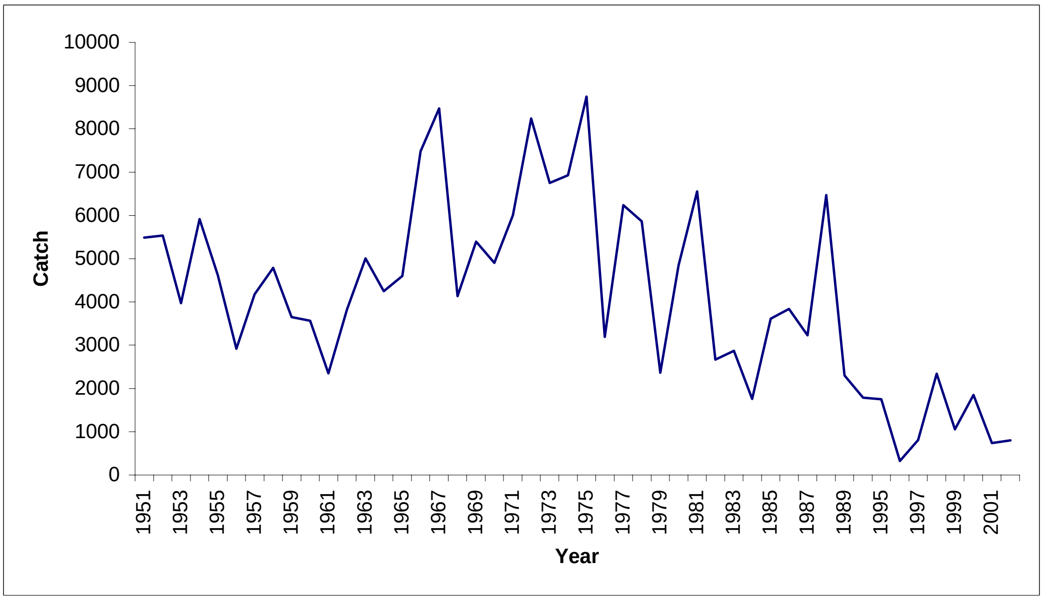


Figure 2.15 River Wye Salmon Catches - Nets and Rods



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3. West Midlands Baseline Climate

3.1 An Introduction to Climate Change

The Earth's climate is always changing. It has changed in the past, it is changing now and will continue to change in the future. In the past the changes have been due to natural causes such as astronomical variations in the Earth's orbit around the sun or huge volcanic eruptions that fill the atmosphere with dust. In the last two to three million years (the Quaternary Ice Age) there have been approximately 20 glacial phases that have lasted for about 100,000 years and interglacial phases that have been warmer that tend to last for about 10,000 to 12,000 years. For 90% of this Quaternary period our normal climate in the United Kingdom has been glacial. For the last 10,000 years or so (Holocene) we have been in an interglacial period. Indeed in the 1970s, scientists were predicting that the onset of the next glacial phase was imminent. However, careful monitoring of the Earth's climate during the 20th century detected a significant warming trend, which is now largely attributed to human activities, for example through the emission of greenhouse gases such as carbon dioxide from the combustion of coal and oil. Scientists are now predicting that this warming trend will continue throughout the 21st century unless we reduce greenhouse gas emissions. What makes this predicted change in climate different from previous natural changes is the speed of change. Whereas natural changes are normally thought to take hundreds or thousands of years to occur, enhanced global warming due to human activity could see dramatic changes in a few decades. The Third Assessment Report (IPCC, 2001b) of the Intergovernmental Panel on Climate Change (IPCC) suggests that:

- the global average surface temperature has increased over the 20th century by about 0.6°C;
- the 1990s was the warmest decade and 1998 the warmest year in the 20th century;
- this 20th century temperature increase is the largest in the past 1,000 years; and
- rainfall has increased by 0.5%-1% per decade during the 20th century over most mid- and high latitudes of the Northern Hemisphere continents.

Looking ahead into the 21st century the UK Climate Impacts Programme (UKCIP) presents four scenarios (Low, Medium-Low, Medium-High and High Emissions of greenhouse gas emissions) to describe four possible climate futures for the United Kingdom. The main conclusions are as follows:

- UK annual temperature could increase by between 1°C (Low Emissions) and 5°C (High Emissions) by the 2080s with a rate of warming greater than in the 20th century;
- winter rainfall is expected to increase with more frequent heavy rainfall days whereas summer rainfall is likely to decrease with increased probability of droughts;
- there is expected to be increased temperatures with higher maximum temperatures in the summer and fewer frosts and less snow during the winter; and

- sea level could rise between 17cm (Low Emissions) and 79cm (High Emissions) in South East England (taking into account isostatic adjustments).

In the West Midlands the trends are predicted to be very similar with warmer wetter winters and hotter drier summers. The predicted rise in sea level is unlikely to affect the land locked West Midlands other than to perhaps push the tidal area of the Severn further north towards the region beyond Gloucester.

3.2 The Climate of the West Midlands

In order to provide a context for the consideration of potential future changes in the climate and the implications of these changes, this section analyses historic changes and the current climate of the West Midlands. Within the region there is a long history of weather observing and recording. Two of the notable stations are in Birmingham and Ross-on-Wye, both of which have daily records of maximum and minimum air temperature, rainfall, sunshine and wind from the 1850s onwards. The later part of the 19th century was a popular time for weather recording and other locations became part of an increasing network. This has resulted in other stations with a century or more of daily weather observations and these include Malvern, Coventry and Newport. In Birmingham members of the Lunar Society designed and built a number of self recording weather instruments, and routine weather observations first commenced in 1793, thus making the Birmingham record the longest in the UK (Giles and Kings, 1996).

There are a number of ways of defining climate and various methods of classifying the climate of a region. One of the most recent is presented in Chandler & Gregory (1976), which assigns the West Midlands to class BD2. This class translates into the following:

- Growing season of 7-8 months;
- Greater than or equal to a 30% probability of at least 750mm of rain during the year; and
- Most rainfall in the second half of the year.

The distinguishing feature about the climate of the Midlands is its variability. Evidence suggests that average weather is rarely attained. On the one hand it exhibits the characteristics of the wetter (maritime) west showing plentiful all year round rainfall and a small temperature range, whilst on the other it clearly features a typical drier (continental) east with adequate rainfall and a larger annual range of temperature. These regimes are controlled by the synoptic (weather) scale features that alternate and persist over the UK. It is the interaction of these differing air mass types and their relative persistence and dominance across the region which result in the climate of the West Midlands. Within the region there is also a west-east transition of these features and it is on this macro scale that geography plays an important part in modifying the synoptic patterns. These manifest in a series of identifiable, often distinctive features, which can be assigned to each county, and are summarised in **Table 3.1** (based on the geography of the old counties).

Table 3.1 Main Features of West Midlands Climate

County (based on old county boundaries)	**Main features of climate**
Herefordshire	Spring and autumn frost; large annual temperature range; low winter temperature. Highest total annual rainfall of region
Worcestershire	Spring radiation frost; spring and summer thunderstorms with hail; high summer temperature; warm nights, less rain than other counties
Staffordshire	Low temperature; advection frost; autumn and spring snow showers; mist and fog; highest frequency of summer thunderstorms in region
Shropshire	Low winter temperature; severe frost; rain shadow; frost hollow; drought prone
Warwickshire	Large annual temperature range; low winter temperature and high summer temperature; snow and blizzards; windy; spring hail and thunder. Most variable county

The following sections detail the regional distribution of the main climatic elements, temperature, rainfall, sunshine and wind, giving where possible station normals (1961-1990).

3.3 Temperature

Table 3.2 shows a southwest to northeast gradient of temperature, with the lower mean annual temperatures in Staffordshire at near 8^{o}C and the higher ones to the southwest in Herefordshire and Worcestershire, with mean temperatures near 10^{o}C.

Mean annual maximum temperatures reflect this gradient with the 14^{o}C isotherm to the south of Birmingham and the 12^{o}C isotherm running across the northeast of the region. Mean minimum temperatures identify the relief of the area quite well with the lowest minima occurring to the south and east of Birmingham as well as to the north and east. The conurbation now reflects the urban heat island (see Section 3.10 for an explanation of this effect), with minima comparable to the more maritime Worcestershire. As a consequence, Birmingham has a large annual range of temperature for both its inland position and latitude. Across the region, January is the coldest month in terms of day maxima, but February the coldest in terms of night minima. The counties of Shropshire and Herefordshire are prone to frequent frosts with minima just below 0°C. Maximum temperatures then rise quickly reaching double figures during April with a peak during the summer months. The warmth is generally short-lived though with July and August being near 2°C warmer than June and September. The highest mean maximum occurs in Worcestershire. The summer warmth leaves about a 60-day frost-free period over most of the region.

The Birmingham Temperature Series (BTS) has a mean annual temperature over the full 210 year record of 9.3°C compared with 9.4°C for the 1961-90 series. The BTS is almost identical to the Central England Temperature (CET) series.

Table 3.2 Mean monthly maximum and mean monthly minimum temperatures, 1961-1990

Station Height (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Shawbury (72m)													
Meanmax (°C)	6.5	6.6	9.2	11.9	15.5	18.5	20.3	20.0	17.5	13.9	9.4	7.3	13.0
Meanmin (°C)	0.3	0.2	1.5	3.1	5.9	8.9	10.8	10.6	8.6	6.1	2.6	1.0	4.9
Keele (179m)													
Meanmax (°C)	5.5	5.6	8.0	10.7	14.6	17.1	19.3	19.1	16.3	12.6	8.5	6.7	12.0
Meanmin (°C)	0.6	0.4	1.7	3.2	6.3	9.1	11.3	11.2	9.0	6.5	3.1	1.8	5.3
Birmingham (132m)													
Meanmax (°C)	5.6	5.9	8.6	11.4	15.1	18.3	20.2	19.8	17.2	13.4	8.7	6.4	12.5
Meanmin (°C)	1.8	1.5	2.7	4.2	7.1	10.1	11.9	11.8	10.0	7.6	4.1	2.7	6.3
Malvern (63m)													
Meanmax (°C)	6.8	7.0	9.7	12.6	16.4	19.6	21.6	21.0	18.3	14.4	9.9	7.7	13.7
Meanmin (°C)	1.7	1.5	2.9	4.7	7.4	10.5	12.5	12.3	10.2	7.6	4.1	2.5	6.5
Ross-on-Wye (67m)													
Meanmax (°C)	6.9	7.0	9.7	12.5	16.1	19.2	21.2	20.8	18.1	14.4	9.9	7.8	13.6
Meanmin (°C)	1.4	1.2	2.5	4.1	6.9	9.8	11.7	11.6	9.6	7.1	3.7	2.3	6.0
Stratford-on-Avon (49m)													
Meanmax (°C)	6.5	6.8	9.7	12.5	16.3	19.5	21.6	21.1	18.5	14.6	9.6	7.3	13.6
Meanmin (°C)	0.4	0.3	1.4	3.0	5.7	8.8	10.6	10.5	8.5	6.1	2.6	1.1	4.9

3.3.1 Maximum temperatures

In Birmingham the mean maximum temperature is 12.5°C ranging from - 6°C to 34°C, with the lowest temperatures confined to January and February and the highest to July and August. Overall mean monthly maximum temperatures range from near 5°C in January to 20°C in July. On an individual day, a cold day in January or February will have a maximum temperature below 2°C, and a warm day during the summer a maximum temperature above 22°C. Conversely a mild day in January will have a maximum temperature above 7°C and a cool summer day a maximum below 16°C.

On average there are 26 days each year with a maximum temperature above 23°C. Individual year frequency can range from 4 days to 57 days and these can occur any month from March to October, though they are most likely to occur during the months June to August. In fact less than 5% of these events occur outside the summer months. Taking a higher threshold, 24°C, gives an average 11 days each year ranging from 0 days in some years to 39 days in others. Again these events occur during the extended summer months, May to September, but the majority occur during the months July and August. **Table 3.3** below shows the monthly distribution.

Table 3.3 Distribution of Warm Days in Birmingham (since 1940)

Max. temp. ^{o}C	23	24	25	26	27	28	29	30	31	32	33	34
Month												
April	4											
May	23	9	8	4	1	3	1					
June	75	32	36	32	14	12	4	4	3			
July	93	55	59	40	32	15	11	11	3	3		
August	70	62	43	37	38	6	3	3	2	2	1	1
Sept	23	11	9	3	4							
Oct	3	0	1	1								

Days with a maximum temperature of 28^{o}C and above currently average two per year. This ranges from 0, in most years, to 16, though 3-6 days is the mode (the most frequent) in those years where events occur. The distribution of these days is interesting in that in general they will occur as single events distributed through the summer months, most in July and August. In other years they will occur in spells of up to 4-6 days. In these spells maximum temperatures can reach between 30^{o}C and 32^{o}C on at least one day.

3.3.2 Minimum temperatures

In Birmingham the mean minimum temperature averages 6.3^{o}C ranging from -12^{o}C to 20^{o}C, with the lowest occurring in January and the highest in July and August. Overall mean monthly minimum temperature ranges from -4^{o}C to 14^{o}C. On an individual day basis minimum temperature can range from below 1^{o}C on a cold winter night to above 12^{o}C on a warm summer night. Alternatively a mild winter night will have a minimum temperature above 3^{o}C and a cool summer night a minimum below 10^{o}C. The lowest minimum air temperatures for 1961-90 are shown in **Table 3.4**.

On average there are 36 nights with minimum temperature -0.1^{o}C or below, that is with an air frost. The air frost season extends from October through to May, though occurrences in these particular months is small.

Table 3.4 Mean frequency of nights with minimum below thresholds, Birmingham, 1961-90

	Air Frost Nights : Below Zero												
Min. temp. ^{o}C	**2**	**1**	**0**	**-0**	**-1**	**-2**	**-3**	**-4**	**-5**	**-6**	**-7**	**-8**	**-9**
1961-1990	21	20	17	11	9	7	4	2	1	1	0.6	0.4	0.4

3.4 Precipitation

Precipitation includes all forms of rainfall both solid (snow, hail, ice pellets, snow grains and hoar frost) and liquid (rain, drizzle, sleet, wet fog and dew). In reality much of the measured precipitation falls as drizzle, rain and snow or combinations of these. The average rainfall over the West Midlands is 719mm per year (1961 to 1990 average), well below the England and Wales average of 901mm, although there are significant variations across the region as shown in **Figure 3.1** (Environment Agency, 2001). Annual average rainfall ranges from over 1,200mm towards the west of the region to under 600mm in the Avon catchment. This distribution reflects the altitude and topography, the higher totals being limited to the higher ground of the Welsh Marches, the Cotswolds and the Birmingham Plateau. Overall there is a northwest to southeast gradient, with the lower totals, below 600mm confined to the southeast. Examination of **Table 3.5** reveals that most stations have an annual total between 600mm and 800mm. However, much of the falling precipitation is lost to evaporation and transpiration by vegetation, especially in the hotter summer season, so, on average, under 30% of the total rainfall remains as 'effective' (i.e. available for some sort of beneficial use).

Figure 3.1 Mean Annual Rainfall in the West Midlands (1961-90)

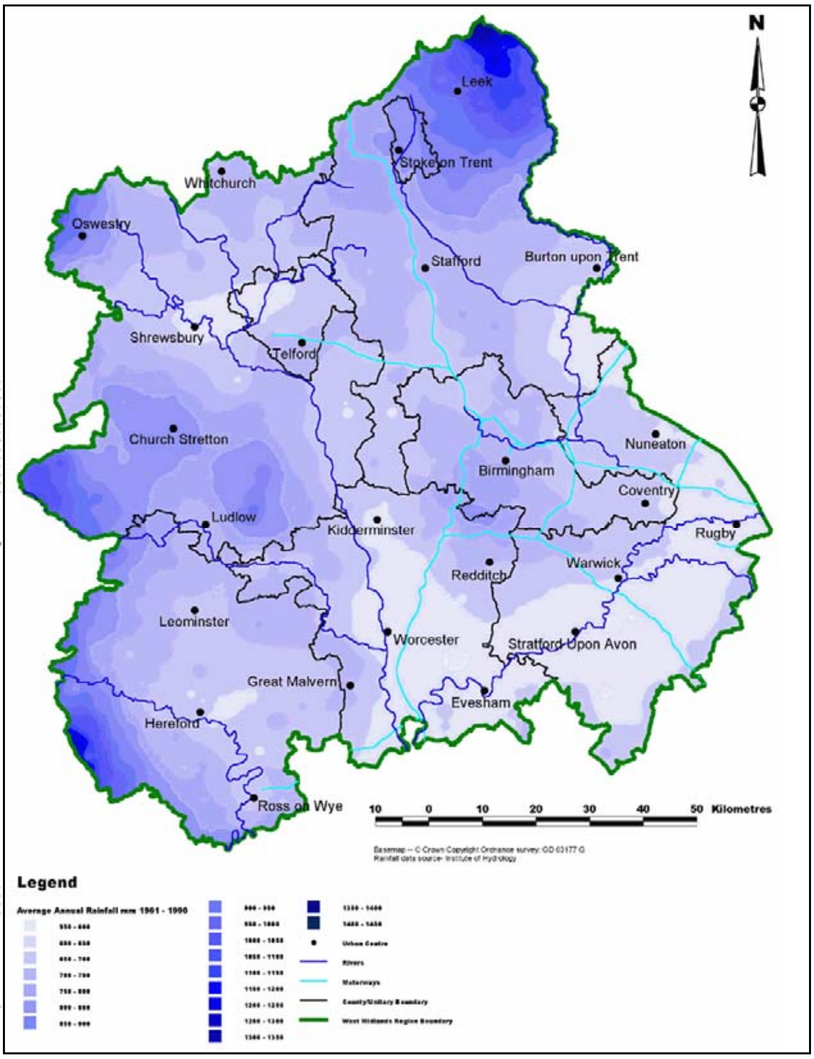


Table 3.5 West Midlands rainfall and monthly total wetday frequency, 1961-1990

Station Height (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Shawbury (72m)													
Total Rain	55	42	49	47	57	52	53	58	58	56	62	63	652
Wetdays	12	9	11	10	11	10	9	10	10	11	12	12	124
Keele (179m)													
Total Rain	75	53	66	56	61	70	55	72	63	71	81	72	795
Wetdays	14	10	14	9	11	11	9	10	19	12	12	13	134
Birmingham (132m)													
Total Rain	70	54	62	58	64	59	56	72	64	62	68	79	767
Wetdays	13	9	12	11	9	9	8	10	9	11	11	12	125
Malvern (62m)													
Total Rain	70	55	58	49	59	57	48	62	61	60	62	74	715
Wetdays	13	10	12	9	9	9	7	8	8	10	10	11	116
Stratford-on-Avon (49m)													
Total Rain	52	40	48	44	49	54	51	65	50	49	53	61	616
Wetdays	12	9	11	10	10	9	8	9	9	10	10	11	117

'Wetday' defined as a day having more than 1mm of rainfall.

In most years, in the driest parts in the southeast of the region, February is the driest and August generally the wettest month. The other counties to the west of Warwickshire show a somewhat different scenario. In Herefordshire and Worcestershire a marked winter maximum occurs with the October to December period being the wettest. Heavy showers in July and August result in a secondary maxima. Shropshire and Staffordshire each show a similar but less pronounced pattern. Most counties have their drier months during spring. In Birmingham December is the wettest month with August close behind. However, most of the intense rain in Birmingham falls in summer as shown in **Table 3.6**. An examination of these events shows that the majority occur during the summer and with thunderstorms. The most intense rainfall recorded in Birmingham reached 250mm/hour, though this only lasted less than five minutes. On average, high intensity rainfall within summer showers and thunderstorm can reach 100mm/hour, but usually lasts for less than 60 minutes.

Table 3.6 Amount/Duration Histogam of Rainfall in Birmingham by Month (Since 1970)

Amount/ Duration	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
16mm/30min							2					
20mm/60min							2					
15mm/60min							3					
25mm/2hrs							2	1				
25mm/6hrs	1					1	3	8	6	2	1	
33mm/6hrs					1		2	3	3			
35mm/24hrs				1		3	3	11	5	1		3
46mm/24hrs							2	3	1			

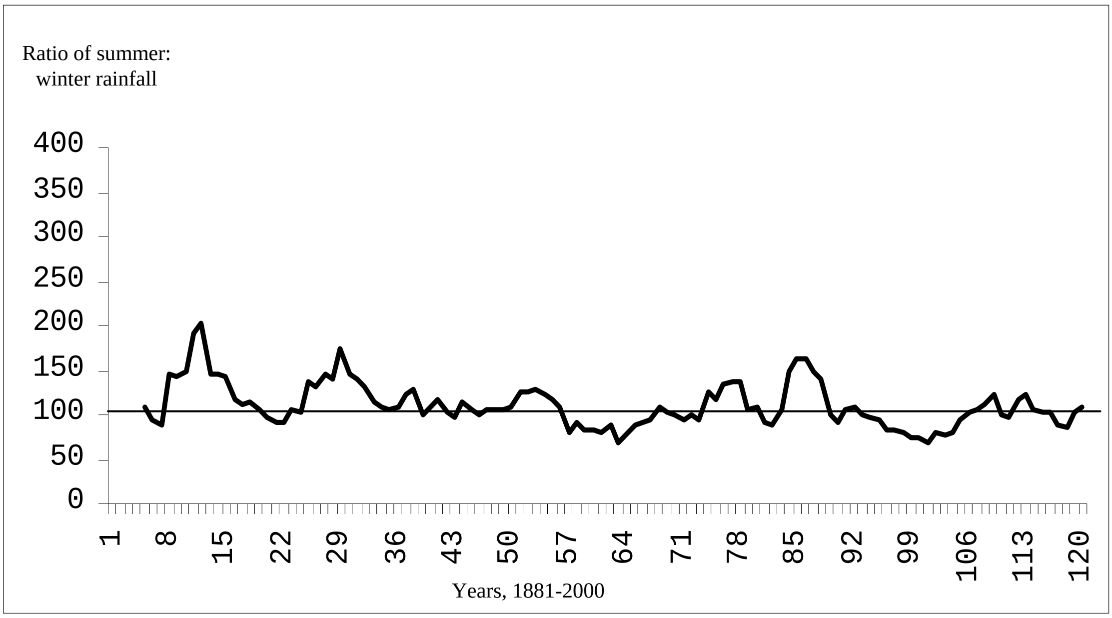
The variability of rainfall in Birmingham in the 20th century is shown in **Table 3.7**. The overall mean in Birmingham is approximately 767mm over the century. 1901-1910 was the driest decade averaging 680mm whereas 1951-1960 was the wettest decade averaging 808mm. This represents a natural variation of between 5% and 10%.

Table 3.7 Mean Annual Rainfall for 10 Year Periods in Birmingham

Birmingham Rainfall	Mean Rainfall mm	% difference from mean
1901-1910	680	-11%
1911-1920	723	-6%
1921-1930	762	-0.7%
1931-1940	745	-3%
1941-1950	744	-3%
1951-1960	808	+5%
1961-1970	778	+1%
1971-1980	735	-4%
1981-1990	789	+3%
1991-2000	793	+3%
Approximate Mean	767	

The variation in summer/winter rainfall in Birmingham in the period 1881-2000 is shown in **Figure 3.2**.

Figure 3.2 Summer: Winter Rainfall Ratio, Birmingham, 1881-2000



3.4.1 Snow

The snow season in the region runs from November to April although snow has fallen in October, May and June. Normally snow is most frequent in January and February especially on the high ground in Shropshire, Warwickshire and Worcestershire. Birmingham has the longest snow record in the UK (Jackson 1979).

The median number of snow days per year is about 30 across the region. A snow day is defined as any day on which snow is observed to reach the ground. A more reliable indicator of the impact of snow is snow cover and depth. Snow is measured at 0900 GMT and snow cover is counted if more than 50% of the ground has snow on it. Depths of snow are usually less than 2cm and less than 2% of all snow days record more than 30cm of snow. Depths of between 1cm-10cm are most common. **Table 3.8** shows the median number of snow days in Birmingham for each month 1961-90 and the maximum and minimum recorded since 1940.

Table 3.8 Frequency of Snow-days, Birmingham, 1961-1990

	Frequency of Snowdays					
Period	**November**	**December**	**January**	**February**	**March**	**Total**
1961-1990 median	2	5	7	8	6	28
Lowest	0	0	0	0	0	0
Highest	9	15	20	19	16	79

Over the last 50 years in Birmingham:

- the maximum snow depth was 43cm;
- nearly 50% of all days with snow lying had depths between 1cm and 10cm;
- less than 2% of days had more than 30cm; and
- about 60% of snow days had snow lying at 0900 GMT.

3.5 Wind

Mean daily wind speeds average 9mph in Birmingham. **Table 3.9** shows the number of hours each month with wind speeds in each Beaufort Force class. From this it can be seen that calm prevails for just under 4% of the year, being slightly more likely in summer than winter. Around 50% of hours have speeds above 8mph but below 19mph. Consequently, most winds are moderate, a term frequently used in weather forecasts. Higher hourly speeds do occur, those between 20mph-24mph account for around 10%-12% of the time. These are most frequent during the extended winter, November to March. Conversely, 10%-15% of winds are light, through summer, and between 8%-10% during winter. At the other end, hours exceeding 39mph (gale force) average under 10 during the year with a high in January and February.

Table 3.9 Distribution (%) of Mean Hourly Wind Speed in Birmingham, 1961-1990

Speed (mph)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Calm	2.0	2.6	2.3	3.5	3.9	4.6	3.1	4.0	5.0	5.1	3.9	3.7	3.6
1-4	9.0	9.5	8.1	11.8	16.5	15.7	8.8	13.5	14.0	15.4	14.9	10.8	12.8
5-7	12.5	12.9	13.8	16.9	18.3	18.1	9.5	13.1	17.8	15.5	17.1	12.0	15.3
8-12	24.5	25.7	27.9	34.5	30.3	31.1	22.3	34.1	30.2	26.2	27.8	26.3	29.1
13-19	32.9	27.6	28.4	27.5	25.6	26.1	25.1	27.9	26.1	25.8	26.5	28.1	27.9
20-24	11.3	11.1	12.1	4.1	4.1	3.5	2.4	6.1	45.0	7.9	6.5	11.5	7.2
25-31	6.4	7.5	5.8	1.6	1.1	0.7	0.6	1.2	1.6	3.5	3.1	6.1	3.3
32-38	1.0	2.4	1.4	0.2	0.1	0.2	0.0	0.1	0.2	0.6	0.2	1.4	0.6
> 39	0.4	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	>0.1

Summing hourly speeds over 24 hours leads to the mean daily wind speed and in turn the mean monthly speed. Examination of this data set shows that the windier months belong almost exclusively to the winter, with February top of the league. However, August comes a close second with top spot in the summer. Days with mean speeds above 18mph, a threshold representing the upper quintile, can be called windy. Windy days average about 13 each year. Events are most frequent between October and April, with a virtual absence during May to September, although in some years up to three windy days have occurred in May, August and

September. Overall, on average there are two windy days each month. Broadly this reflects the seasonal distribution, with the highest speeds in the winter period.

Since wind is a vector, an assessment of direction is also required. Records for Birmingham exist since the 1930s. The prevailing wind direction is southwest. All in all 45% of hours have winds originating in the southwest quadrant. However, there are some interesting variations. Northeast winds are felt in April and May with a low count during September and October. Continental winds blow (pollution as well) through February at around 12% of the time and again during October at 10% of the time. A combination of both speed and direction for each month is shown in **Figure 3.3**. This shows that the higher speeds have a westerly component with the highest of these from the northwest.

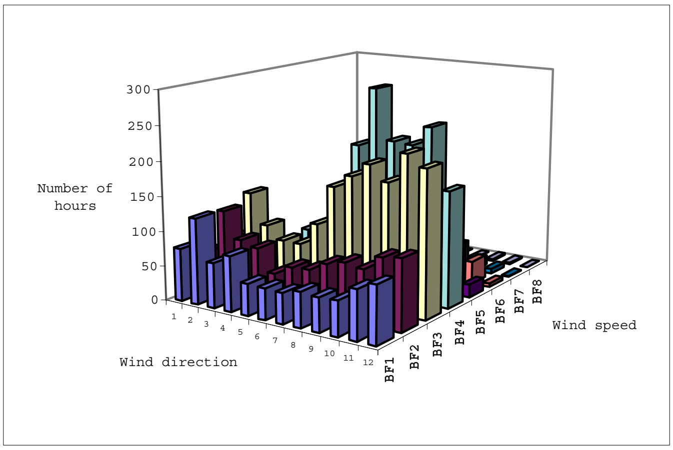
The following points are evident:

- Some 45% of all hours have winds from the SW quadrant (180-270 degrees, numbers 7, 8 and 9 in **Figure 3.3**);
- Winds from each of the SW (210-240 degrees, number 8 in **Figure 3.3**) and NW (300-330 degrees, number 11 in Figure 3.3) account for around 23% of the hours of wind during the year;
- Winds from the NE quadrant (360-090 degrees, numbers 1, 2 and 3 in Figure 3.3) account for nearly 25% of all hours during the year; and
- Whilst there is little seasonal variation in the frequency of SW winds, there is a notable increase in the NE winds during April and May.

3.5.1 Gales

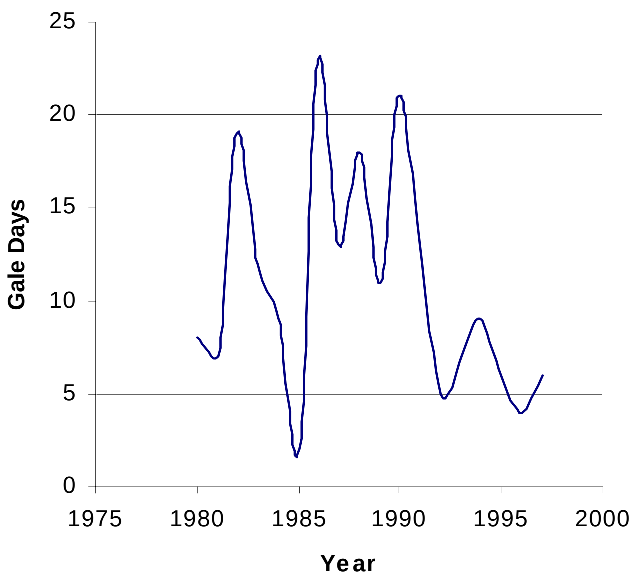
A gale day is defined by the Met Office as a day on which the wind speed at a height of 10m attains a mean value of 34 knots or more over any period of 10 consecutive minutes. The number of gale days in Birmingham has been recorded from 1896 to 1997. The number of gale days was estimated subjectively until 1923 and thereafter using anemometer charts. However, the site changed in 1979 from the Edgbaston Observatory to the top of the Muirhead Tower at the University of Birmingham and this significantly contributed to a step change. Taking the data from 1980-97 (**Figure 3.4**) shows that the number of gale days peaked around the late eighties and early nineties and has declined since. The mean number of gale days 1980-97 is eleven. Since 1997 the wind speed has been measured using an automatic weather station which takes the average wind speed over the 10 minute period before the hour and therefore cannot be used to estimate gale days. Jenkinson and Collinson (1977) developed a method to estimate the number of gale days using pressure gradients across the UK. In the 20th century they estimated a slight downward trend from about 60 per year to about 30 per year in the 1940s, followed by a sharp rise to a peak in 1943 of 78, followed by a decrease to the lowest value of about 14 in 1965. Since then values have risen dramatically to values mostly above 60 per year coinciding with a pronounced westerly phase in the North Atlantic Oscillation.

Figure 3.3 Annual average frequency of wind speed and direction in Birmingham, 1961-1990



(Note in that in **Figure 3.3** the 12 wind directions are: 1=NNE; 2=NE; 3=ENE; 4=ESE; 5=SE; 6=SSE; 7=SSW; 8=SW; 9=WSW; 10=WNW; 11=NW; 12=NNW).

Figure 3.4 Frequency of gale days in Birmingham



3.6 Sunshine

Sunshine is the feel good factor of climate. The West Midlands has several Spa Towns including Ross-on-Wye, Droitwich Spa, Leamington Spa and Malvern. At these Spa locations records of sunshine began during the 1860s. At the turn of the 20th century interest turned to the industrial cities where air quality became an issue and observations of sunshine began in Birmingham and Coventry. **Table 3.10** shows that overall the West Midlands fares reasonably well for sunshine; annual totals vary from nearly 1,300 hours in Staffordshire to more than 1,400 hours further south. The isohel gradient thus runs from highs in the southwest to lows in the north. Monthly totals range from nearly 50 hours in January and December, to 180 hours in June and July. The duller months can have as little as 10 hours during the winter and 90 hours during the summer, whereas the sunnier months can have as high as 80 hours during the winter months and near 300 hours during the summer months. These equate to an average 3.5 hours on a sunny winter day to near 16 hours in the summer.

Table 3.10 Total Monthly Hours of Sunshine in the Midlands, 1961-1990

Station height (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Shawbury (72m)	50	60	100	134	182	179	176	162	124	90	61	44	1363
Keele (179m)	44	58	87	129	179	152	170	161	117	88	59	38	1281
Birmingham (132m)	52	62	102	130	177	182	182	170	134	97	66	47	1401
Malvern (62m)	50	61	107	139	178	185	191	173	134	91	62	45	1415
Ross-on-Wye (67m)	52	63	106	139	175	181	182	167	131	92	65	47	1401

3.7 Cloud

The modal (most frequent) cloud cover is around 70% all year. There is a slight monthly and diurnal deviation from this by around 10%-15%, but overall the West Midlands is definitely cloudy. Low cloud types are most common, accounting for just over 60% of all types present. When visible, medium as well as high cloud indicate the prevailing synoptic influence of daily weather in the region. Convective cellular clouds show both seasonal and diurnal variation tending to occur mostly on summer afternoons.

Interestingly up to 20% of mornings are cloud free, most in March (24%) and least in September (9%). Both medium cloud and high cloud often go unreported since they are usually obscured by a lower layer. Consequently their frequency remains generally constant during the year at around 30%. Similarly, high clouds are noted throughout the year at 0900h resulting in a red sky in the morning.

3.8 Visibility

Visibility is determined by a number of factors:

- Air mass type;
- Season;
- Humidity;
- Wind speed and direction; and
- Pollution sources, both local and imported.

For climatological purposes the reported visibility at 0900h each day is taken as being representative of the day. It is also at this hour that days with fog are counted. However, visibility is essentially a continuously varying parameter and as such average figures are not representative. Consequently detailed statistics are not available. In general the modal (the most frequently occurring) visibility is 5-20km, that is moderate/good throughout the year. However, the poorest visibility will occur:

- generally through the winter months with the higher humidity, and frequency of mist/fog; and
- with prevailing wind direction from the east, usually during the spring months, associated with anticyclonic conditions and a temperature inversion. It is also under these conditions that local and imported pollutants contribute to poor air quality.

The best visibility (in excess of 35km) often occurs with northwest winds under unstable conditions after rain when the air has been washed clean.

3.9 Humidity

Humidity is a measure of the moisture content of the atmosphere, and is expressed in several ways:

- Vapour pressure (mb) - the pressure due to the amount of water vapour in the atmosphere; and
- Relative humidity (%) - the amount of water vapour in the air compared with the amount of water vapour needed to make the air saturated at the air's current temperature.

Humidity is temperature dependent, and varies continuously. Overall the higher values will occur during the winter months and during the mornings, the lower values during the summer months and during the afternoons. **Table 3.11** gives monthly averages of vapour pressure and relative humidity along with the average 0900h and 1500h air temperature. Data for 0900h corresponds to the highest values of relative humidity and that for 1500h corresponds to the lowest values, given a typical diurnal variation. The vapour pressure is similar at these times throughout the day. The mean relative humidity for the year at 0900h is 83% and at 1500h is 70%, whereas the vapour pressure is the same at 9.6mb.

Table 3.11 Monthly Averages of Humidity in Birmingham, 1961-1990

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
0900hrs													
Air temp.	3	2	4	7	11	14	15	14	13	10	5	3	8
Vap pres	6.9	6.6	6.9	8.2	9.6	11.8	13.0	13.3	12.5	11.0	8.1	7.0	9.6
Rel hum	90	88	83	80	75	75	77	81	84	89	90	90	83
1500hrs													
Air temp	5	5	8	11	15	18	19	19	16	13	8	5	13
Vap pres	7.1	6.7	6.9	8.1	9.5	11.9	12.9	12.9	12.2	11.1	8.4	7.2	9.6
Rel hum	82	76	66	64	61	60	62	63	66	73	80	83	70

3.10 Urban Heat Island

The built up areas of the West Midlands exhibit urban heat islands, in other words the cities tend to be warmer than the surrounding rural areas. Several studies have examined Birmingham's heat island (Unwin 1980, Johnson 1985 and Bradley et. al. 2001, 2002). **Figure 3.5** shows a cross section of Birmingham's heat island predicted for December 21st at 0100h using an energy balance model (Bradley et. al. 2002). The city centre is predicted to be 4.62^{o}C warmer than the rural surrounds. The urban heat island develops most distinctly on calm clear anticyclonic nights in early autumn and Unwin found that for 3,652 nights over 10 years (1965-1974) the mean heat island was 1.7^{o}C with a maximum recorded of 10^{o}C. The mean for all anticyclonic nights was 2.26^{o}C but was typically 5^{o}C in settled anticyclonic conditions. Unwin also showed the existence of a daytime 'cool' island when the city centre could be cooler than surrounding rural areas. Johnson (1985) and Bradley et al. (2001, 2002) show that the heating and cooling of the urban and rural areas relates to the sky view factor - that is the amount of sky visible from the ground. The sky view factor controls the radiation balance at the surface. A sky view factor of 1.0 means that the sky is completely open, and a sky view factor of zero means that the sky is completely obsured (e.g. in a tunnel). In the city centre where there are tall buildings the sky view factor is reduced as shown in **Figure 3.6**. **Figure 3.7** shows how the sky view factor varies across an industrial part of Birmingham over a distance of about 1.5km.

Figure 3.5 Cross section through Birmingham city centre (5 km grid) heat island

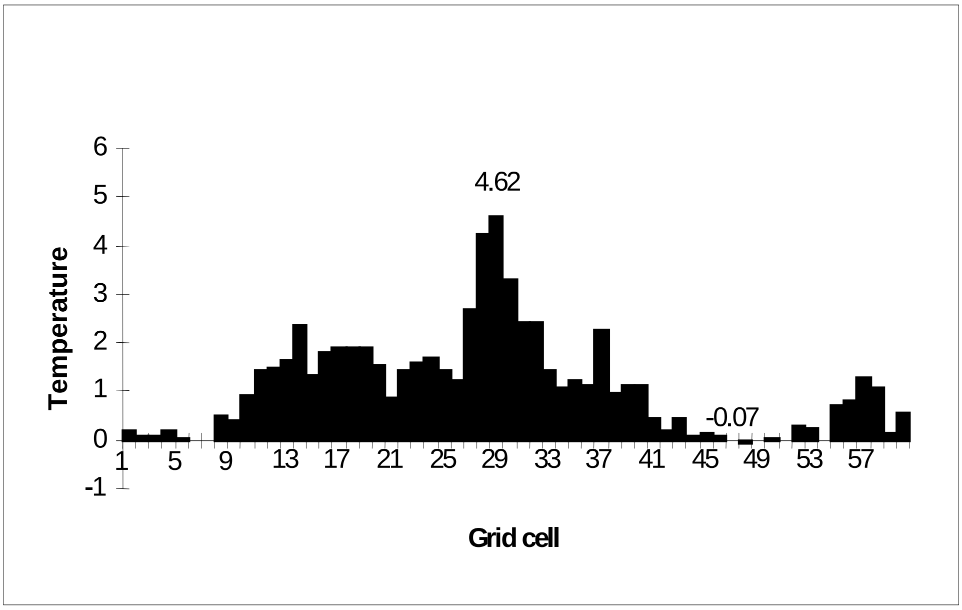
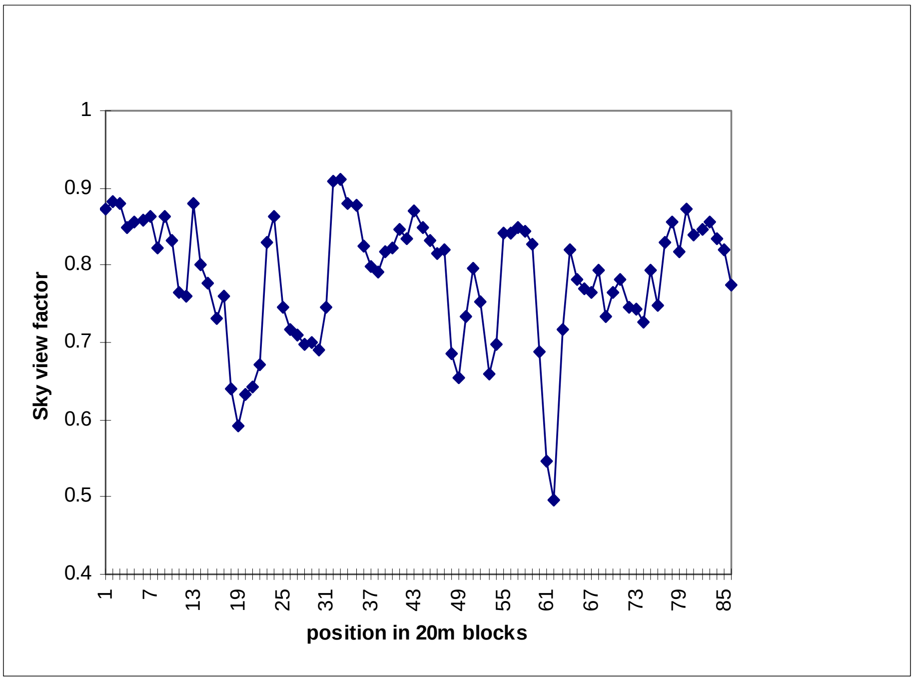


Figure 3.6 A sky view factor image of Birmingham city centre

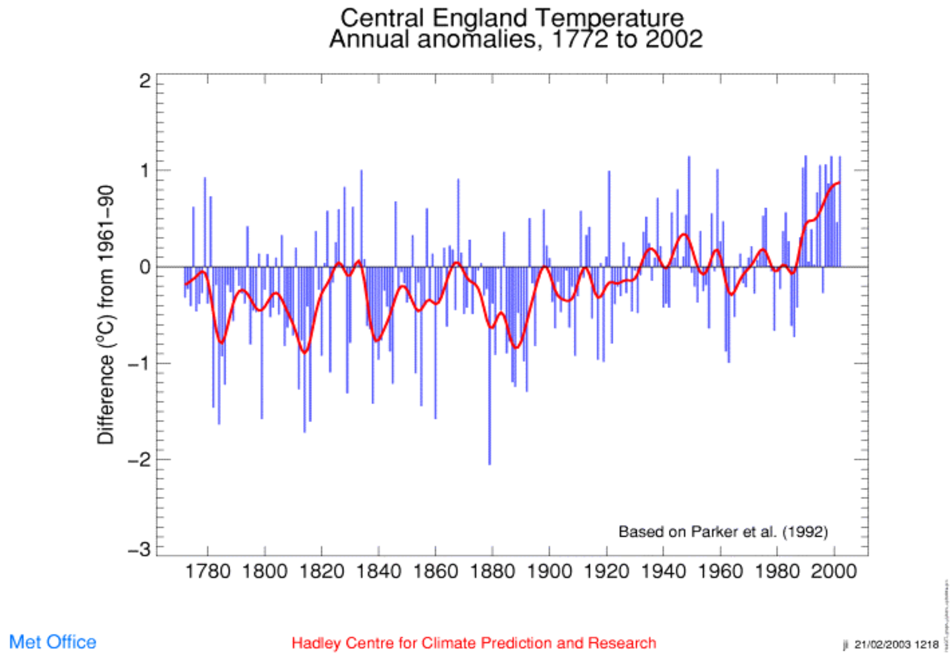
Figure 3.7 Variations in sky view factor in an industrial part of Birmingham



3.11 The Central England Temperature

In addition to the long-term stations mentioned, the region is also the home of the Central England Temperature (CET) series developed by Manley (Manley, 1953). The CET is meant to be representative of a triangular area with Preston, Bristol and London at each vertex, and comprising the lowland area to the west and south of the Birmingham Plateau. Indeed it is the CET that has been used extensively to show the warming that has taken place since 1772 especially in the 20th century in England as shown in **Figure 3.8**.

Figure 3.8 Central England Temperature Annual Anomalies 1772-2002



The Central England Temperature (CET) series is the longest instrumental climate record in the world. The monthly catalogue extends back to 1659 and provides a unique insight to climate variability in the UK (Manley, 1953; 1974; Parker et al., 1992). Although the CET record describes temperature changes in the West Midlands it is untarnished by urban heat island effects. **Figure 3.8** shows the CET temperature changes relative to 1961-90. During the 20th century annual mean temperatures showed a warming of +0.6ºC, with six of the warmest years in the 20th century occurring since 1989: 1999, 1990, 1997, 1995, 1989 and 1998. Relative to 1961-90 all these years were between 0.9ºC and 1.2ºC warmer than average. The years 1994 and 2000 were also unusually warm with anomalies close to +0.8ºC. Within the year, warming has been greatest from mid-summer to late autumn: July (+ 0.8ºC), August (+ 1.2ºC), September (+0.9ºC), October (+ 1.2ºC) and November (+1.3ºC) respectively.

The daily CET series has been used to investigate the annual frequency of days classified as 'hot' (mean temperature above 20ºC) or 'cold' (mean below 0ºC) since 1772 (Hulme and Jenkins, 1998). Since the 18th century, the number of cold days has fallen from around 15-20 per year to around 10 per year presently. Most of this change occurred prior to the 20th century and is, therefore, probably unrelated to human influences on climate and is more related to the climate warming after the 'Little Ice Age'. At the same time, there has been an imperceptible rise in the frequency of hot days in the 20th century, despite 1976, 1983, 1995 and 1997 returning some of the highest frequencies of such days. The daily CET series also indicates that the growing season for plants has increased by about 30 days since 1900 (Mitchell and Hulme, 2002), and that central England presently enjoys longer frost-free spells than at any time during the pre-industrial era (Wilby, 2001).

3.12 Summary

The preceding sections provide a review of the recent trends and changes in the baseline climate of the West Midlands, focusing on Birmingham. The benchmarks, summarised in **Table 3.12**, form the basis for subsequent discussions of future climate scenarios and potential environmental impacts facing the West Midlands region.

Table 3.12 Key Climate Trends in the West Midlands

Climate indicators	Recent trend
Air temperature	Annual average temperature has risen by +0.6ºC since 1900's
	Several of the warmest years on record have occurred since 1989
	Most rapid warming in period July to November
	Fewer 'cold' days and longer frost free season
	Growing season has increased by 30 days since the 1900s
	Nocturnal urban heat island intensifying
Rainfall	Decreasing summer rainfall since 1880's
	Increasing winter rainfall over last 150-200 years
	Two of three driest summers were 1995 (1st), 1976 (3rd)
	Two of three wettest winters were 1989/90 (2nd), 1994/95 (3rd)
	More winter rain days and longer wet-spells since 1960's
	Heavy storms have contributed more to winter rainfall totals since 1960's
	Lighter, more frequent summer storms
Snowfall	Fewer snowfall events and smaller snowfalls since 1960's
Gales	Record wind speeds in 1987 and 1990
	No long-term trend but cluster of severe gales in the 1990's
Evaporation and relative humidity	Increases in potential evaporation in all seasons but especially spring and autumn
	Decline in summer relative humidity since 1920's

In summary the current baseline (1961-90) climate of Birmingham (taken as a representative of the West Midlands) is as follows:

- Annual Mean Temperature 9.4^{o}C
- Mean Maximum Temperature 12.5^{o}C
- Mean Minimum Temperature 6.3^{o}C
- Mean number of Frost Days 36
- Mean Annual Rainfall 767mm

• Mean Number of Rain Days	180
• Mean Number of Snow Days	30
• Mean Number of Snow Lying Days	18
• Mean Daily Wind Speed	9 mph
• Mean Number of Windy Days	13
• Mean Number of Gale Days	11
• Modal Cloud Cover	70% (5 or 6 octas)
• Mean Vapour Pressure	9.6 mb
• Mean Relative Humidity 0900hr	83%
• Mean Relative Humidity 1500hr	70%

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4. Future Climate Of The West Midlands

4.1 Introduction

Climate model projections of future global-mean temperature and sea level change depend on future estimates of greenhouse-gas and sulphate aerosol emissions. In 2000, the IPCC approved a new set of emission scenarios to update and replace the IS92 scenarios used in the IPCC Second Assessment Report. The new scenarios, presented in the IPCC *Special Report on Emission Scenarios* (SRES), have much lower emissions of sulphur dioxide than the IS92 scenarios. Although the scenarios cover a total of 40 future demographic, economic and technological 'storylines', just four marker scenarios have received most attention within the scientific community (**Table 4.1**). It is not possible to attach probabilities to any of the SRES scenarios; they are all plausible descriptions of socio-economic trends that could affect future emissions of greenhouse gases.

Table 4.2 summarises the key features of observed and projected climate changes presented in the *Summary for Policymakers' Report* (IPCC, 2001a).

Table 4.3 (IPPC, 2001a) focuses on extreme events and the levels of confidence attached to observed global trends and model projections.

Table 4.1 SRES storylines used by the IPCC for future greenhouse gas emission scenarios

Scenario	Outline
A1F1 (High)	Very rapid economic growth, a global population that peaks in mid-21st century and thereafter declines, and the rapid introduction of new and efficient technologies. The scenario also envisages increased cultural and social interaction, with a convergence of regional per capita income.
A2 (Medium-High)	A very heterogeneous world, characterised by self-reliance and preservation of local identities. Population continues to grow but economic growth and technological change are slower than other storylines.
B2 (Medium-Low)	A world with lower population growth than A2, accompanied by intermediate levels of economic development, with less rapid and more diverse technological change than in B1 and A1.
B1 (Low)	The same population dynamics as A1, but a transition toward service and information economies, with lower material consumption and widespread introduction of clean and efficient technologies.

Table 4.2 Observed and projected changes in the climate system

Temperature

The global average surface temperature has increased by 0.6 ± 0.2ºC since 1861, although most of the warming occurred during two periods, 1910 to 1945 and 1976 to 2000.

Globally, it is likely that the 1990s was the warmest decade and 1998 the warmest year in the instrumental record, since 1861.

Proxy data for the Northern Hemisphere indicate that the increase in temperature in the 20th century is likely to have been the largest of any century during the past 1000 years.

Between 1950 and 1993 night-time daily minimum temperatures over land increased by about 0.2ºC per decade (about twice the rate of increase in daytime daily maximum air temperatures).

Since 1950 it is very likely that there has been a reduction in the frequency of extreme low temperatures, with a smaller increase in the frequency of extreme high temperatures.

Globally averaged surface temperature is projected to increase by 1.4 to 5.8ºC over the period 1990 to 2100.

Precipitation

It is very likely that precipitation has increased by 0.5 to 1% per decade in the 20th century over most mid- and high-latitudes of the Northern Hemisphere continents.

It is likely that there has been a 2 to 4% increase in the frequency of heavy precipitation events in the latter half of the 20th century over mid- and high-latitudes of the Northern Hemisphere.

Over the 20th century (1900 to 1995), there were relatively small increases in global land areas experiencing severe drought or severe wetness.

There has been a 2% increase in cloud cover over mid- to high-latitude land areas during the 20th century.

Northern Hemisphere snow cover and sea-ice extent area projected to decrease further.

Global water vapour concentration and precipitation are projected to increase during the 21st century.

Larger year to year variations in precipitation are very likely over most areas where an increase in mean precipitation is projected.

No systematic changes in the frequency of tornadoes, thunder days, or hail events are evident in the limited areas analysed.

Sea level

Global sea level is projected to rise by 0.09 to 0.88 metres between 1990 and 2100, for the full range of SRES scenarios.

Table 4.3 Estimates of confidence for selected observed and projected changes in extreme weather and climate events

Changes in phenomenon	Confidence* in observed changes (latter half of 20th century)	Confidence* in projected changes (during the 21st century)
Higher maximum temperatures and more hot days over nearly all land areas	Likely	Very likely
Higher minimum temperatures, fewer cold days and frost days over nearly all land areas	Very likely	Very likely
Reduced diurnal temperature range over most land areas	Very likely	Very likely
Increase of heat index over land areas	Likely, over many areas	Very likely, over most areas
More intense precipitation events	Likely, over many northern hemisphere land areas	Very likely, over many areas
Increased summer continental drying and associated risk of drought	Likely, in a few areas	Likely, over most mid-latitude continental interiors

* IPCC qualitative classification of confidence levels: Likely (66 to 90%), Very likely (90 to 99%)

4.2 Climate Change Scenarios for the UK and The West Midlands

Since the publication of the UKCIP98 scenarios (Hulme and Jenkins, 1998), significant advances in computing power have enabled a greater number of climate model experiments to be conducted at higher spatial resolutions. The Hadley Centre global climate model (HadCM3) was used to drive a high resolution atmospheric model (HadAM3H) and, in turn, a regional climate model (HadRM3) for Europe. These experiments resulted in the development of the UKCIP02 scenarios (Hulme et al., 2002) which describe how the climate of the UK land area may change in the 21st century at a resolution of 50 km (as opposed to the 300 km resolution of UKCIP98). The new scenarios also provide more information about changes in extremes of weather and sea level, and are explicitly linked to the four SRES storylines described in **Table 4.1** (B1~**Low Emissions**, B2~**Medium-Low Emissions**, A2~**Medium-High Emissions**, A1F1~**High Emissions**). In contrast, the UKCIP98 scenarios were based on much simpler descriptions of future population and fossil fuel use. Since these changes derive from a higher resolution model that simulates UK weather better than the global model used for this purpose in 1998, we have more confidence in the results of this report than those in the 1998 report.

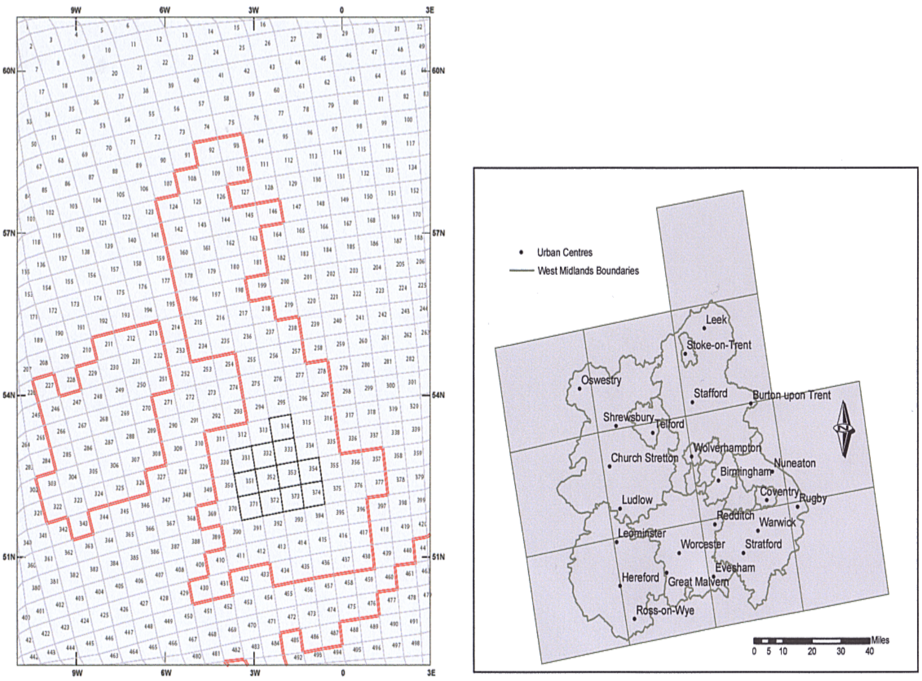
Despite these advances, the UKCIP98 and UKCIP02 scenarios (**Table 4.4**, Hulme et al., 2002) are qualitatively very similar. The main differences in UKCIP02 are: a) slightly higher warming rates over the UK; b) smaller rates of sea level rise; c) summers are now projected to become drier over the *whole* UK, and by a larger amount; d) changes in the patterns of average wind speed; e) less marked increase in the frequency of heavy rainfall days; and f) slight reduction in precipitation in spring and autumn.

Table 4.4 Summary of results presented in the UKCIP02 Scientific Report

- The UK climate is expected to become warmer by between 0.5°C and 3ºC by the 2050s and by 1°C to 5.0ºC by the 2080s.
- Higher summer temperatures could become more frequent and very cold winters could become increasingly rare.
- Winters are likely to become wetter and summers may become drier everywhere.
- Summer soil moisture may be reduced by 40% or more over large parts of England by the 2080s.
- Daily maximum temperatures of 33ºC, which occur about 1 day per summer in the south-east, could occur 10 days per summer by the 2080s.
- Snowfall amounts are expected to decrease throughout the UK.
- Heavy winter precipitation might become more frequent.
- Relative sea level could continue to rise around most of the UK's shoreline.
- Extreme sea levels might be higher and be experienced more frequently, although uncertainties in modelling such changes remain very large.
- The Gulf Stream may weaken in the future, but it is unlikely that this weakening would lead to a cooling of UK climate within the next 100 years.
- In central Birmingham the urban heat island effect could add a further 3 to 4ºC to temperatures during summer nights.

Figure 4.1 shows the grid boxes used for the West Midlands and the county boundaries and main towns. Projected changes in temperature, precipitation, cloud cover, relative humidity and average wind speed for the West Midlands are given in **Figures 4.2 - 4.6**. Changes are all with respect to the mean 1961-1990 climate, for the UKCIP02 **Low Emissions** and **High Emissions** scenarios respectively. These figures indicate possible climate changes for the 2020s, 2050s and 2080s. Each of these periods relates to an average over thirty years. For example, expected changes in the 2020s are the average of changes modelled for the period 2011-2030. Similarly, the 2050s relate to the average of the period 2041-2070, and the 2080s to the average from 2071-2100. The scenarios presented in **Figures 4.2 - 4.6** should be regarded only as indicative because the regional climate model treats the West Midlands as a vegetated surface.

Figure 4.1 Location of the West Midlands UKCIP02 50km tiles with respect to a) the UK and b) West Midland county/unity boundaries and urban centres



4.2.1 Estimated mean temperature changes

Figure 4.2 shows that by the 2080s the annual mean temperature is expected to be between 1.5°C and 4.5°C warmer than the 9.4°C (Birmingham) it is today (1961-90). **Table 4.5** shows how dramatic these changes could be in comparison to the last 200 years in Birmingham where the temperature has not varied by more than 0.4°C over any 30 year period.

Figure 4.2 Daily Mean Temperature Anomalies

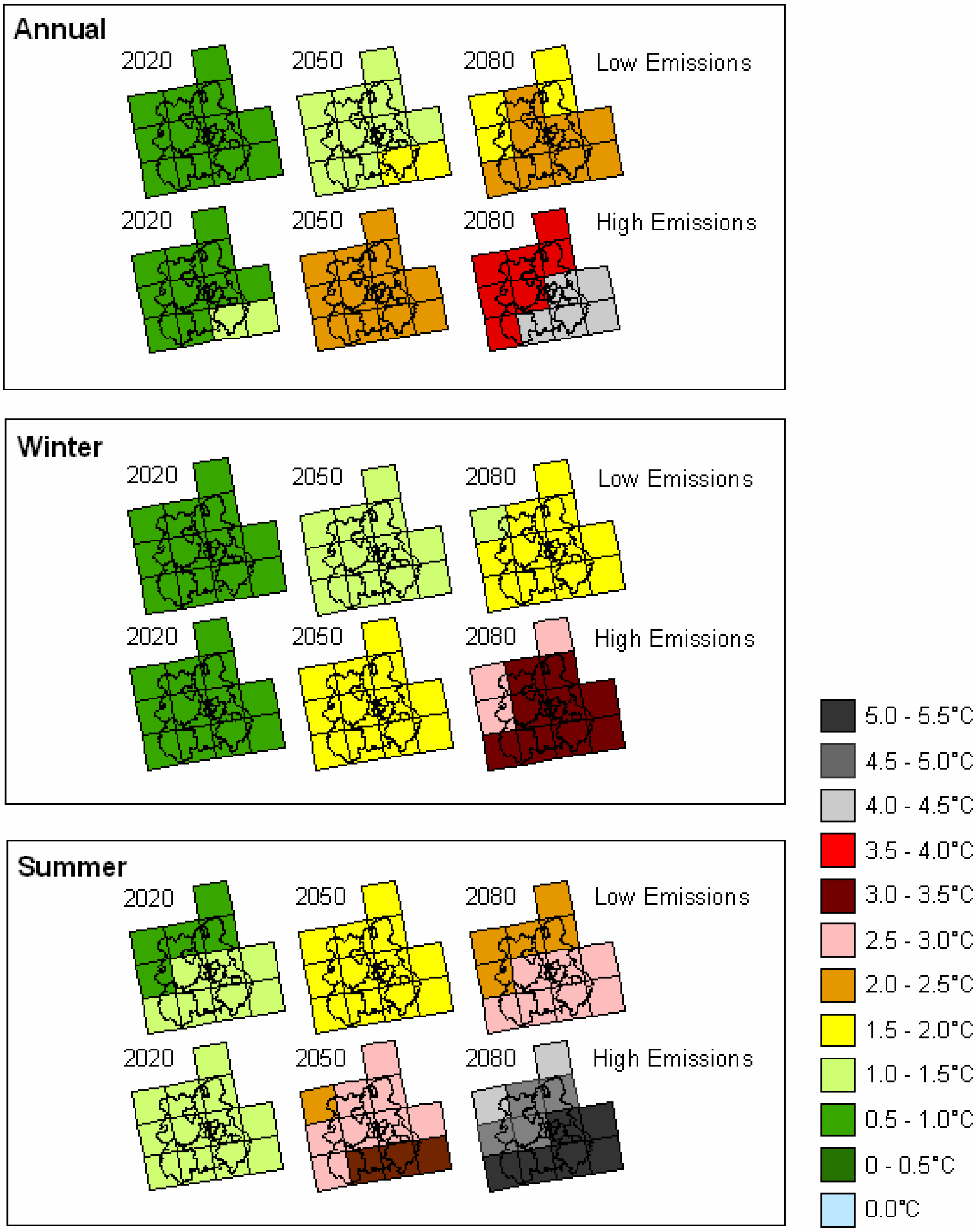


Table 4.5 Estimated Warming of the Annual Mean Temperature

	Mean annual temperature	Difference in mean temperature from 1961-1990 mean	Range of difference under high and low emissions scenarios
1811-1840	9.0	-0.4	
1841-1870	9.2	-0.2	
1871-1900	9.2	-0.2	
1901-1930	9.2	-0.2	
1931-1960	9.6	+0.2	
1961-1990	9.4	+0.0	
1991-2010*	9.7	+0.3	
2011-2040	10.4	+1.0	+0.5 to +1.5
2041-2070	11.2	+1.8	+1.0 to +2.5
2071-2100	12.4	+3.0	+1.5 to +4.5

* Note that the period 1991-2010 is only 20 years and these figures are estimates

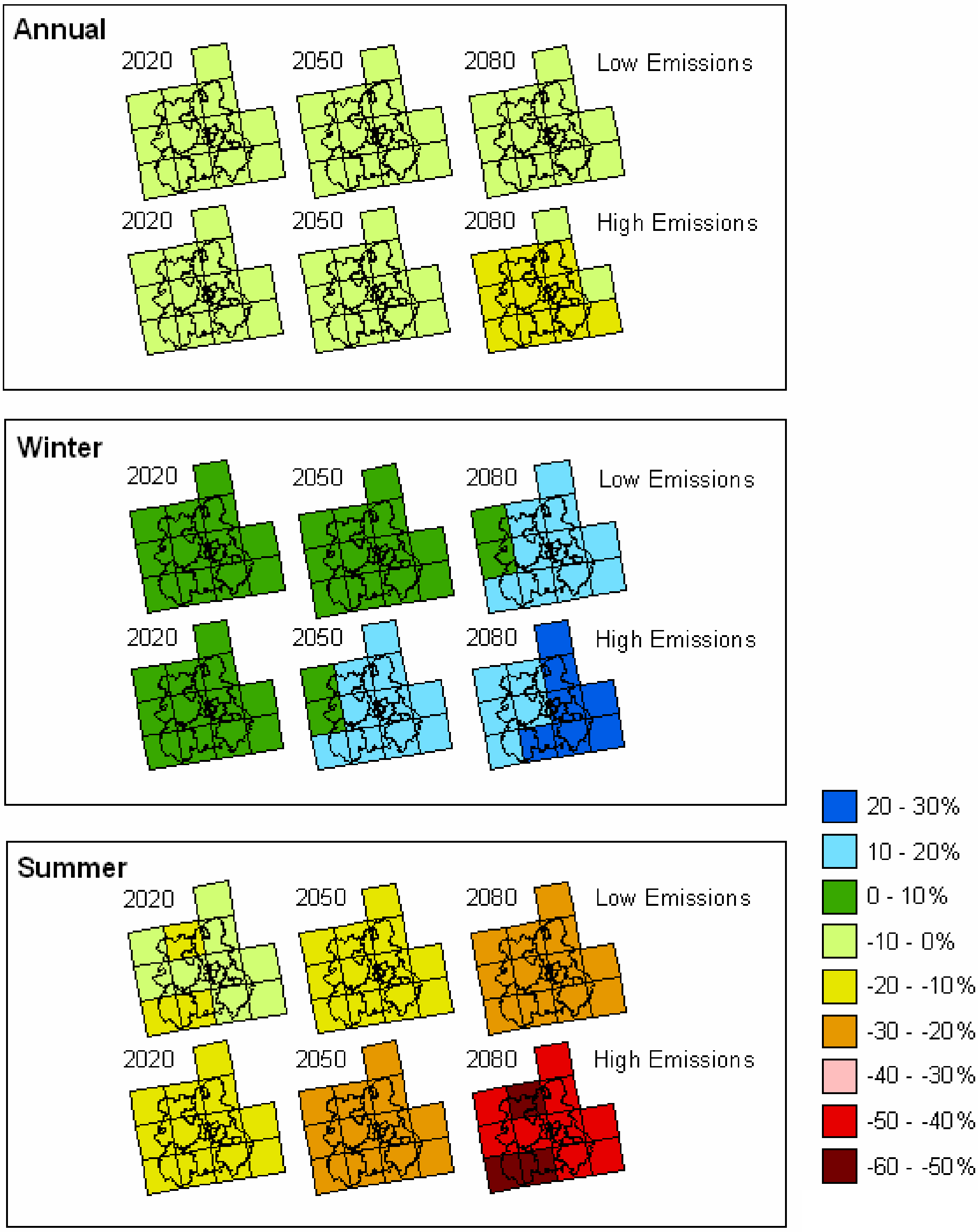
Most of the warming is expected to take place in summer although winters are also expected to be significantly warmer. There is a temperature gradient shown such that Warwickshire and the south east of the region is expected to warm up more than Shropshire and the north east of the region. Annual rates of warming vary from 0.1^{o}C to 0.3^{o}C per decade for the Low Emissions scenario to 0.3^{o}C to 0.5^{o}C per decade for the High Emissions scenario.

4.2.2 Estimated mean precipitation changes

The estimated mean annual precipitation changes by the 2050s are less than 10% for all scenarios. However, this hides a dramatic anticipated change in seasonal precipitation. **Figure 4.3** shows that winter precipitation might increase by between 0% and 10% by the 2020s and between 0% and 20% by the 2050s. On the other hand, summer precipitation might decrease by between 0% and 20% by the 2020s and between 10% and 30% by the 2050s. Again there is a estimated gradient with the south east of the region likely to have the greatest increase in winter and the greatest decrease in summer. **Table 3.5** showed that Keele in the north west of the region receives 795mm of rain on average whereas Stratford-on-Avon receives on average only 616mm of rain per annum. This means that Keele receives almost 30% more precipitation than Stratford-on-Avon. The estimated changes are therefore of a similar magnitude to the current variations the region. The anticipated winter changes would tend to even out the rainfall across the region whereas the summer changes would be similar across the whole region.

Although the amount of precipitation is estimated to increase in winter, because of the warmer temperatures the amount of snowfall is likely to decrease significantly. Reductions by as much as 50% to 90% are possible by the 2080s.

Figure 4.3 Daily Mean Precipitation Anomalies



4.2.3 Estimated mean cloud cover changes

In line with the expected changes in precipitation and temperature, **Figure 4.4** shows that cloud cover could decline slightly overall (between 0% and 6% by the 2050s) with a small increase of up to 2% in winter and a larger reduction of up to 10% in summer. Again the biggest changes are likely to be in the south east of the region. These changes would increase the amount of sunshine especially in the south east of the region.

4.2.4 Estimated mean relative humidity changes

Figure 4.5 shows that the relative humidity changes are closely related to the predicted temperature changes. Overall the mean relative humidity could decline by a small amount in winter (up to -2%) and decline much more in summer (between 0% and 4% by the 2020s and between 2% and 8% by the 2050s) as the air temperature is predicted to increase. This may lead to a reduction in the number of fogs.

4.2.5 Estimated daily mean 10m wind speed changes

Figure 4.6 shows that the mean daily wind speed is not expected to change very much over the year but winter mean wind is likely to increase by up to 2% by the 2020s and up to 4% by the 2050s. Summer mean wind speed is estimated to stay the same (+/- 1%). However, it must be noted that there are low levels of confidence in the modelled wind speeds (Hulme et al., 2002).

4.2.6 Estimated changes in soil moisture

Figure 4.7 shows that the predicted changes in soil moisture are quite dramatic. Soil moisture is a function of temperature, precipitation, humidity, sunshine and wind speed. Overall in summer the region could be drier and warmer and hence soil moisture would fall by up to 15% by the 2020s and between 5% and 35% by the 2050s. In winter However, the increased precipitation would lead to higher soil moisture levels and the increased probability of flooding.

4.2.7 Future changes in other climate variables

In addition to the variables discussed above, which were modelled in the UKCIP02 scenarios, the UKCIP02 Scientific Report (Hulme et al., 2002) also indicated potential changes in a number of other variables using information contained in the models. Information on depression tracks, lightning and fog is summarised below.

Depression tracks (storms associated with high winds) are estimated to increase in frequency during an average winter from five (in the baseline period 1961-1990) to eight (by the 2080s) under the Medium-High emissions scenario. This is largely due to the current pattern of depressions moving south across the country. However, the average number of depressions during summer could fall from five to four per season. The frequency of depressions during autumn and spring is not expected to change. However, it should be noted that confidence in estimates of the number of depressions is low, and therefore analysis based on these effects should be treated with caution.

The frequency and severity of lightning was estimated using information on the velocity of updrafts. This suggested that during summer, the season when lightning is most prevalent, the peak lightning flash rate could increase significantly under the Medium-High emissions scenario. This increase is expected to be most pronounced in the south-west, where the flash rate could double by the 2080s.

Figure 4.4 Daily Mean Cloud Cover Anomalies

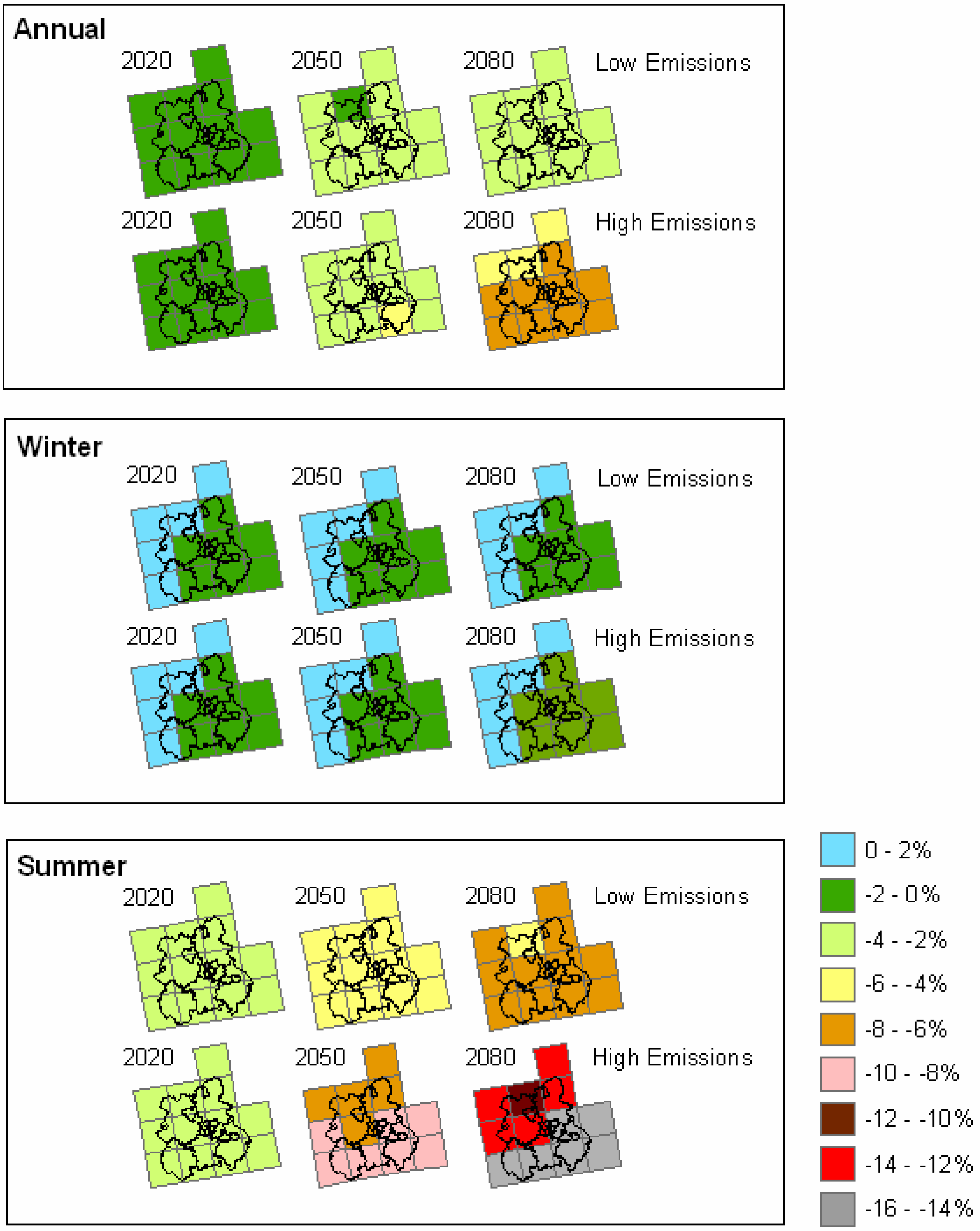


Figure 4.5 Daily Mean Relative Humidity Anomalies

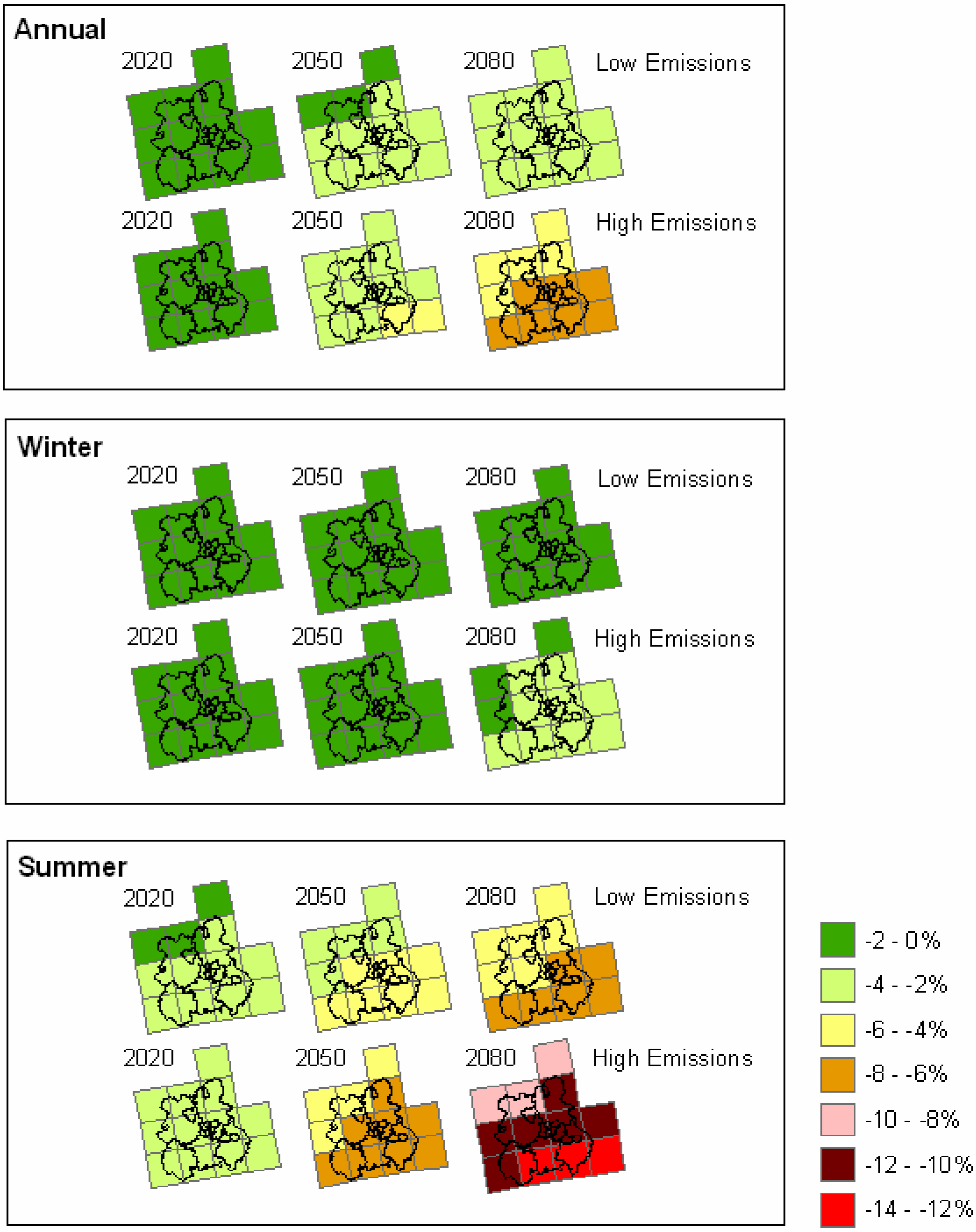


Figure 4.6 **Daily Mean Wind Speed Anomalies at 10m**

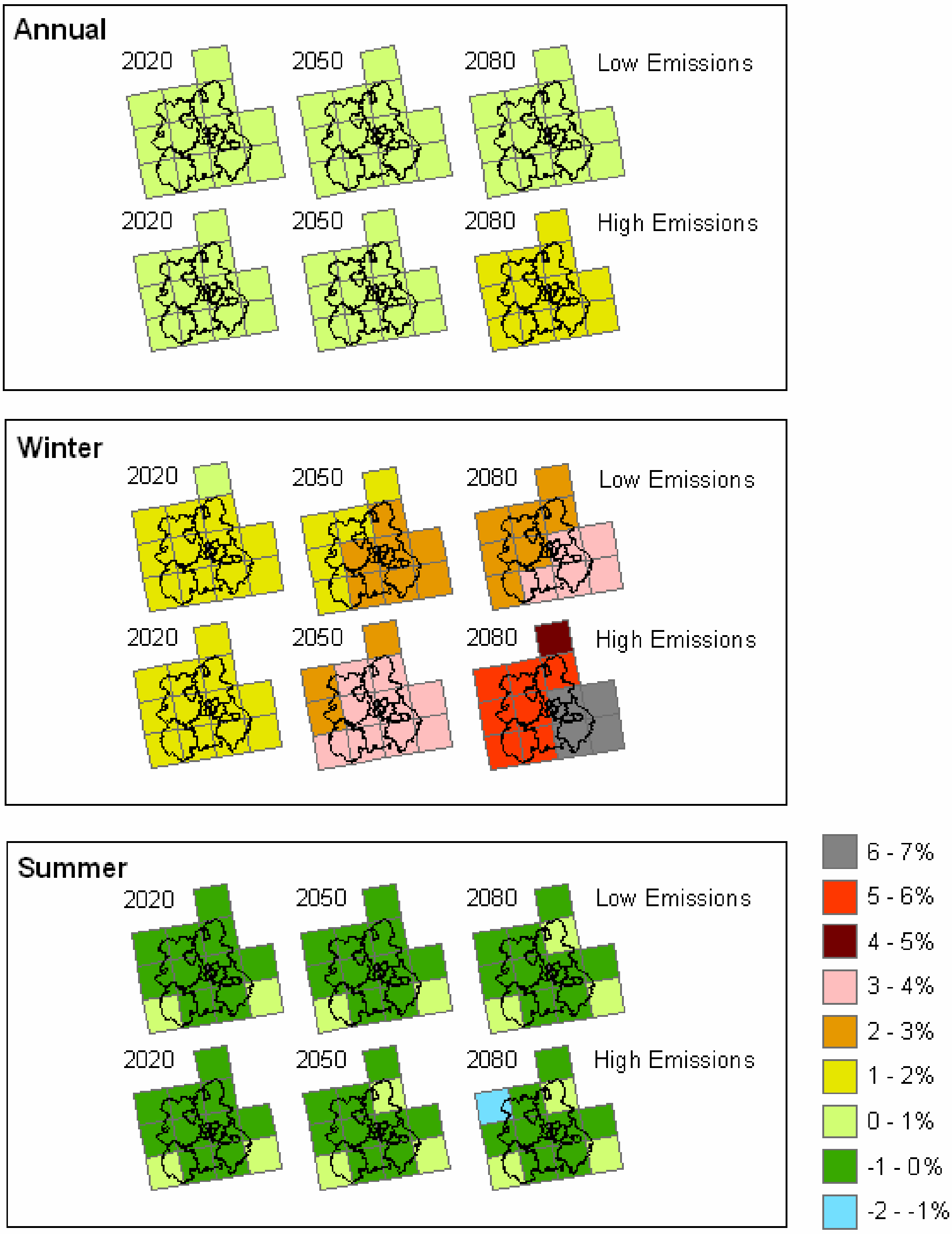
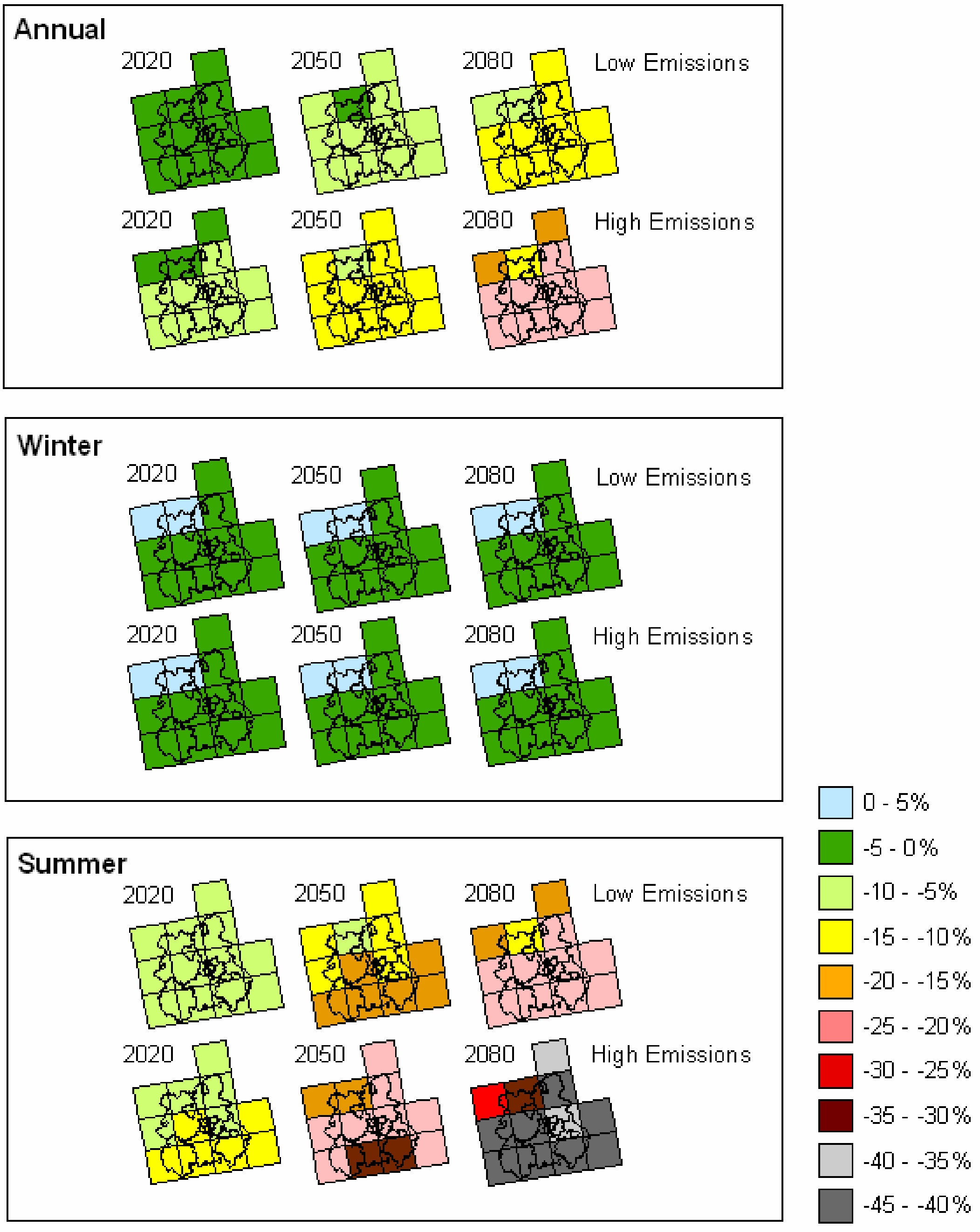


Figure 4.7 Daily Mean Soil Moisture Anomalies



However, it was also estimated that the number of thunderstorms could halve under the same scenario by the 2080s. Therefore, little overall change in the overall number of lightning strikes would be expected.

The number of days with fog was estimated using predicted changes in relative humidity (see Section 4.2.4). This suggested that by the 2080s there could be a reduction of about 20% in the number of days with fog under the Medium-High emissions scenario.

4.3 Climate Change Analogues

The future weather will continue to display much natural year-to-year and decade-to-decade variability. Indeed, for some aspects of climate, such as precipitation, natural variations are expected to be greater than changes due to increased greenhouse gas emissions until the second half of the 21st century. One approach to visualising future probabilities of selected seasonal climate extremes is to describe their occurrence with reference to events in the past. **Table 4.6** (Hulme et al., 2002) compares the predicted scenario data with actual events that happened in the 1990s. Climate change analogues are thus constructed by identifying climate records that could typify the future climate of the region. A major advantage of the approach is that the future climate scenario (and accompanying environmental impacts) may be described in far greater temporal and spatial detail than might otherwise be possible (see Subak et al., 1999). For example, the hot/dry summer of 1995 and the wet winter of 1994/95, provide useful analogues of the projected climate of the 2050s. **Table 4.6** shows the predicted percentage of years in which climatic events similar to those recently experienced could occur. Thus, by the 2050s, the ‘1995-type’ summer might be expected to occur in one year out of five (20%), and by the 2080s, nearly two in every three years (63%).

Table 4.6 Percentage of years in which England and Wales could experience different climate change analogues under the Medium-High emissions scenario

Analogue	Anomaly	2020s	2050s	2080s
A hot ‘1995-type’ August	3.4ºC warmer	1	20	63
A warm ‘1999-type’ year	1.2ºC warmer	28	73	100
A dry ‘1995-type’ summer	37% drier	10	29	50
A wet ‘1994/95-type’ winter	66% wetter	1	3	7

The anomalies shown are relative to the average 1961-1990 climate

Another way of expressing likely changes in climate is to examine the predicted alterations to the probability of daily extremes. For example the maximum daily precipitation could increase by more than 20% in winter by the 2080s. Currently there is a 1% chance of a summer day reaching 33^{o}C; by the 2080s, 1% of summer days could reach temperatures as high as 40^{o}C (Hulme et al., 2002).

4.4 Key Uncertainties

There are a large number of scientific uncertainties concerning the future behaviour of emitted greenhouse gases, the significance of aerosols and soot particles, carbon-cycle feedbacks and ocean responses to greenhouse gas forcing. Different global and regional climate models will, therefore, produce different results depending on the treatment of these factors. The HadCM3 model produces rainfall changes close to the model range for winter, but simulates a larger reduction in summer rain than most models. Such inter-model differences over the UK may be expressed as uncertainty margins to be applied to the UKCIP02 scenarios of change in temperature and precipitation (**Table 4.7**, Hulme et al., 2002).

Table 4.7 Suggested uncertainty margins to be applied to the UKCIP02 scenarios of changes in average winter and summer temperature and precipitation

	Low Emissions	Medium-Low Emissions	Medium-High Emissions	High Emissions
Average Temperature				
Winter (ºC)	±0.5	±1.0	±1.5	±2.0
Summer (ºC)	±0.5	±1.0	±1.5	±2.0
Average Precipitation				
Winter (%)	±5	±10	±15	±20
Summer (%)	+10	+15	+30	+40

Note: all summer rainfall sensitivities are positive because UKCIP02 summer rainfall changes are already considered to be at the drier end of the inter-model range

For example, one source of uncertainty relates to the north Atlantic Gulf Stream. Most climate models, including HadCM3, suggest a weakening (but not a shut-down) of the Gulf Stream over the next 100 years. However, changes in the salinity and temperature profile of north Atlantic surface waters could in theory lead to a cooling of UK climate over the next 100 years because of a weakening of the Gulf Stream. Although this is considered unlikely, it can not be completely ruled out. However, this could be more than compensated for by a warming over the UK.

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5. Potential Sectoral Impacts of Climate Change

5.1 Updating the Pre-Scoping Report

This study builds on a previous pre-scoping study in the West Midlands, which provided an overview of the potential impacts of climate change in the region (West Midlands Climate Change Impacts Study, 2001). The pre-scoping study considered the potential impacts of climate change on fifteen sectors, including the natural environment (e.g. biodiversity, natural resources, flooding) and business groups defined by Advantage West Midlands. There is a short summary for each sector in the main body of the pre-scoping report, followed by a qualitative inventory of potential impacts, both positive and negative. This section outlines some of the issues identified by the authors of the pre-scoping report. The complete report is included as **Appendix G**.

5.1.1 Issues Identified in the Pre-Scoping Report

Creative Industries
The creative industries include telecommunications, IT, the media, marketing and advertising. The sector faces potential damage from subsidence and wind storms to telecom infrastructure. Changes in technologies, particularly those that alter the energy use of the sector, could contribute to climate change or offer an opportunity for mitigation. For example, teleconferences and technologies to support home working could reduce the need to travel. As well as their own issues, the sector could also be seen as a resource that could be used by other sectors in developing adaptation and mitigation strategies. This could offer opportunities for the creative industries in new markets to support other sectors.

Built Environment
Climate change could affect the costs of construction through disruption from winter flooding and high winds. An increase in extreme weather events could also increase the repair and maintenance costs for property owners, particularly those with historic buildings. These buildings and the associated infrastructure could be at risk of flooding in the winter and subsidence in the summer. Design standards and health and safety legislation may change in response to changing risks, particularly if the properties of building materials are affected. Use of energy in buildings may also change, with lower demand for winter heating, but higher use of cooling units in the summer. Windows left open in the summer to improve ventilation may increase the noise in the building and could increase the risk of burglary.

Ceramics
The greatest impacts on the ceramics industries could arise from changes in the lifestyle of those living in the West Midlands. There could be greater use of ceramics for internal and external floors to improve cooling in summer, and also for use in photovoltaic cells if there is a move towards use of solar energy. However, there could be changes in the transport and material costs, particularly if taxes similar to the Climate Change Levy are introduced to improve

mitigation of climate change. In general, there is little information about the potential impacts on ceramics, and more work would need to be done to understand more about this sector.

Finance and Banking

Many of the impacts on this sector relate to changes in insurance premiums and claims. The number of claims for weather related damage to buildings could increase, particularly during periods of extreme weather. This could increase insurance premiums for properties in areas at risk of flooding, and insurers may even refuse to insure some properties. Mortgage lenders could also require an assessment of property risk from climate change. There may also be changes in claims on health insurance during periods of high temperature in the summer. Changes in the competitiveness of different industries could affect the banking sector, with opportunities to fund companies to invest in energy efficient equipment, but potential loss of business from energy intensive sectors.

Food and Drink

The food and drink sector stretches from agricultural production through to consumption of products. Changes in the climate could have significant impacts on agriculture. There could be advantages from increased summer temperatures and a ‘longer’ summer, but risks from pests and diseases and loss of crops during extreme weather events. There could be a need to change to drought resistant plants, and better irrigation and land drainage. There could also be impacts on the availability and quality of food imported to the region, including fish and tropical fruits, and the transport requirements to ensure that food does not deteriorate in transit. Consumers could also change their demand for different food types; for example, salads may become more popular.

Health

The major impacts on health are likely to be through changes in vector borne diseases such as malaria, digestive disorders, and viral and bacterial infections. Higher summer temperatures could increase air pollutants, increasing the incidence of inflammatory eye diseases, while higher winter temperatures could increase the risk of mould in houses, encouraging respiratory illness. There could be a reduction in deaths during winter as temperatures become milder, but more deaths associated with hot summer weather. Extreme weather events could also have a negative impact on health, and flooding could disrupt delivery of clean water and disposal of sewage. On a positive note, people may become less sedentary if milder temperatures encourage more outdoor activity.

Environmental Services

Environmental services include supply of water, treatment of waste water, disposal of waste, and pollution control. The quality of raw water could be affected by climate change, through higher runoff of soil and pollutants during periods of intense winter rainfall and increased risk of algal blooms at higher temperatures. Lower rainfall during the summer could also constrain the supply of water. Sewage treatment could become harder due to reduced summer rainfall and an increased requirement for effluent sterilisation, although biological treatment will be facilitated by higher temperatures. Higher summer temperatures will also require waste disposal facilities to take account of the increased decomposition of waste, production of landfill gas, odour generation and pests. However, there may be opportunities for development of pollution control systems and technologies, particularly if emissions are more tightly controlled to mitigate climate change.

Natural Resources
There is little indication that climate change will have a significant effect on mineral extraction, including oil, gas, industrial minerals and aggregates. However, there could be more significant effects on energy generation, water availability, and forestry. There is a general perception that climate change could have a beneficial effect on the viability of renewable energy, particularly for solar energy and biomass. Water availability could be constrained during the summer, and increased during the winter. There could also be negative impacts on water quality, particularly during periods of low rainfall. The changes in temperature and atmospheric carbon dioxide could increase timber production, although forestry could be adversely affected by pests and diseases and extreme weather events.

Leisure and Tourism
Potential lengthening of the summer season and a greater number of warm days could increase the number of visitors to rural locations and key attractions in the West Midlands. Family groups and short break holidays are likely to be the most affected by climate change. This could provide a boost for the local economy, but could increase the pressure on local infrastructure and the environment. There may also be an increase in the number of visitors from abroad if the popularity of Mediterranean destinations decreases. However, the impact on the West Midlands is likely to be lower than that experienced by traditional holiday destinations in coastal areas. It is also likely that social factors will override any climate change impacts.

Transportation and the Automotive Industry
An increase in annual temperatures will have a beneficial effect on roads and railways through reduced frost damage, but could damage the road surface and structures. Increased risk of flooding could lead to more road closures, increased scour around road and rail bridges, and risk of subsidence and slippage of railway tracks. Climate change may create opportunities for an expansion of air transport if the demand for tourism in the West Midlands increases. However, this needs to be balanced with concerns over the contribution of air transport to climate change. For canals, higher temperatures may reduce water levels, but there may be opportunities to use canals to transfer water to areas of low water availability. Pressure to reduce the contribution of vehicle emissions to climate change could present opportunities for the automotive industry to develop new vehicle technologies. Mitigation of climate change may also involve a move towards public transport systems rather than private vehicles.

Engineering
Effects on engineering could relate to impacts on working conditions, sites, and competitive advantage. Working conditions could be adversely affected by increases in summer temperatures, and this may also increase the requirement for cooling in some of the production processes. However, the region may be able to attract engineering firms relocating from parts of the world with higher temperatures. When choosing sites, engineering firms will need to consider the location of the site, particularly in relation to flood risk. Much of the engineering in the West Midlands relates to the car industry. This industry will need to plan ahead in order to ensure that they are in a position to move to alternative car fuels to mitigate climate change.

Textiles
There is little published information on the potential impacts of climate change on the textile sector. However, there may be changes in demand, for example through replacement of carpets

with tiles, and a reduction in demand for winter clothing, with a compensating increase in demand for summer clothing.

Biodiversity

As temperatures increase, the migratory characteristics and diversity of species may be affected. There may be a loss of species at the southern end of their climatic range, and an increase at the northern end. Responses to climate change in other areas, particularly natural processes and agriculture, could have positive or negative effects on biodiversity. Reductions in summer precipitation could affect spring flora in woodlands and could increase the risk of grassland fires. Aqualate Mere in Staffordshire and north Shropshire, one of an important series of open water and peatland sites in the north west of the region, has been identified as being particularly vulnerable to periods of drought or flooding. There could also be risks of uniformity with some species responding well to increases in atmospheric carbon dioxide, for example rosebay willowherb and nettle.

Society

Little information was available on the impacts of climate change on society (including religion and education) at the time of the pre-scoping report. Published information tends to indicate that the most vulnerable people in society (the poor, elderly and young) will also be the most vulnerable to the adverse impacts of climate change. Changes in society could occur in response to the impacts on other sectors. For example, increases in home working to reduce transport emissions would also have social consequences.

Regulatory

Consideration of regulatory impacts includes local, regional and national government, central government departments and agencies (Environment Agency, former DETR, Home Office, Ministry of Defence) and other regulatory organisations (OFWAT, OFGEM, etc.). Impacts on the Environment Agency are based around increased uncertainty over environmental changes, for example in water quality and resources. The Environment Agency is considering the move to time-limited abstraction licences and improved flood defences. There is also an ongoing debate on the extent to which ecosystems should be preserved in their current state rather than allowed to adapt to changing conditions. The main impact identified for local authorities is the introduction of the Climate Change Levy.

5.1.2 Use of UKCIP98 Scenarios in the Pre-Scoping Report

The pre-scoping study was undertaken using UKCIP98 scenarios, rather than the more recent UKCIP02 scenarios considered in this report. Section 4.2 noted the main differences in the more recent scenarios. Those relevant to the West Midlands are as follows:

- Slightly higher warming rates, especially for the Low Emission scenario;
- Greater reduction in summer precipitation;
- Less marked increase in the frequency of heavy rainfall days;
- Changes in the patterns of average wind speeds, although confidence in the expected changes is still low; and
- Slight reduction in precipitation in spring and autumn, compared to an expected increase in the UKCIP98 scenarios.

The first three of these changes are a matter of degree. The changes were anticipated in the UKCIP98 scenarios but the extent of these changes has altered between the two sets of scenarios. Therefore, these changes may affect the extent to which possible impacts identified in the pre-scoping report occur, although it should not affect the validity of the suggested impact. For example, one potential impact suggested in the pre-scoping study was that “hotter summers could lead to more smell complaints”. With slightly higher warming rates, this would remain a potential impact, although the likelihood of it occurring or the number of people affected could increase.

Although the UKCIP02 scenarios indicate a change in the pattern of average wind speeds, there is still significant uncertainty about this. The pre-scoping study identified some potential impacts of increased average or extreme wind speed. However, these impacts were also based on significant uncertainty and were qualitative. Therefore, it is not likely that the UKCIP02 scenarios will change the potential impacts identified in the pre-scoping study.

The final difference identified in the list above is not simply a matter of degree, but involves a change from increased precipitation in the spring and autumn to a slight decrease. This is likely to exacerbate water shortages in the summer. However, most of the potential impacts identified in the pre-scoping study did not differentiate between seasons, or were limited to consideration of summer and winter. Therefore, this difference is likely to increase those impacts related to restrictions on summer water availability. This will be particularly important for West Midlands infrastructure, which will be at increased risk from subsidence of clay soils, and those industries with high water use.

The analysis above suggests that there may be some changes in the likelihood or degree to which the potential impacts identified in the pre-scoping study occur. However, the study did not include quantitative assessment of these potential impacts. Therefore, it seems reasonable to assume that the validity of the potential impacts is not affected by the differences between the scenarios, but the unspecified likelihood may change.

5.2 Five ‘Hot Issues’

In contrast to the pre-scoping study described above, this study examines five ‘hot issues’ in more detail. These ‘hot issues’ were identified as most important for the West Midlands from a number of issues discussed by individuals and organisations from across the region. A summary of the workshop, held in March 2003, is included as **Appendix A**. The five ‘hot issues’ are:

- water management;
- agriculture;
- energy;
- land use and the built environment; and
- transport.

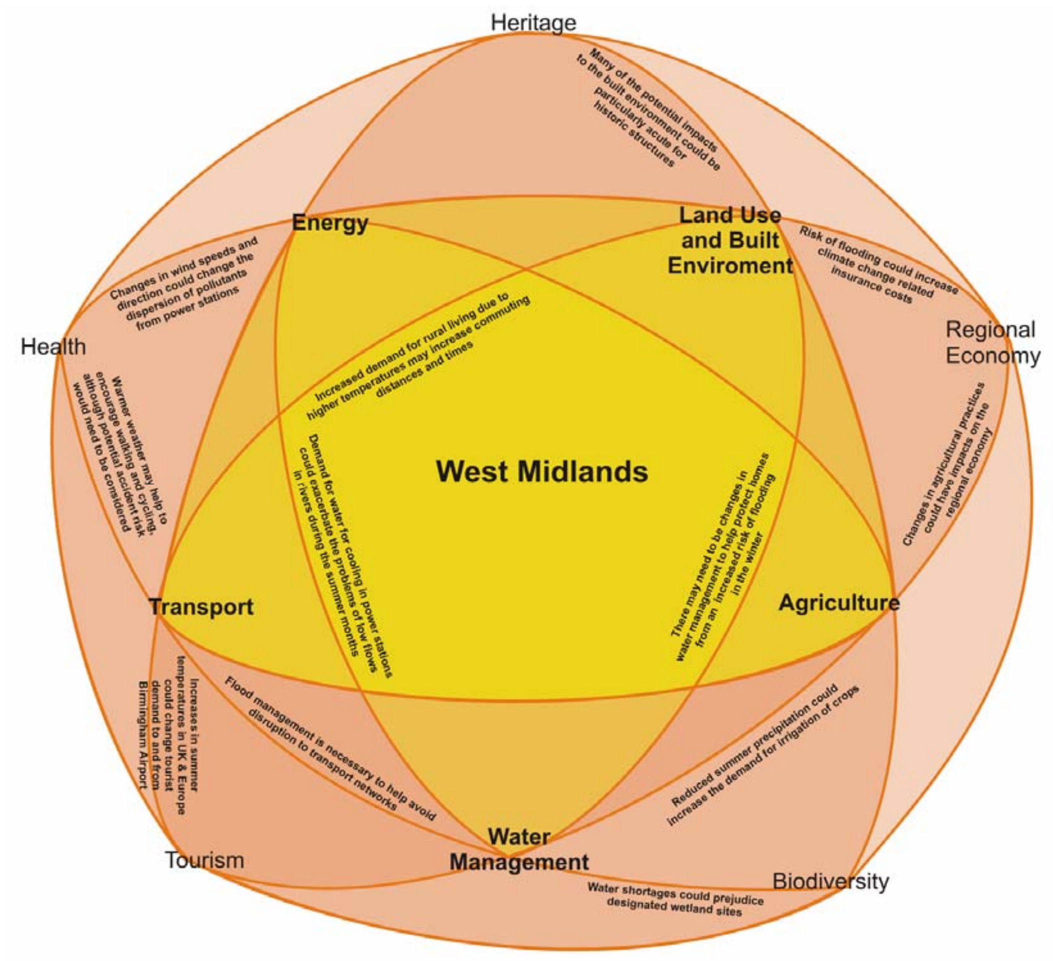
For each of the five ‘hot issues’ the study considers the potential impacts of climate change. In all cases, the relationship between the ‘hot issue’ and climate change is neither simple nor in only one direction. Not only are there potential impacts of climate change on the ‘hot issue’, but the ‘hot issue’ will also have an effect on the extent of climate change. Although it is important to note this two-way relationship, this report only considers the potential impacts of climate change. This is in recognition of the traditional focus on the impacts of various sectors on climate change, and the need to assess the potential impacts of climate change in order to incorporate them into regional policies.

For each of these issues, this study builds on the pre-scoping study, existing work and discussions with individuals and organisations across the West Midlands to determine the potential impacts of climate change. However, this is still a scoping study, and therefore does not constitute a comprehensive review. Instead, it aims to provide an introduction on all five topics that prompts thought and discussion to those interested in the issue. In all areas there is more work that could and should be done to provide a rigorous assessment of the potential impacts of climate change. Recommendations are made in the following chapters for each of the ‘hot issues’. These recommendations are a combination of ideas from the workshops and the authors.

However, it is important to note that the five ‘hot issues’ selected for special attention in this report are far from the only issues affected by climate change in the region. In addition, the problems and opportunities facing any one issue cannot be addressed in isolation from those facing other issues. The solution to one problem (e.g. growing bioenergy crops as an alternative to other agricultural crops that may not respond well to changes in climate) may only exacerbate problems in other areas (e.g. farmland biodiversity may be adversely affected) if the implications are not thought through and handled carefully.

Figure 5.1 shows just a few of the links and interactions between the five ‘hot issues’ shown in the inner circle of the diagram and some further issues and sectors not selected for attention in this report towards the outside of the figure. Many more lines and implications are possible between the issues shown, as well as with other issues not mentioned in the figure.

Figure 5.1 Illustrating the interdependence of the 'hot issues' and other issues



5.3 Adaptation to Climate Change

From the assessment of the potential impacts of climate change, the analysis also considers the possible adaptation measures that could be taken to ensure that opportunities are maximised and that threats are managed, as well as further work that may be needed to support this adaptation. However, the potential impacts of climate change are uncertain, and this results in risks. There is uncertainty over the climate changes themselves, presented in Section 4 of this report, although scientific improvements are generating more confidence in these results. The second source of uncertainty is over the impacts of these climate changes on our society and environment. For this study, these impacts have been considered in two separate socio-economic circumstances and with reference to historic climate events. However, it is acknowledged that this does not provide a perfect solution, and that the uncertainty associated with the potential impacts of climate change is an important consideration in considering the appropriate response.

Although uncertainty remains, that does not indicate that there should be no adaptation to the potential impacts of climate change until they are guaranteed. Burton (1996) suggests six reasons for undertaking adaptation now:

- Climate change cannot be totally avoided;
- Anticipatory and precautionary adaptation is more effective and less costly than forced, last minute, emergency adaptation or retrofitting;
- Climate change may be more rapid and more pronounced than current estimates suggest, that is, there is a risk of under-adaptation. Unexpected events are also possible (i.e. there is potential for high levels of regret associated with climate change);
- Immediate benefits can be gained from better adaptation to climate variability and extreme climatic events- i.e. no regret options may be available;
- Immediate benefits can be gained by removing policies and practices that result in mal-adaptation. An important aspect of adaptive management is to avoid the implementation of decisions that constrain or reduce the effectiveness of future options for adaptation; and
- Climate change brings opportunities as well as threats. Future benefits can result from climate change, and these opportunities can be realised or increased by appropriate adaptation.

At a general level, there are a number of possible adaptation options to climate risk (Willows and Connell, 2003). These can be summarised as follows:

- Share loss, e.g. insure business against weather losses;
- Bear loss, e.g. accept that some land will flood during winter;
- Structural or technological change, e.g. strengthen building foundations to cope with increased subsidence risk;
- Legislation or institutional change, e.g. strengthen planning guidance on developments in flood risk areas;
- Avoid risk, e.g. grow new agricultural crops better suited to new climate;
- Research, e.g. use research to better understand the climate risk; and
- Education, e.g. increase public awareness about coping with flooding at home.

While some of these will be more suitable for implementation at the national and international level, many can be used at the regional and local level. These have been suggested as possible responses for the potential impacts outlined in the following sections. However, it will also be a challenge for those living and working in the region, and those developing regional plans and policies, to consider where else the adaptation strategies can be used to respond to the potential impacts of climate change.

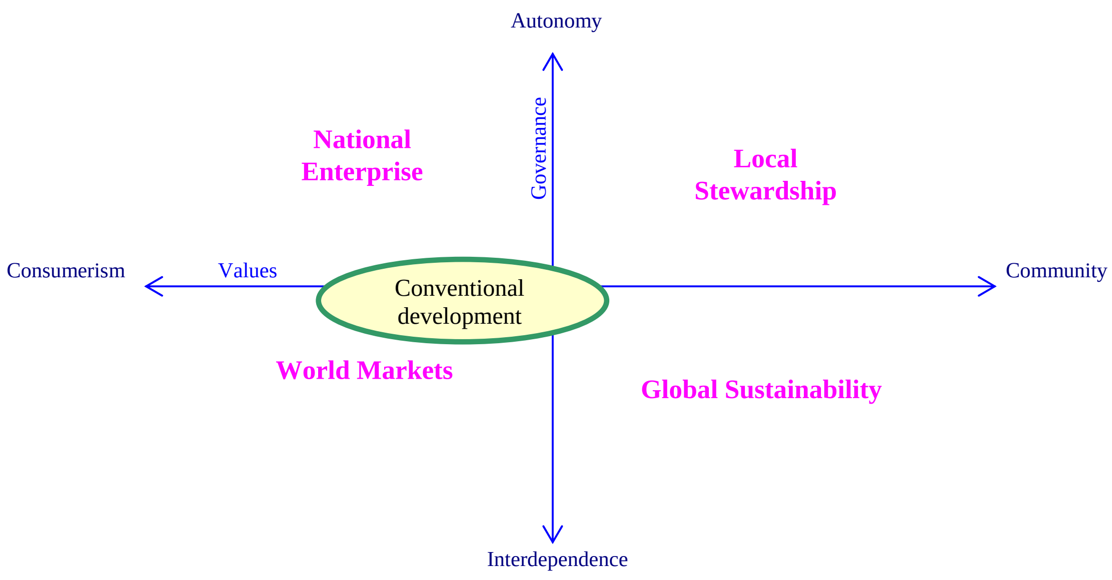
5.4 A Scenario Approach

It is important to note that for each of the five issues above, climate change will not be the only change, but that it will take place in a particular social and economic context that might be significantly different from that existing today. This will affect the degree to which climate changes will impact on the society, economy and environment of the West Midlands.

In order to assess the potential social and economic changes, this study adopts a 'scenario' approach, using socio-economic scenarios developed by the UK Climate Impacts Programme (UKCIP, 2001). These scenarios were developed drawing on other relevant work, particularly the DTI's Foresight Programme. The scenarios do not make predictions about the future, but suggest a range of possible alternatives.

The UKCIP socio-economic scenarios considered social and political values, and the nature of governance to be fundamental and independent determinants of future change. By examining a continuum scale between 'automony' and 'independence' and between 'consumerism' and 'community', four possible scenarios were generated. Each scenario is differentiated by the governance structures of political and economic power, and by the values held by consumers and policy makers. These are shown in **Figure 5.1** (UKCIP, 2001).

Figure 5.2 Four socio-economic scenarios for the UK



These scenarios are driven by differences in changes to a range of factors, including economic growth rates, demographic change (e.g. rates of population growth or decline), changes in technological development, different approaches to regulation (e.g. market-based instruments or traditional regulation) and changes in consumer behaviour (e.g. preferences and demand).

For the purposes of this study, only two of the four scenarios are considered: World Markets and Local Stewardship. The analysis is restricted to these two for a number of reasons. Particularly, it was felt that considering all four of the scenarios would extend the project significantly, but that the added value of the further two scenarios would not be that great in the context of a scoping study. Instead, two of the four scenarios would provide a relatively simple analysis of the possible range of social and economic changes. World Markets is an interesting scenario in that it relates most closely to the perception of 'business-as-usual', with high rates of economic growth and global trade. On the other hand, Local Stewardship is diagonally opposite. Choosing two scenarios on a diagonal shows the extent of the range of possibilities, and is in line with the recommendations made by UKCIP for the use of the scenarios (UKCIP, 2001). Local Stewardship is also slightly more challenging than Global Sustainability, since it does not allow for as much substitution of production on an international scale. However, it is also recognised that even four scenarios would not encompass all potential changes, and the limitation to only two does restrict the analysis.

Quantitative information underlying the scenarios for each 'hot issue' is given in **Appendix D**. However, the descriptions below indicate some of the main features of the two scenarios.

5.4.1 Local stewardship

Values

- Values are community orientated encouraging co-operative self reliance and regional development. There is a strong emphasis on equity, social inclusion and democratic values. Cultural and political variations lead to a stronger regional flavour in policy making. The most important role of the state is the promotion of these social values. Traditional regulation is replaced by a more diffused structure of governance involving participation throughout society. Tight planning controls leads to denser urban development. Growth is concentrated within existing urban areas.

Population

- UK population is stable and the trend towards smaller households is reversed due to lower income growth, strong planning controls on new housing development and revival of more collective social values. Household numbers decline slightly and urbanisation stops.

Welfare, health and education

- There is a high level of public provision and access to health and social services.

Environmental policy

- The conservation of resources and the natural environment are strong political objectives.

Economic policy and development

- Economic growth is slow at +1.25%. Small and medium sized enterprises in the manufacturing sector, co-operatives and locally based financial and other services prosper. Agricultural production stabilises. International trade is less important. Economic growth is more evenly spread across the regions. Transportation is affected by a major slowdown in the growth of trade and the demand for mobility.

5.4.2 World Markets

Values

- People are primarily concerned with personal consumption and their material well being. The market, as opposed to state institutions, is presumed to best deliver these goals. There is a strong desire for mobility, and people are less tied to locality. The nation state is in retreat and certain decisions are transferred to the EU whilst there is further, though limited, local devolution. The planning system is weak and not used to counter wider economic and social trends.

Population

- The UK population grows slowly but the labour force becomes increasingly mobile. High incomes and individualistic values reinforce the trend to smaller households leading to rising demand for housing and increased urban land use.

Welfare, health and education

- There is a declining role for governments in the provision of healthcare, education and other public services. Privatisation leads to increasing inequalities in access and quality of social services. Access to high quality education becomes very uneven because of higher costs.

Environmental policy

- This is aligned to meeting competitiveness goals. It relies heavily on economic instruments and focuses on problems which immediately affect the population, such as noise and air quality. Longer term, global issues such as climate change tend to be neglected.

Economic policy and development

- This scenario is characterised by liberalised national and international markets. Income distribution widens in this scenario more than in any other.

- Economic growth is rapid at +3% per annum. Much of the UK's goods and services are produced for an EU market. Global markets are important for a growing number of firms. The service sector (financial, healthcare and education, leisure, distribution and transportation) dominates overall economic activity. Mining, manufacturing and agriculture all decline.

- Much of the manufacturing and construction sectors experience high growth rates and technological innovation and the quality of built developments and infrastructure drastically improves. New roads are built to meet increased demand for passenger transport. The quality of water, energy and communication infrastructure improves significantly.

- Regions and localities offering world class knowledge based services tend to grow fastest, wherever they are. This leads to local and regional specialisation. Areas close to airports and ports benefit from the growing volume of trade.

5.4.3 West Midlands strategies

It is interesting to examine existing regional strategies in the context of these scenarios. Policies designed to increase development in existing urban areas, improve the quality of life for society as a whole through regeneration, protect environmental assets and reduce emissions, encourage locally based trading initiatives, and encourage more local involvement in achieving these aims are all suggestive of a Local Stewardship scenario. On the other hand, aspirations for higher growth rates and competitiveness on a European and global level, identifying trends for growing and declining sectors, using the market and private sector for delivering social objectives, and enabling increased mobility are all suggestive of the World Markets scenario. This mix is most apparent in the draft Regional Planning Guidance. Whether one or another of the scenarios is being pursued is not the most important issue. What is important is that the scenarios are a means of illustrating and understanding the potential social and economic implications of our actions and choices.

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6. Water Management

6.1 Context

Water resources management, both surplus (which can lead to floods) and shortage (which can lead to droughts), is a major challenge for the West Midlands. Water affects nearly all of the sectors considered in this scoping report, whether directly, for example as a source of supply for irrigation in agriculture, or less directly, in the provision of important water based heritage features along the historical canals in the region for example. The objective of this assessment is to identify the headline water management issues in terms of the potential impact of climate change. Water management planners in the West Midlands in the Environment Agency, Water Companies, Local Authorities and British Waterways, to name a few, have paid a great deal of attention to climate change in recent years, and considerable research and policy change has already been implemented to assess impacts on water demand, flooding and the needs of the environment. The potential significance of climate change to water management in the West Midlands is put in context with reference to some examples from the key features of the region.

- Parts of the West Midlands, especially the Vale of Evesham, are among the driest areas of England and Wales with annual totals less than 650mm on average. By comparison in a typical year the regional rainfall is approximately 750mm.
- Studies into water demand projections by the Environment Agency for the next 25 years suggest that there could be considerable change depending on people's attitudes and technological innovation. The choices made could significantly affect available resources.
- Recent flood events along the River Severn in 1998 and 2000 and more locally in parts of Birmingham highlight the need to prepare for and manage extreme events.
- The River Severn is also designated as a salmonid fishery from its source downstream to Shrewsbury and as a cyprinid fishery from Shrewsbury downstream to the tidal limit under the EC Freshwater Fish Directive. Management of water quality and ecology in the Severn and other rivers such as the Avon must also take account of potential climate change.
- In Minworth Wastewater Treatment Works, Severn Trent Water operate the largest inland works for Europe in the treatment of wastewater.

The above examples serve to illustrate the range of water management challenges in the West Midlands, and that the challenges not only cut across all sectors but must address the urban and rural differences, both clean (water supply) and wastewater (sewage) management, and the range of objectives for catchment and more local management of fisheries, biodiversity, navigation, heritage, flood protection and public health.

The conclusions from the Environment Agency Water Resources Strategy (Environment Agency, 2001a) further illustrates the complexity of issues that are potentially sensitive to both climate and socio-economic change in the West Midlands:

- Water is becoming a scarce resource and should not be taken for granted;
- Future developments in the West Midlands should recognise the limited availability of water as an influence on their location and timing, and should incorporate water efficiency measures and sustainable drainage systems at the feasibility or planning stage;
- Water abstraction cut-backs are necessary in some areas to improve the environment;
- A ‘twin-track’ approach to meeting future demands should be followed, combining further water resource developments and improvements with sensible management of our demands through efficient use;
- The River Severn has the potential to provide a sustainable source of further public water supplies, following commissioning of the Shropshire Groundwater Scheme phases 4 and 5, and a review of the Severn Control Rules;
- Water Companies should maintain the good progress made in recent years to reduce mains leakage, and further attention to leakage control may also be necessary;
- Over the next 25 years, it is expected that household water metering will become more widespread, providing a greater incentive for sensible use of water in the home, with appropriate tariffs to protect vulnerable households;
- Industry should strive to use water efficiently and realise the economic and environmental benefits;
- Farmers should strive to use water efficiently and consider opportunities to work with others to develop new sources of water and consider the development of winter storage to ensure reliable supplies; and
- Mineral and aggregate companies should take steps to minimise the impact of their extraction operations on the local water environment.

6.2 Social and Economic Change

Table 6.1 indicates some of the potential social and economic changes in water management, as indicated in the UKCIP socio-economic scenarios (UKCIP, 2001). Quantitative information on these scenarios is given in **Appendix D**.

Table 6.1 Water in the UKCIP Socio-Economic Scenarios

Local Stewardship	Water demand falls as a result of low growth and effective demand-side management measures. Consumers install water conservation technologies, grey water systems and radically reduce the use of public supply water in gardens. There is an increasing consciousness that water resources have to be protected. Exchange of water resources between regions in the UK becomes more difficult. High water-using activities either innovate in regions with shortages (like the South East) or relocate to other regions. Major investments are made to reduce water leakage. Few new supply-side investments are needed. Water quality improves dramatically as a result of acute concerns about the quality of the local environment, reduced pesticide use and changes in industrial structure. Dry waste systems are increasingly adopted resulting in a decline in demand for waste water treatment.
World Markets	Water demand increases significantly due to economic growth, higher living standards, small household sizes, minimal environmental concern and the development of more distributed communities. Metering is universally adopted and water prices are high. This encourages the adoption of low-cost efficiency measures. High water prices encourage a significant reduction in water leakage and the development of new sources of supply. There is little resistance to the development of new reservoirs except where significant recreational opportunities are threatened. Water quality is mixed: agricultural and road run-off are a severe problem; river quality improves in recreational areas; and groundwater quality declines.

The above scenarios provided by UKCIP (2001) are broadly similar to the scenarios used by the Environment Agency in their Water Resources Plans for England & Wales, including the West Midlands in 2001 (Environment Agency, 2001a). The Environment Agency scenarios were developed from the UK Foresight Programme. The Foresight scenarios define a broad framework of possible social, economic, political and technological change and can be mapped approximately to the UKCIP socio-economic models referenced in this scoping report.

The impact of climate change on water demand under the different socio-economic scenarios has been addressed in the Environment Agency Water Resources Plan for the West Midlands and is summarised below. This work has also been recently updated for the UKCIP02 climate change scenarios by the Climate Change and the Demand for Water (CCDeW) project (Downing et al., 2003) which is also covered in the next section.

In terms of possible impacts on other aspects of the water cycle not referred to in the above UKCIP socio-economic scenarios, the key issue for the West Midlands is the potential impact of increased development pressures on flood risk. This risk could result from increased development in areas at risk of flooding, or development without adequate drainage. This pressure is much greater under the World Markets scenario, but may be less of an issue under Local Stewardship with the adoption of more sustainable drainage and water efficient measures encouraging more recycling of runoff (grey water re-use) for example. Drainage in urban areas is also considered in Section 9.3.1.

6.3 Potential Impacts of Climate Change

The analysis undertaken in this scoping study is based on the key Environment Agency response and targets for the West Midlands from the State of the Environment Report (Environment Agency, 2001b). The key challenges identified by the Environment Agency are as follows:

- Public Water Supply;
- Overabstracted Rivers and Groundwater;
- River Severn Regulation;
- Rising Groundwater in Birmingham; and
- Transfer of Water using Canals.

The potential impact of climate change on these key issues is considered in turn below, but this section also includes a case study to illustrate the choices and options available to respond to another key challenge for the region, namely flooding. It is recognised that these issues do not represent all the key water management issues across the West Midlands, for example, flooding in Birmingham due to short duration intense rainstorms is also a key topic, but for this scoping study the Environment Agency challenges provide a useful breadth of topics for consideration.

6.3.1 Public water supply

Future household water use depends on the choices of individuals and society. For example using a power shower for five minutes can use more water than taking a bath. If increasing summer temperatures predicted by UKCIP02 are coupled with a large scale individual move in behaviour towards power showers, then demand for water could increase. This could of course be mitigated by a move towards more water efficient homes. Similar arguments and choices on water management practices can be applied to both agriculture and industry.

The Environment Agency Water Resources Strategy concluded that under the less sustainable scenarios (such as the World Markets scenario), water use would grow with increased domestic use for garden watering and power showers. Taking this increased use and growth in population together, increases in demand of up to 40% could occur by 2025 in the West Midlands. Alternatively, under more sustainable water use patterns, with tighter leakage controls and water efficiency gains, the increase due to population growth could be offset, resulting in an overall decline in water use in the planning period by around 30%.

A recent study by CCDeW (Downing et al., 2003) has taken this work by the Environment Agency forward using new datasets, including the UKCIP02 climate change scenarios. The results of the study are presented for each Environment Agency Region and therefore provide results for Midlands as a whole, as summarised in Case Study 1 below.

Water Management Case Study 1: Future Water Demand in the Midlands Compared to England and Wales
The results of the CCDeW Study are expressed as percentage changes from a “without climate change” demand scenario so that water resource practitioners can apply the results to their own projections of demand. The results apply to average demands only (with the exception of agricultural demand which are for design dry year), although some comments on the potential impacts on peak demands are included in the report. For domestic demand, the socio-economic reference scenarios indicate a range of future demand across England and Wales in 2024/25 of between 118 and 203 litres/household/day, compared to 162 litres/household/day in 1997/98. The additional impact of mean climate change on domestic demand is a modest increase in average annual demand, up to 1.8% by the 2020s. For the 2050s, the climate scenarios indicate an increase of 1.8%-3.7% above the socio-economic scenarios. Nationally, the highest increase in the 2050s forecast is in the Midlands Region (3.68% increase) and the Midlands Region values for the 2020s are also amongst the highest (1.8% increase).

The study suggests that domestic demand will be sensitive to the interplay of warmer climates, household choices regarding water-using technologies and the regulatory environment. The CCDeW project developed an agent based social simulation model to explore these interactions. The model revealed that an increased frequency of drought could provide the catalyst for the adoption of water saving technologies and associated reductions in demand, or alternatively if the presumption of entitlement to a private good were to exceed the willingness to conserve water during periods of drought, increased frequency of drought could lead to consumers increasing their demand beyond the high reference scenarios. Critically the model identifies the extent of community interaction and particularly the mimicking of neighbour behaviour as a key determinant of the uptake of new water saving technologies. Neighbourly interaction also determines the extent to which households are influenced by policy agent exhortations to use less water in times of drought - closely knit communities appear to be less impressionable. The findings, although purely qualitative, suggest key social determinants of future water demand for the West Midlands.
Climate change impacts in industry and commerce are likely to be higher in percentage terms - up to 2.8% in the 2020s - than the impacts on domestic consumption. The impacts do not appear notably different across the scenarios. Among the industrial/commercial sectors sensitive to climatic variations, soft drinks, brewing and leisure are likely to be most sensitive to changes in public water supply. There appear to be more significant differences between the regions for industrial demand than for domestic demand, attributable to the different mix of industrial/commercial sectors in each region. For the Midlands the forecast change for the 2020s is in the range 1.7% to 2.0%. Climate change could affect irrigation water use via changes in plant physiology, altered soil water balances, cropping mixes, cropping patterns that take advantage of longer growing seasons, and changes in demand for different foods. The survey of irrigation of outdoor crops by the CCDeW study in 2001 confirmed that water use for irrigation is currently growing at 2%-3% per annum, and provided a new baseline for the demand modelling. Agroclimatic zones defined by soil-moisture-deficits will move northwards and westwards in the UK as a result of climate change. By the 2020s, central England will experience conditions similar to those currently typical of eastern England, and by the 2050s eastern, southern and central England will have irrigation needs higher than those currently experienced anywhere in England. The climate change impacts (including changes in demand for water by crops, effects of CO_2 enrichment, and expected irrigation use) modelled in this study indicate increases in irrigation use of around 20% by the 2020s and around 30% by the 2050s. The impacts are region specific, with expected changes relative to the baseline, ranging from a decrease of 4% in the North West to an increase of 24%-25% in the Thames region. The corresponding figure for the Midlands is an increase of 23% over and above the socio-economic scenarios outlined in section 6.3.2 below.

6.3.2 Over abstracted rivers and groundwater

According to the Environment Agency (2001b), many river catchments and groundwater units within the West Midlands are approaching the limit of sustainable abstraction, and any further resource exploitation would lead to general environmental degradation. In some areas the Environment Agency believe that this limit has been exceeded. Consequently large areas are deemed closed to further abstractions, severely limiting the availability of new water resources.

As with public water supply, the potential increase in demand for water depends on social and technological change. In terms of spray irrigation, the Environment Agency demand projections study (Environment Agency, 2001a) concluded that this component of demand could decrease by up to 20% or increase by 50% by 2025, depending on the different scenario assumptions of customer and supermarket produce quality demands, international competition, and crop varieties.

One of the potential impacts of climate change under the UKCIP02 scenarios is that reduced summer precipitation could lead to a depletion on summer river flows, and unsupported river abstractions may become more unreliable. Although this situation could be partly offset by increased winter aquifer recharge and increased winter reservoir inflows, a potential increase in demand due to climate change could exacerbate this current problem.

A related issue for reduced summer river flows is the potential loss of dilution for sewage and trade effluent. However, this is related to demand for water and the production of sewage effluent, which in some rivers in the region (e.g. the Tame) are dependent on treated sewage effluent for the sustainability of low flows. One potential challenge for water resources planners is therefore the requirement to ensure that the discharge consent process takes into consideration potential climate change impacts on both quality and quantity of flows.

6.3.3 River Severn regulation

The River Severn has been developed as a 'regulated' river since the construction of Llyn Clywedog reservoir in the mid 1960s. This means that the natural river flows are artificially enhanced by releasing stored water to meet the needs of the ecology, recreational users and abstractors. Both Llyn Clywedog and Llyn Vyrnwy reservoirs support the river flows in dry weather along with a series of groundwater boreholes in Shropshire. Without this support there would be increased constraints on abstractors during low flow periods or a greater risk of environmental damage. This demonstrates the interregional nature of climate change, since the effect in the West Midlands will depend on the impacts in Welsh reservoirs.

Additional phases of the Shropshire Groundwater scheme will increase the regulation support to the River Severn and an important area of further work will be in the revision of control rules for the River Severn (Environment Agency, 2001a) to ensure environmental and licence abstraction needs are met. Severn Trent Water have been undertaking a river modelling study to assess the effect of these changes on the deployable output (yield) from this catchment, taking account of possible climate change effects.

6.3.4 Rising groundwater in Birmingham

Groundwater levels have risen in the Birmingham conurbation due to the reduction in abstraction for industrial processes. This has caused local flooding in basements and the rising groundwater can also move into areas of contaminated land causing it to become polluted.

The work undertaken by CCDeW (Downing et al., 2003) does not suggest large increases in water demand in the Midlands for industrial use, compared to spray irrigation for example. It is therefore assumed that this situation will not be reversed, and with increased winter recharge due to the increased precipitation from the UKCIP02 scenarios, the situation may worsen unless controlled. The development of the Birmingham Groundwater scheme by Severn Trent will potentially help this situation by transferring groundwater to the East Midlands via the River Tame to supplement water resources in that region. Although this scheme is not aimed directly at alleviating possible increases in groundwater due to climate change, it is an example of the options that water resources planners may consider in future as a response to climate change impacts.

6.3.5 Transfer of water using canals

The transfer water beyond the West Midlands using canals could become an important issue where climate change impacts cause potential water shortages in adjacent regions. British Waterways and others have proposed this use and as the general move would be from north and west to south and east this could increase flows through the Midlands. Climate change is significant for these proposals in that changes to rainfall patterns could affect key sources of water for canals including reservoirs, feeder streams and groundwater. Furthermore, depending on socio-economic change, a potential increase in canal use (either pedestrian or navigation) and demand for canal side property development could also have water management implications. For example, the use of canals as a source of water is a commercial venture currently being developed by British Waterways, and the sustainability of water resources in view of possible climate change will need to be considered in a similar way to the sustainability of low river flows.

Water Management Case Study 2: Choices and Options in Flood Risk Management

The River Severn Flood Management Strategy (Environment Agency, 2002) recognises the potential increase in flood risk with effects of climate change. This was highlighted earlier in this scoping report as a result of increased winter precipitation but also more frequent intense winter precipitation events. Current advice from Defra is that a factor of 20% is applied to peak flows in hydrological modelling as a sensitivity test for the assessment of flood risk to incorporate the various anticipated changes in climate.

In order to illustrate the potential range of management and policy options and choices available to adapt or reduce the effects of climate change, this case study summarises some of the possible solutions put forward in the River Severn Strategy Scoping Report.

The possible flood management strategies are as follows:

Do Nothing

This would not reduce flood risk, and this situation would probably deteriorate with climate change and as existing flood defence assets deteriorate.

Do Minimum

This is also unlikely to reduce current or future flood risk due to climate change, as existing standards defences are likely to be worsened by peak flows under climate change.

Altering Rate of Runoff

Altering the rate that surface water enters watercourses can be used to manage the incidence of flooding along the fluvial Severn, to prevent peak flows from tributaries from coinciding. Generally this is effected by slowing the rate of run-off from land or by providing attenuation in a watercourse. However, other measures are possible but there is a need to ensure that attenuation that produces benefits in one location does not exacerbate flooding elsewhere.

One potential measure is provision of some form of storage to contain floodwaters, such as increasing existing reservoirs such as Lake Vyrnwy, changing operating rules or using new storage. The merits or otherwise of storage to address potential climate change impacts are complex and need to account for the environmental and economic costs, and the need to balance flood storage with possible water supply benefits. Storage does not only mean large schemes however, and more local options on tributaries may have other benefits, for example in providing some potential irrigation supplies for individual farms. This is specifically an option in the Wye Valley, Shropshire Plain and Vale of Evesham.

River Corridor Optimisation

These measures include dredging, removal of floodplain obstructions, river maintenance, or river restoration, to improve river flow.

Flow Diversion

This would include the creation of diversion channels to take floodwater away from sensitive areas.

Managing Flooding

This would include development control such as protecting floodplains. Worcester City Council for example has developed a suite of local plan policies, which are based on preserving and protecting the floodplain function by not allowing development within areas of high flood risk, and reducing the flooding of existing properties.

Other measures include the policy of managed retreat, flood proofing and flood forecasting and warning.

As this case study illustrates the potential increase in flooding from climate change presents a considerable challenge in terms of developing a solution through a policy response and the objective of formulating a ‘no regrets’ response. Current policies such as PPG25 have included an approach to allocation of development in floodplain areas, and in setting out guidance for flood risk assessment including the requirement to take account of climate change. However, this policy does not make an automatic presumption against floodplain development.

6.4 Policy Considerations

The Environment Agency Water Resources Strategy represents one of the key policy documents for the implementation of policies, plans and programmes to address the potential impact of climate change in the West Midlands. This document and the Environment Agency State of the Environment Report have been used as the basis for the water management ‘hot issue’ impact assessment work reported in this section. Other key water management policies with specific reference to climate change include the following:

- Planning and Policy Guidance Note 25 (PPG25) - this is concerned with development control and flood risk, making specific reference to the need to take account of climate change in flood risk and planning decisions. The policy is being implemented across the region in terms of both greenfield and brownfield developments. The guidance also makes recommendations on the need to incorporate Sustainable Drainage Systems (SuDs) in the attenuation and control of runoff from impermeable services.

- River Catchment Flood Management Plans - the Environment Agency timetable for the completion of the River Catchment Flood Management Plans is currently being implemented, taking account of climate change and land use change over the next 50 years.

- Water Company Asset Management Plans - water companies submit their asset management (investment plans) to OFWAT as part of the Periodic Review process on a five year cycle. Part of the submission includes the update of Water Company Resources Plans, which set out the Supply/Demand balance projections over a thirty year time horizon. The Environment Agency have recently (April 2003) published guidance to water companies on the requirement to address climate change in the submissions of Business Plans of OFWAT and Water Resources Plans to the Environment Agency in 2004. Work is ongoing by Severn Trent Water and South Staffordshire Water to investigate potential climate change effects using water resources modelling techniques. This work will inform the key decisions by these companies and the Environment Agency for the adaptation to climate change using the ‘twin track’ (supply and demand management measures) approach.

6.5 Summary and Recommendations

Potential impacts and opportunities

Increased winter precipitation and precipitation intensity could increase flood risk on major rivers such as the River Severn.

Urban drainage systems, in particular those in Birmingham, may not be able to accommodate intense precipitation in the winter, impacting on the design, capacity and maintenance requirements of these systems.

Increased winter rainfall could have potential benefits for winter recharge to reservoirs and groundwater such as the Shropshire Groundwater Scheme.

There are concerns over greater winter recharge further increasing rising groundwater under Birmingham during winter months.

Changes in the seasonal pattern of rainfall could require changes to water resources operational practices in river regulation (River Severn) and direct supply reservoirs.

Low summer rainfall could result in further low flow problems and water quality deterioration in the region's rivers and the need for greater flow regulation from existing reservoirs or groundwater.

Reduced precipitation over the summer could result in increased water demand and stress on resources for water supply management and from direct abstractions from rivers for irrigation, navigation and industry, in particular in the drier Vale of Evesham area.

There could be increased demand for irrigation due to higher soil moisture deficits in the summer. The CCDeW study for the Midlands suggests that this increase could be as much as 23% under some climate change and socio-economic scenarios by the 2020s.

Where water surpluses over the winter months can be controlled, this may represent an opportunity for attracting investment from other parts of the UK where more extreme water shortages are predicted (e.g. the South East).

Water trading opportunities may arise between individual farms with potential surplus water stored during periods of increased precipitation.

Possible adaptation responses

Improve flood risk management through use of agricultural land for flood water storage, use of sustainable drainage systems, and extension of wetlands.

Make use of increased winter refill in storage for irrigation at the local farm level, and for low flow alleviation in summer from possible rising groundwater such as the Birmingham Groundwater and Shropshire Groundwater schemes.

Consider public flood defence needs under future climate change conditions.

Consider need for appropriate flood protection of individual properties.

Promote water efficiency and demand management across industrial, commercial, agricultural and domestic sectors for both current and future developments.

Recommendations

There is considerable research and investigation on the impact of climate change on water management in the West Midlands, so the recommendations here are based on the need to improve key gaps in our understanding. Some of this has already started e.g. climate change has been considered as part of the regional water resources strategy. Water companies are also assessing water resources investment needs as part of the asset management planning (AMP) process. They have received guidance from the Environment Agency on how to consider climate change in this process.

One key challenge will be the ability to influence long term 'no regrets' investment decisions on water management (resources and flood prevention) schemes, to ensure effective adaptation to climate change. The challenge involves the management and communication of uncertainty from climate and socio-economic change scenarios. UKCIP launched a key report on managing uncertainty and risk in climate change in May 2003. The communication of risk and uncertainty in water management will be particularly important for the non-specialist.

A key communication challenge for the wider public in the West Midlands is to explain that potential water shortages may arise from climate change, while at the same time, advise on potential flood risk and surplus water scenarios.

Most of the key water management policies and strategies relevant for the West Midlands take into account climate change and present recommendations for the application of climate change factors in planning and investment studies. A possible exception identified in this scoping study is the implication of climate change on the canal network, and a recommendation is that British Waterways give further consideration to climate change in future canal management and water resources development strategies.

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7. Agriculture

7.1 Context

Agriculture is historically, and continues to be, one of the most important sectors in the West Midlands, not only in land use terms, but also through its contribution to society and the environment. As was indicated in Section 2.2 of this report, although the gross value added by agriculture, hunting, forestry and fishing is higher than the UK average, it is still relatively small at 1.5%. The total income from farming in the region is £142 million, compared to a UK total of £1,513 million (National Statistics, 2002). However, 34.6% of land in the region is used for arable and horticultural purposes, and a further 35.4% is improved grassland (National Statistics, 2002). The link between agriculture and other sectors of the economy was highlighted very strongly in 2001, when tourism suffered very badly during the foot and mouth crisis.

Within the region there is significant agricultural heritage. Herefordshire, famous for its distinctive cattle, Shropshire, northern Staffordshire, and western Worcestershire are important for their livestock sectors. Both Shropshire and Staffordshire contribute more than 30% each to the land area of the West Midlands used for cattle. Shropshire also has over 30% of the region's land for sheep (Defra, 2002a). There is a strong arable sector in Warwickshire, home of the Royal Agricultural Centre, south Staffordshire, and Shropshire, which hosts the region's only sugar beet factory. Overall, the majority of agricultural land in the West Midlands is used for permanent grazing (39.9%) and arable crops (37.4%). Of these crops, by far the most extensively grown is wheat, although field beans, oilseed rape and winter and spring barley are also significant. Land use and farm types are shown in **Figure 7.1** (Defra, 2002a) and **Figure 7.2** (MAFF, 2000b).

Figure 7.1 Agricultural land use in the West Midlands

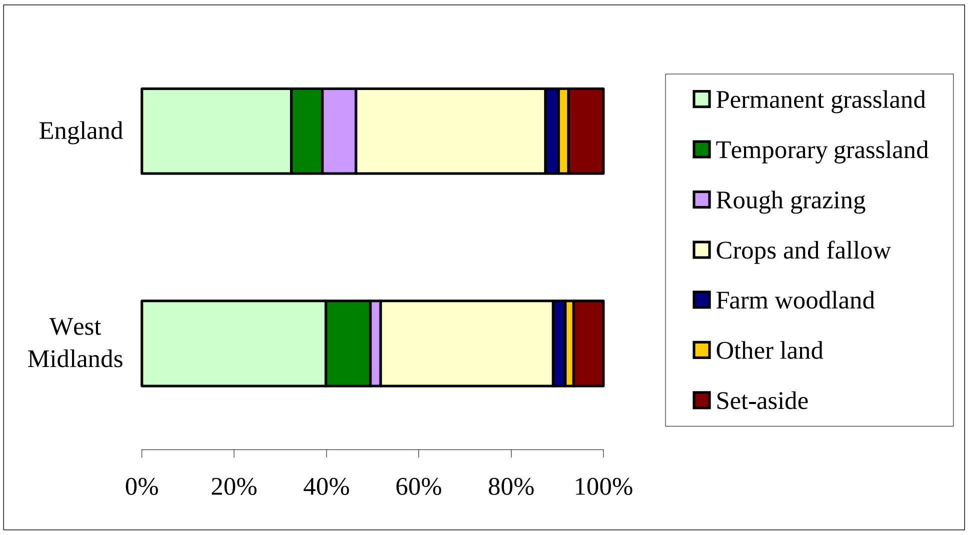
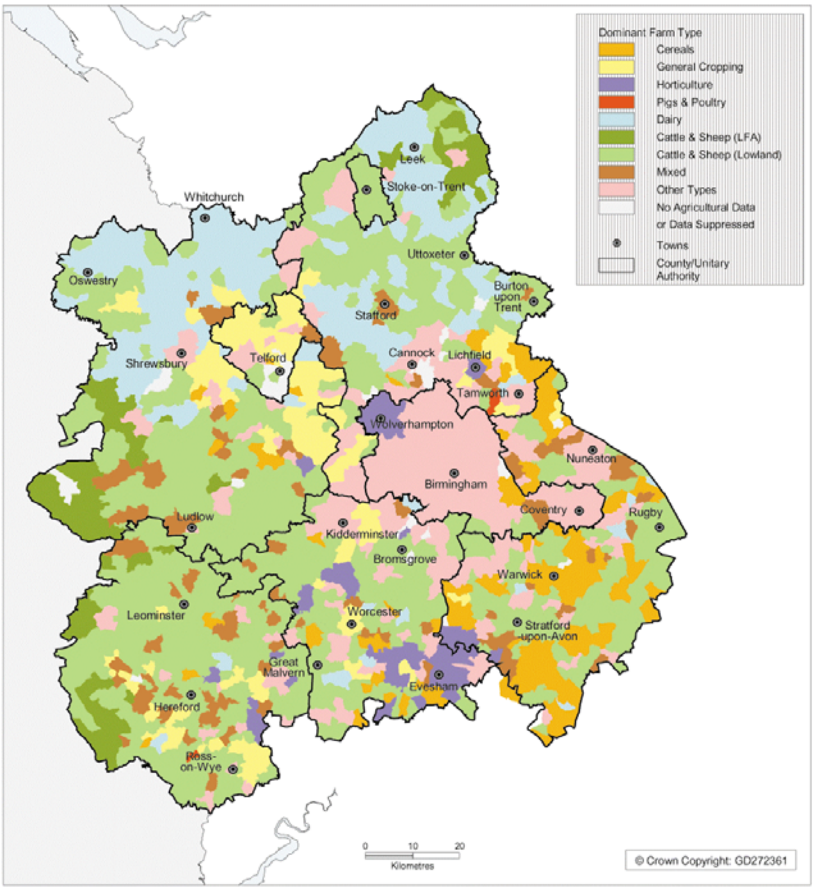


Figure 7.2 Dominant farm types in the West Midlands



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However, agriculture throughout the UK is facing one of its most difficult periods, and the West Midlands is no exception. An economic recession in the industry was compounded in 2001 by the effects of foot and mouth disease. Generally, world commodity prices have fallen, while the strength of the pound against the Euro has also made exports less competitive. Total income from farming has fallen by 60% since 1996, with a 40% drop in wheat prices and a 30% drop in milk prices (UK Agriculture website).

The industry is also undergoing significant change, in particular as a result of the structure of the wider food sector, and the restructuring of agricultural businesses. Although there has been some consolidation of agricultural businesses, there are still over 21,000 in the UK. In contrast, the number of manufacturing and retailing companies is small. For example, the top five food retailers have well over 50% of the food retail market (Roberts, 2003). This has led to a shift in the power of manufacturing and retail companies to control the conditions and produce of agricultural businesses and has created uncertainty amongst farmers supplying to these organisations.

Agriculture has also been undergoing significant restructuring in response to continuing changes in national and international markets. There are a number of indicators of this restructuring, including farm expansion, significant enterprise change, widespread labour shedding and asset liquidation. Although historic and current restructuring does not indicate that it should continue, it would appear that the drivers of the restructuring still exist, and there is no reason to expect agriculture to stop changing in response to them. A study of agricultural restructuring for Defra (Lobley et al., 2002) suggested future changes in both arable areas and for lowland livestock. In the West Midlands, this could involve further marginalisation of grassland in arable areas, with intensive production on core land, particularly the high quality land in Herefordshire and Worcestershire. In those areas with significant lowland livestock, such as Herefordshire, Shropshire and Staffordshire, there is likely to be further polarisation between dairy and extensive livestock, and increased diversification and conversion of farm buildings to non-agricultural uses.

Although there is no specific regional strategy for agriculture, there are a number of regional interpretations of national policies that are relevant to agriculture and are likely to determine its future development. The West Midlands Regional Delivery Plan (AWM, 2003) combines consideration of the aims of the food and drink cluster of the Regional Economic Strategy (AWM, 1999) and the objectives of the Sustainable Food and Farming Strategy (Defra, 2002b) that are achievable at a regional level. The England Rural Development Plan (MAFF, 2000b) is divided into regions, each with their own set of priorities.

Recent changes to the proposals of the Common Agricultural Policy (CAP) are also likely to change the nature of agriculture in the region. The CAP was introduced in Europe in 1962, at a time when one in five people in the six member states was employed in agriculture and the overwhelming priority was to ensure secure food supplies and a fair standard of living for farmers. The situation since then has changed radically, and has required changes to be made to the CAP. This has led, most recently, to the mid-term review of Agenda 2000, which included proposals to deal with EU enlargement and the pressures for reform imposed by the Doha Development Round of the World Trade Organisation negotiations.

The proposals set out three aims and the methods of achieving them (EC, 2003a): to enhance competitiveness by allowing intervention only as a ‘safety net’ measure; by promoting a greater market orientation through the introduction of a single farm payment decoupled from production; and to providing greater support for rural development through the transfer of funds. The main shift is in the decoupling, which conditions payments on compliance with environmental, food safety and animal welfare requirements. Research for the EC (EC, 2003b) has compared the expected impacts of these proposals with the previous policies in Agenda 2000. At an EU level, this suggests that total cereal production would fall slightly on the Agenda 2000 situation, with production constrained by the allocation of land to energy crops and voluntary set-aside. Beef production would fall slightly and become more extensive, while the increase in the milk production quota is expected to increase milk production in the EU.

7.2 Social and Economic Change

The context above outlines the situation in agriculture in the West Midlands today, and how the current plans and policies are likely to influence this in the future. However, in order to broaden the discussion of future changes, it is necessary to consider alternative future socio-economic change. The text in **Table 7.1** is taken directly from the UKCIP document (UKCIP, 2001), and there are differences in the relevance of the issues in the table to the discussions of change in this study. Quantitative information on the potential changes in agriculture under the two scenarios is given in **Appendix D**.

Table 7.1 Agriculture in the UKCIP Socio-Economic Scenarios

Local Stewardship (LS)	The main goal of agricultural policy is to support a broader social desire for local self-sufficiency and what are seen as traditional farming practices. Research and technical support increases the productivity of low-input farming system. Large scale farming is not encouraged. Agriculture is heavily subsidised to protect food security, local landscapes and reduce environmental impacts. Retailers and consumers place considerable emphasis on procurement of local supplies while sales of exotic fruits and out-of-season vegetables decline. Demand for meat continues to fall, and broader support for animal rights brings an end to the transport of live animals over long distances. There is a rapid growth in organic and low input farming. Farm size declines and the use of fertilisers and pesticides decreases. Genetically modified crops are banned. The shift to extensive farming practices decreases productivity and the total agricultural area is extended. Production of arable increases slowly, while livestock production decreases.
World Markets (WM)	Agricultural policy becomes much less interventionist and subsidies are reduced to a comparably low level. The CAP plays only a minor role and lower food prices prompt farmers to search for improved productivity. Food markets are increasingly dominated by the large retailers. There is a growing differentiation between staple 'engineered' foods, and higher value unadulterated food produced using traditional methods. More processed food is consumed, and a greater proportion of food is eaten outside the home. Agriculture becomes increasingly concentrated, industrialised and global in scope. Farms increase in size, accelerating the adoption of technological approaches such as 'precision farming'. The use of genetically modified crops becomes pervasive, and has a major impact, raising productivity. Fears about the environmental impact of genetically modified crops on biodiversity are demonstrated, but are primarily of concern to environmentalists, who have little influence in this scenario. The total agricultural production rises because of higher productivity. Substantial tracts of land are converted from agricultural to recreational uses, or are sold for development.

Recent changes in agriculture in the West Midlands tend to reflect the World Markets scenario, with an increasing demand for processed food and a concentration of the buyer market to a number of large organisations and supermarkets. However, some of the issues raised in this scenario have not occurred, and there are some elements of the Local Stewardship scenario beginning to appear. For example, the West Midlands has an increasing number of farmers markets that provide a link for consumers to local food production (see the National Association of Farmers Markets website- www.farmersmarkets.net).

A complete move towards the World Markets scenario would have a number of implications for agriculture in the West Midlands. The industry would need to be competitive not only at a national scale, but also internationally. This would be a result not only of the low world prices, but also the dominance of the large retailers, who have large geographical procurement areas. However, one area in which the region could build on existing capabilities would be in the food preparation and processing. Although this is not considered specifically in this analysis, it is worth mentioning as a potential opportunity for the region. The use of technology in agriculture would continue to grow, with farms becoming larger and more industrial. This would be a significant change, particularly for those farms in the west of the region, which tend to be smaller.

On the other hand, changes similar to those suggested in the Local Stewardship scenario would also involve significant changes to the region’s agricultural sector. In this scenario, farming tends to be at a small scale and focuses on arable and horticultural production. The falling demand for meat would result in changes for all beef, pork, lamb and poultry meat producers, who are particularly concentrated in the Herefordshire and Shropshire.

7.3 Potential Impacts of Climate Change

Some of the potential changes in the climate of the West Midlands were outlined in Section 4. That section presented a range of scenarios and quantitative analysis. However, because of the degree of uncertainty and in order to facilitate the analysis in this section, this section does not attempt to analyse the impacts of different climate change scenarios. However, it is worth noting that for each of the suggested impacts, the degree to which they occur will, of course, depend on the degree to which the relevant change in climate occurs. In general, higher temperatures, a longer growing season and higher carbon dioxide levels could benefit some aspects of agriculture in the region. Farmers in the region are already making changes in response to technological and business pressures that would be consistent with adapting to climate change, for example on-farm water storage and double-cropping of strawberries. The following sections consider some of the potential impacts of climate change and possible adaptation responses.

7.3.1 Increased average winter precipitation and increased number of intense winter precipitation events

The climate change scenarios suggest that wetter winters will occur, increasing the risk of flooding across the region. Flooding of agricultural land from rivers or high soil moisture can cause a number of problems on agricultural land. Firstly saturated soil cannot support the weight of tractors and implements as well as drier soil, so that machinery can become stuck in ruts or soil becomes more compacted by the weight, reducing its ability to grow crops. Alternatively, seeds in flooded land are prone to rotting, and plants can drown if the ground is waterlogged and air cannot get to the roots. Finally, waterlogging will limit the release of nitrogen from the soil, restricting the nutrients available for plant growth.

Although the majority of the region is a rolling landscape, without fenland for example, drainage will become more of a priority. In the scenarios discussed earlier, the World Markets scenario would involve a reduction in the area of land used for agriculture. However, the alternative uses differ, and it is not clear whether it would be possible to remove land that was at risk from flooding, thereby reducing the impact of flooding on agriculture. Under a World Markets scenario, world class performance is emphasised. If agriculture in the West Midlands could be internationally competitive this might support its extension. On the other hand, the Local Stewardship scenario would see the area of land used for agriculture extended as a result of lower productivity. In both scenarios, flooding could have a significant impact on the agriculture sector. However, under Local Stewardship a priority would be given to addressing climate change issues and this could reduce potential negative impacts such as flooding. In order to adapt to the risks presented by flooding, it will be necessary to consider the requirement for flood management and the economic implications of various options. Flood management strategies could include a range of measures outlined in Section 6.3 of this report. The costs of flooding for agriculture are considered more fully in the case study in Section 11.2.

The following box indicates one way in which flooding is being dealt with and converted to an opportunity within the West Midlands. This approach is consistent with a Local Stewardship scenario. The Severn and Avon Vales Wetlands Partnership project supports farmers to convert some of their agricultural land to wetlands to act as biodiversity habitats and reduce the risks of flooding further downstream. If there is an increase in the number of intense precipitation events in the winter due to climate change, schemes similar to this could offer a way of maximising the opportunities for farmers, while at the same time minimising the risk to built up areas downstream. However, it should be recognised that the main benefits are in terms of biodiversity rather than agriculture.

Agriculture Case Study 1: The Severn and Avon Vales Wetlands Partnership

The national reduction in the areas of wet grasslands supporting a wide range of plants and animals has attracted increasing attention from a number of environmental organisations. Since 1950, over 95% of species-rich meadows and pastures in the UK have been lost, including a number of wet grasslands. These areas are seasonally flooded or waterlogged by freshwater, and managed by cutting or grazing. In response to the concern, the Environment Agency and English Nature set up the Severn and Avon Vales Wetlands Partnership in 2000 to promote restoration of wet grasslands in the lower Severn and Avon vales. The partnership works with local farmers to restore wetlands in eighteen ‘zones’ identified as having potential for restoration.

Farmers are also supported with grants from Defra’s Countryside Stewardship Grants Scheme. This scheme aims to support landscape and wildlife conservation on farms by providing farmers with a ten-year management plan specific to their circumstances. The agreement includes an annual grant for managing land in the specified way, with an option for additional support for agreed capital works.

In addition to the biodiversity objectives, the project also has advantages for managing the flood risk further down the Severn and Avon rivers. These have been badly affected by flooding in the past, and continue to be included in the Environment Agency’s list of areas at risk of flooding.

An alternative possible adaptation response would be to consider the production of alternative crops less vulnerable to damage from waterlogging. Although the use of traditional crops on land prone to flooding would obviously depend on the degree to which land was waterlogged, a possible change would be to growing willow coppicing for fuel. This would link with the forthcoming Regional Energy Strategy.

7.3.2 Reduced summer precipitation

A reduction in rain over the summer months is likely to have a number of impacts on agriculture. These relate not only to the overall quantity of rainfall, but also the increasing erratic nature of rainfall.

The grassland used throughout the county for livestock pasture could be affected by the lack of water. Grass has one of the highest water demands of any crop, and lush grass relies on a relatively even rainfall throughout the year. The effects of lower summer rainfalls can be seen on a national basis at the moment, where the grassland in the east of the country tends to be of poorer quality than that in the west. If rainfall reduces, it is likely that quality of the grassland in the West Midlands will be poorer. This might in turn require livestock feed to be supplemented to compensate for this reduction.

The drier summers, without rain to swell the grain in cereal crops and vegetables and fruit with summer growing seasons, are likely to reduce yields from these crops. Although this will be in part counteracted by a reduction in crops lost in the field because of high or intense rainfall, it is unlikely that this will compensate completely.

The drier summers might also offer an opportunity for the agriculture sector by allowing new types of crops to be grown in the West Midlands. This might affect the horticulture sector through increased opportunities for growing soft fruits, and also for agriculture where it might be possible to grow sunflowers and soya. This could also link to changes in consumer demand if warmer weather increased demand for salads and fruit. However, these opportunities are likely to be limited to the long term and high climate change scenarios. A study of the potential impacts on agriculture in East Anglia and the North West found sunflowers to be profitable only in the 2050s High scenario (Holman et al., 2002).

Water is used for agriculture in a number of different ways, for livestock, for diluting pesticides and fertilisers, and for irrigation. These uses vary in both the volume of water that they require and the ability to reduce this water use if climate change and associated policy measures reduce the supply of water available for agriculture. The impact of restrictions on water use are likely to vary depending on the intensity of agricultural production. In the socio-economic scenarios above, agricultural intensity would increase in the World Markets scenario, but would decrease in Local Stewardship. It is likely that the most serious restrictions on activity will be in irrigation (see also Section 6), resulting in constraints for the horticulture sector in the Vale of Evesham. Water is particularly important to the horticulture sector to ensure the consistent size and appearance of fruit and vegetables demanded by the retailers and consumers. If water use is constrained, the size and yields of fruits and vegetables is likely to decrease, although the degree to which this poses a problem will depend in part on the preferences of consumers. The constraint on water use could be addressed in different ways under the two scenarios: significant investment in infrastructure, as in the World Markets scenario, or significant improvements in efficiency, as in Local Stewardship. A specific adaptation option would be to consider the on-farm storage of winter precipitation in reservoirs for use in the summer.

7.3.3 Reduced cloud cover

A decrease in the number of cloudy days in summer will increase the risk for livestock farmers of animals suffering as a consequence of heat and sun. This is not only the case with extensive livestock housed outdoors, where the provision of shelter might need to be improved, but also for intensive livestock, particularly pigs and poultry. Increased temperatures might encourage further use of temperature controlled housing. However, this could increase energy use, particularly if the difference between diurnal and nocturnal temperatures increases.

Reduced cloud cover also has benefits as the increased sunlight can increase the rate of photosynthesis (the process by which plants create energy for growth). When combined with the higher atmospheric concentration of carbon dioxide this could increase the yield of some crops.

7.3.4 Higher winter temperatures

As weather in the winter and spring becomes more mild, livestock rearing will face less of a problem with freezing weather late in the year. Lambs, in particular, suffer higher mortality rates in years when there is sudden unexpected cold weather. Milder springs will reduce the likelihood of such episodes, and might also allow for earlier lambing, although there would still be risks from unexpected cold spells later in the spring.

If winter temperatures rise, a change in cereal varieties may be required. Winter cereals differ in their vernilization (the number of days of cold weather that a plant needs to go into its sexual stage and produce seed). While some will be more suitable to milder climates, others will not be suitable for growing, since the lack of freezing days will lead them to be simply vegetative, without producing grain. Although spring cereals will not be affected, it will be necessary to consider the warmer winter temperatures when considering winter cereal variety choices. One view is that genetic modification may offer scope to develop more cereals that do not suffer as a result of mild winters, but the use of genetically modified organisms (GMOs) remains contentious. However, this may change in the future. For example, GMOs are presumed to be used widely in the World Markets scenario above, but are banned in the Local Stewardship scenario.

Many fruit trees and bushes also require cold winter weather to move from dormancy to flowering and growth. As with winter cereals, these crops, which include blackcurrant, apple and raspberry, require an accumulation of temperature below a particular threshold in order to form flower buds. Therefore, an increase in winter temperatures could delay formation of flower buds, or result in abnormality or failure of flowering, which would thereby reduce the subsequent crop of fruit. There have already been noticeable reductions in blackcurrant crops after mild winters (Bulgrove and Hadley, 2002), and further warming could have negative impacts for fruit growers, for example in the Vale of Evesham. In the short term, adaptation could involve substitution of cultivars to those that require less cold weather, while it may be possible to move away from crops such as apples to those such as peaches in the long term (Bulgrove and Hadley, 2002). However, the reduction in the frequency and severity of cold weather in the spring could also have benefits for horticulture through reduced frost damage to tender young shoots and buds.

Even for those cereals with lower vernilization, warmer, wetter winters will encourage more lush growth. While this may appear to be a benefit, the vegetation associated with cereal crops is not productive, but increases the amount of straw produced that has to be disposed of. Instead, planting could be left later to reduce growth, although there are risks associated with this, particularly if the land becomes waterlogged and it is not possible to cultivate it. The increased production of straw may be suitable for use as a biofuel.

7.3.5 Higher summer temperatures

For arable farming, milder winters and warmer summers carry the risk of more diseases and pests. This will be exacerbated by increased wet weather in the winter. Some of these pests and diseases are already present, but are controlled by the cold weather in the winter, while others may develop or move from more southern areas. In order to control these pests and diseases, it might be necessary to develop more resistant crops, perhaps through genetic modification, to increase the use of pesticides and fungicides, or to consider the use of natural predators. However, the first two options for adapting to this risk would need to be moderated given the uncertainty surrounding the use of GMOs and a desire to minimise inorganic applications to crops. The option to use natural predators would be favoured under the Local Stewardship scenario, but the feasibility of such an option would need to be assessed. Analysis of the hot summer of 1995 (Orson, 1997) suggests that there was an increase in the severity of diseases that establish themselves early in the life of the crop but do not exhibit their severity except in drought conditions (e.g. legume foot rots, asparagus wilt and phoma canker). The increase in pests and diseases can also be encouraged by reduced precipitation, which increases the concentration of sap for sucking insects and mites. This combination resulted in a major problem with red spider mite in outdoor crops of lettuce, apple and raspberry in the summer of 1995 (Bisgrove and Hadley, 2002), and could pose risks for horticulture in the West Midlands.

The higher summer temperatures and reduced cloud cover could generate increased demand for outdoor leisure and tourism in the region. This is discussed in greater detail in Section 9.3.5, but is mentioned in this section as there could be an opportunity for agricultural businesses to diversify to take advantage of this.

7.4 Policy Considerations

As outlined in Section 7.1, there is currently no regional policy for agriculture, although it is included in regional plans such as the England Rural Development Plan and the forthcoming regional interpretation of the Sustainable Food and Farming Strategy. In addition, the Regional Economic Strategy highlights a closely related cluster as a focus for development i.e. food and drink (the chain of producers, processors and retailers in the food and drink sector). The extent to which the region's agricultural produce is part of the supply chain for the region's food and drink cluster has not been examined in detail in this study but it is likely that they are closely related. Therefore there is a need to consider in more detail the opportunities and threats to the food and drink cluster as a result of potential climate change impacts on agriculture. This could be carried out as part of the development process for the food and drink cluster. Climate change may also present opportunities for agricultural diversification e.g. through tourism and leisure and production of energy crops. The tourism and leisure cluster development should therefore consider the impacts of climate change on agriculture and the forthcoming Regional Energy Strategy should consider the opportunities for the production of energy crops from agriculture and forestry.

7.5 Summary and Recommendations

Potential impacts and opportunities Increased precipitation and precipitation intensity during the winter could limit the use of land for agriculture due to an increased risk of flooding. Reduction in quality and quantity of grass caused by lower rainfall and higher temperatures during summer may require feed for livestock to be supplemented. There could be a reduction in yields of fruit, vegetables and cereals that do not have as much water during growing period. Some crops may flourish due to higher temperatures and increased carbon dioxide in the atmosphere. Changing climate conditions could make it possible to grow alternative crops, including crops for energy. Water available for spraying, irrigation and livestock may be restricted during drier summers. Higher summer temperatures and reduced cloud cover could increase the risk of heatstroke and sunburn for livestock in open pasture. Higher average winter temperatures could reduce problems for livestock in freezing weather. Higher winter temperatures and fewer days of freezing weather affects vernilisation of winter cereals and formation of flower buds on some fruit trees. Milder winter temperatures and higher atmospheric concentrations of carbon dioxide may result in more lush growth during winter, which could in turn create more straw. Higher temperatures could increase the risk of pests and diseases in arable and horticultural crops. Higher temperatures and reduced cloud cover could increase the demand for outdoor leisure and tourism, which could create opportunities for diversification.
Possible adaptation responses Farmers and policy makers need to consider various flood management options, including hard defences or alternative drainage systems. Alternative adaptation options would be to consider growing more water tolerant crops or converting the land to a non-agricultural use. Storage of winter precipitation in on-farm reservoirs may help to compensate for the reduction in summer rainfall. The change in the risk of pests and diseases could be controlled using new crop varieties, more pesticides, or natural predators. There is a need to maximise the opportunities presented for different crops by monitoring changes in both climate and consumer demand.
Recommendations There is a need to raise awareness amongst farmers about the potential future changes in climate, the effects of the impacts, and how to maximise opportunities. This awareness raising should also be extended to others in the agricultural supply chain and to consumers. Support mechanisms for opportunities need to be integrated into regional plans, especially the Regional Planning Guidance. The close links between the impacts on agriculture and other sectors, particularly water management and land use, need to be emphasised. This should also be the case for developing policy, with agriculture seen as part of the wider supply chain, especially linking to the Food and Drink Cluster of the Regional Economic Strategy.

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8. Energy

8.1 Context

Energy can be divided into three areas, generation, distribution and use. Although these are linked very closely, it can be useful to consider them separately.

8.1.1 Generation

Fuels can be used directly, to yield heat for example, or indirectly to generate electricity. Direct use includes use as fuel for transport and for home heating, and is considered in Section 8.1.3. Electricity generation in the UK is primarily from coal, gas and nuclear fuels.

Electricity generation in the West Midlands is not significant, although there are power stations at Rugeley and Telford. Therefore, most of the electricity used in the West Midlands is imported on the National Grid, particularly from the East Midlands, which has a number of large power stations. Generation from renewable resources in the West Midlands is also extremely small, with the region generating only 0.1% of its consumption from renewable resources in 2000 (WMLGA, 2001).

A future challenge to electricity generation across the UK will occur after 2025, if capacity becomes constrained. Although there was significant investment in new capacity in the 1990s in response to the high electricity prices, interest in investing in new facilities, except for renewables, has declined since then. In addition to the lack of investment, there is expected to be a decline in capacity as existing plants are retired. Policies to improve air quality are likely to cause the closure of some of the older coal fired power stations. Nuclear power currently supplies about 23% of the UK's electricity (DTI, 2003), but without any new nuclear power stations or extensions to the life of those existing, there will be only one nuclear power station in operation by 2025.

Although the current electricity generation in the West Midlands is fairly limited, there are potential opportunities. There are significant reserves of unworked coal in the region which have left a technical and environmental legacy in the form of mineshafts, methane ventilation, drainage for minewater and colliery spoilage heaps. The venting of methane, which currently contributes to climate change, could provide an opportunity for generation to supply local energy needs. Although conventional coal mining in the UK has fallen dramatically reserves in the region may continue to be exploited with newer, cleaner coal technologies such as coalbed methane (CBM) and underground coal gasification (WMLGA, 2001). There is also potential for renewable sources to be developed, such as biomass and wind (CLA, 2001).

8.1.2 Distribution

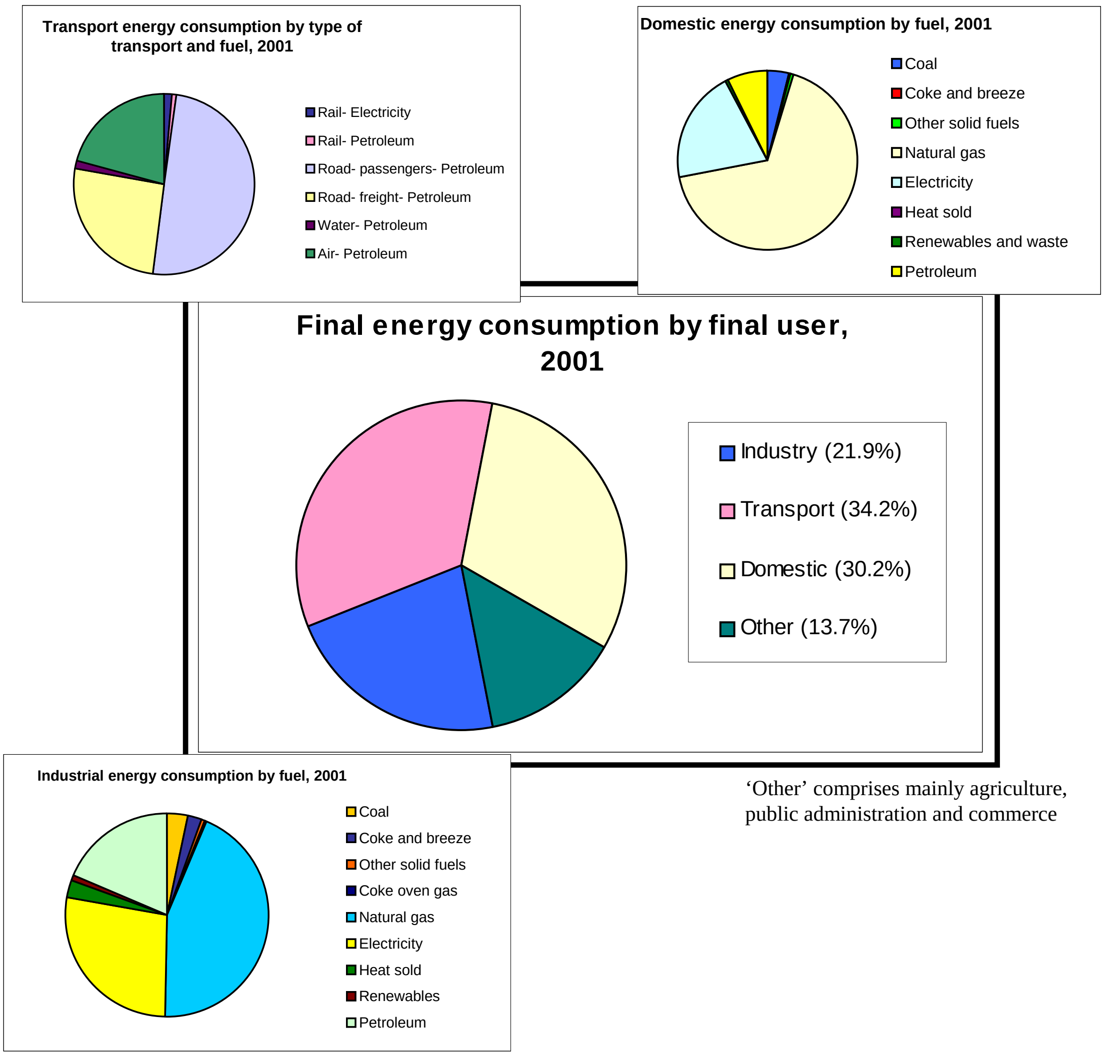
Distribution of fossil fuels tends to be by tanker lorries to petrol stations and individual homes, or for gas, through underground pipes. The distribution by tanker is seen as part of the discussion of transport in Section 10.

Electricity is distributed via a network of overhead lines and underground cables that runs throughout the UK. In the UK as a whole in 2000/01, there were 812,380 kilometres of electricity cables, of which 463,153 were underground cables and 349,227 were overhead lines. In general, overhead lines tend to be used in rural areas, whereas underground cables are used in urban areas.

8.1.3 Use

As elsewhere in the UK, energy use is dominated by fuel for transport, heating for households, and electricity by households and industry. The energy consumption of different sectors is shown in **Figure 8.1** below (Source: DTI). Figures for energy consumption in the West Midlands were not available, and therefore **Figure 8.1** shows use in the UK. This provides some indication of use in the region, but there are likely to be differences, in particular because the West Midlands has maintained its heritage of heavy industry which still accounts for just under 30% of gross value added in the region.

Figure 8.1 UK energy consumption by final user, 2001



'Other' comprises mainly agriculture, public administration and commerce

The demand for energy, or conversely the demand for energy efficiency, is driven in significant part by the price at which energy is available. The real price of energy for domestic use has been falling for a number of years - the prices for all fuels fell in real terms by 23% in the ten years to 2001 (DTI, 2002a) - and this has allowed the relatively unhindered use of energy. Indeed in order to meet its social objectives and to minimise the risks of fuel poverty for those households on low incomes, the government is committed to reducing the chances of high fuel prices by offering a reduced rate of VAT on domestic fuel (5% compared to a standard rate of 17.5%). However, the draft Regional Planning Guidance (WMLGA, 2001) has aimed to reduce domestic energy use through reduction in need rather than increasing prices. Policy EN3 states that plans should include measures to minimise energy demands from development by encouraging the use of energy efficient materials, and to encourage the use of combined heat and power and district heating systems.

In contrast to the low tax rates on domestic energy use, there are a number of government policies aimed at increasing the energy prices for transport and industry. Taxes on fuel for cars are particularly high, with a typical price of 74.9 pence per litre of unleaded petrol in March 2001 including 46.8 pence in excise duty and 11.2 pence in VAT (House of Commons Library, 2001). The rate of duty on fuel is now determined in each budget, after the road fuel duty escalator was revoked in November 1999 following significant political pressure.

The most significant policy affecting industrial energy prices is the Climate Change Levy (CCL), introduced in April 2001, following the recommendations of the Marshall Report (HM Treasury, 1998). The CCL was designed to be revenue neutral overall, with the tax compensated for through reductions in National Insurance Contributions, and there was an option for climate change agreements in forty four energy intensive sectors. However, the CCL was, and continues to be, widely opposed by business, particularly because it is not seen as revenue-neutral and it is perceived to have damaged international competitiveness and encouraged business to move abroad (Roberts, 2003).

Although this debate on the effectiveness of the CCL continues, there is ongoing political interest in the use of economic instruments to reduce carbon emissions and encourage energy efficiency (HM Treasury, 2002). Therefore, although no commitments have yet been made, further energy or carbon taxes may be introduced in the future.

The Energy White Paper (DTI, 2003), outlines three main challenges for energy in the UK. The first is environmental, particularly climate change, and prompts the endorsement of the challenging recommendation that the UK should reduce its emissions of CO_2 by 60% by 2050. The government hopes to achieve this through a move towards renewable energy (with a target to increase the percentage of UK electricity supplied from renewable sources to 10% by 2010) and improving energy efficiency. The target for renewable energy is supported by the Renewables Obligation, which requires electricity suppliers to source an increasing proportion of electricity from renewable energy. The second challenge is posed by the decline of the UK's indigenous energy supplies - oil, gas, nuclear and coal - some of which were mentioned earlier in this section. Although the Energy White Paper is realistic in its assessment of the need for foreign policy to support imports, the decline of traditional energy sources may also result in opportunities for the West Midlands to enter into the energy markets. This links to the third challenge - the need to update much of the UK's energy infrastructure. The closure of nuclear facilities and the likely shut-down of many coal-fired power stations in response to air quality controls will lead to a reduction in the traditional sources of electricity. The likely switch, at least to some degree, to renewables may again offer opportunities for the region. Technical studies as part of the draft Regional Planning Guidance (WMLGA, 2001) have indicated that over 15% of the region's energy requirements could be met using a combination of biomass, solar energy, energy from waste and wind power.

8.2 Social and Economic Change

As for the other 'hot issues', this analysis takes the socio-economic scenarios produced by UKCIP as a starting point. The sections of these scenarios relating to energy are shown in **Table 8.1** (UKCIP, 2001).

Table 8.1 Energy in the UKCIP Socio-Economic Scenarios

Local Stewardship (LS)	The exploitation of local energy resources is a particular feature of this scenario. A wide range of renewable energy technologies is exploited, facilitated by a willingness to invest in technologies with low rates of return. Some local coal resources are also exploited in this scenario, but with high standards of environmental control. Locally based combined heat and power schemes flourish. Green tariffs are taken up by environmentally conscious consumers and reinforce more formal regulatory controls. High energy prices lead to the large-scale adoption of energy efficiency measures.
World Markets (WM)	Energy markets are dominated by fossil fuels, particularly natural gas. Exploitation of alternatives to conventional oil begins. Demand for electricity and transportation fuels continues to grow. Electricity supply investments are generally in modular, distributed power systems. Energy prices remain low, and there is little concern for energy efficiency, although most of the easy energy efficiency opportunities have been realised. High discount rates and the low priority attached to global environmental problems preclude the widespread adoption of renewable energy. Neither is there a revival of nuclear power because of high discount rates and low fossil fuel prices.

As indicated in Section 8.1, energy distribution and use in the West Midlands are largely similar to other parts of the country, although generation takes place largely outside the region, with both fossil fuels and electricity imported. Under the World Markets scenario many of the current trends in energy would continue because of the dominance of fossil fuels and generation in the West Midlands would remain limited, with most electricity and fuels imported into the region.

In contrast, the Local Stewardship scenario would involve significant change to energy generation, distribution and use. In particular, the move towards local energy resources could increase the viability of using the region's coal supplies to provide energy. Although the scenario suggests a move away from traditional coal mining, and high standards of environmental control, there could be opportunities to use newer, cleaner coal technologies. These opportunities would also fit with the stated aims of the draft Regional Planning Guidance (WMLGA, 2001).

The Local Stewardship scenario would also pose both threats and opportunities for the industrial sector of the West Midlands. In contrast to the World Markets scenario, energy prices would rise to high levels, resulting in a significant financial burden for energy-intensive manufacturing. However, the high energy prices would generate demand for energy efficiency improvements and there would be a significant move towards the use of renewable energy resources. Under this scenario, there could be opportunities for the skills and technologies currently used in West Midlands' industry to be applied to the development of both energy efficiency and renewable energy technologies.

8.3 Potential Impacts of Climate Change

This section considers the potential impacts of climate change on the generation, distribution and use of energy in the West Midlands. However, it should be noted that these activities will also have impacts on the extent of climate change, and there may be options available to mitigate the impacts. However, the impacts of energy on climate change and mitigation is beyond the scope of this report.

8.3.1 Generation

The potential climate changes outlined in Section 4 indicate that there could be a significant reduction in cloud cover in the summer months, with a fall of up to 16% by the 2080s. This could result in opportunities for the region in the use of solar power technologies. As noted earlier, the region currently generates very little of its energy requirements from renewable sources, although policies in the draft Regional Planning Guidance (WMLGA, 2001) aim to encourage the use of renewable energy resources. Wind power may also be an option, although this is less likely given the marginal wind resources of the region for power generation and only marginal increases in average wind speeds estimated in the UKCIP02 scenarios. However, the extent and effectiveness with which renewable power technologies can be used in the region will not only depend on the weather conditions, but will also depend on the development of the technologies with which to take advantage of the reduced cloud cover. Although this is to some extent outside the control of those in the West Midlands, it may also offer opportunities for the region's manufacturing sector to develop these products.

In addition, the potential reduction of water quantities in summer must be considered for the operation of UK power stations, which use water for cooling (TRL, 2002). This would be particularly problematic if the demand for electricity during the summer increased for use in air conditioning. Although there is little electricity generation in the West Midlands, the power generated in other areas is used in the region, and therefore, the potential impact should not be ignored.

Figure 2.11 illustrated the dispersion of pollutants from power stations on a particular day with a northeasterly wind, with many of the air quality impacts occurring downwind of the large power stations in Nottinghamshire and Derbyshire. The climate change scenarios outlined in Section 4 suggest that although summer wind speeds are expected to remain fairly constant, winter wind speeds could increase by up to 7%. This may affect the air quality impacts of the emissions from power stations, and although there is not sufficient certainty about this to make any definite predictions, the pollution risks should be re-evaluated (UKCIP and EPSRC, 2003). The prevailing wind in the region is likely to remain southwesterly and this would disperse pollutants out of the region.

8.3.2 Distribution

As discussed in Section 4.2, the UKCIP02 scenarios suggested that under the medium-high scenario, the number of depressions (storms with high winds) during an average winter could increase from five to eight, although confidence on this issue is low. This could result in significant risk for the distribution of power, especially electricity supplied in overhead cables. The West Midlands suffered significant damage from storms in the winter of 2002, when up to 30,000 people across Worcestershire lost power supplies (Birmingham Evening Mail, 28th October 2002). Much of the damage was a result of growing trees contacting lines or falling trees and broken branches contacting lines, with little evidence of inadequate design or maintenance (DTI, 2002b). In response to the disruption to power supply, OFGEM has announced that the companies operating the disruption networks across the UK will be required to pay £1.8 million in compensation. Aquila, which supplies customers in Birmingham and parts of Staffordshire, Shropshire, Herefordshire and Worcestershire, will be required to pay £92,650 to just over 1000 claimants (OFGEM, 2003). The report into the storms for the DTI (DTI, 2002b) found that those distribution companies with the best record were “more accurate in estimating the relationship between the forecast bad weather, physical damage to the network and the resources required to effect repairs and restore supplies speedily”. The report also highlighted the need to invest effectively in maintenance of trees near power lines.

Increased mean winter temperatures and the reduction in the number of days below freezing would have positive impacts on the energy distribution infrastructure. Freezing rain and fog can lead to a build up of ice on power cables, which then stretch. At its extreme, this can pull the pylons together and cause collapse of the distribution lines, causing failure of the power supply to homes and businesses. Even where the damage has less dramatic effects, it increases the need for maintenance. Therefore, an increase in temperatures reduces this risk and the costs associated with it. It also reduces the risk of damage to the insulators separating the pylons and lines that are susceptible to damage in freezing conditions.

However, increased summer temperatures could increase the sag of the cables on the electricity distribution network. This reduces the space between the cables themselves, and between the cables and nearby structures. If higher wind speeds also occur, the risks are increased, although there is not predicted to be significant change in summer wind speeds (Hulme et al., 2002). Higher temperatures might also reduce the capacity of the overhead lines (TRL, 2002).

As is the case in much of the discussion of infrastructure in a number of sectors, the increased intensity of winter precipitation and the associated increase in soil moisture and flooding could increase the risk of damage to the foundations of the energy distribution network. This could increase the amount of network maintenance required in order to minimise the number and length of disruptions to power supply. It is unclear at this stage whether more dispersed generation would help to reduce these problems. Local production and distribution, which could increase under a Local Stewardship scenario but would not under a World Markets scenario, could reduce the distance over which electricity was transported. This may in turn help to minimise damage and disruption associated with climate change, although it will be necessary to consider the relative risks of damage and disruption associated with alternative distribution systems in more detail.

The reduction in summer precipitation could exacerbate the risk of damage to energy infrastructure by increasing the risk of soil subsidence, particularly of clay soils. This would not only risk damaging electricity pylons, but could also risk damaging the underground pipes used to distribute gas.

8.3.3 Use

Milder winter weather is linked to lower demand for energy for domestic heating. It is also expected that demand for energy for space heating in other sectors would decline in milder weather. However, 62% of domestic energy consumption is used for space heating (DTI, 1995 cited in Palutikof), whereas space heating is a much lower proportion of total energy use in other sectors, and therefore the correlation between energy use and temperature is not as clearly defined. The change in energy demand is likely to vary by energy type, with demand for gas, which is used primarily for heating, falling much more than demand for electricity, which has a range of domestic uses. The warm winter of 1994 caused a fall in consumption of gas equal to a £220 million saving in the UK domestic sector, as well as a £95 million saving in the public administration/commerce/agriculture sector (Palutikof et al., 1997). This reduced demand for fuel could have a positive effect on the number of households in fuel poverty, defined as a household that needs to spend more than 10% of its income on all fuel use, including heating its home to an adequate standard. The most recent statistics suggest that 11% of households in the West Midlands live in fuel poverty, compared to an average of 8.6% for England (BRE, 2003), so this could be a significant benefit to the region.

In contrast to the analysis above of the potential reduction in winter demand for energy caused by higher winter temperatures, warmer summers may result in an increase in the demand for energy. In the assessment of the effects of the warm summer of 1995, it was found that gas consumption fell, saving the domestic consumer £74 million across the UK compared to an average year (Palutikof et al., 1997). However, electricity demand increased by £34 million. In the period studied (1972-1995), the relationship between summer temperatures and demand for electricity changed from a negative relationship at the start of the period to a positive relationship at the end. If this relationship continues, it suggests that future warm summers could result in much greater increases in demand for electricity. This is primarily for space cooling and refrigeration, and may also have a significant effect on the use of electricity by industry and public administration/commerce/agriculture. Where demand for space cooling does occur, it will be important to consider low emissions ways of providing this cooling. An alternative to air conditioning and mechanical cooling is the use of natural ventilation, which is discussed in Section 9.3.4.

Increases in temperatures over the summer months could be felt disproportionately in built-up areas - the ‘urban heat island’ effect. This would make summers more uncomfortable in urban areas, and could encourage people living in the city to travel to the countryside in their leisure time for more comfortable temperatures. There would also be further motivation to travel to the rural areas because of the warmer weather. The increased number of trips would require more energy to be used for transport, particularly if people used private cars to make their journeys. This links to the discussion of transport in Section 10.3.2.

8.4 Policy Considerations

The Energy White Paper, outlined in Section 8.1, proposes that future policies will require greater involvement from English regions and local communities, complemented by a planning system that is more helpful to investment in infrastructure and new electricity generation, particularly renewables.

The forthcoming Regional Energy Strategy will focus on energy in the West Midlands. It should consider the potential impacts of climate change in the region alongside how the above objectives can be met in the region. It will also be important for the strategy to link the possible impacts and adaptation measures discussed here to energy efficiency and climate change mitigation measures, since the link between adaptation and mitigation for energy is very close. For example, if the demand for summer cooling increases, and this demand is supplied using fossil fuel based power generation, this could lead to greater emissions of greenhouse gases.

8.5 Summary and Recommendations

Potential impacts and opportunities

Milder temperatures could reduce demand for energy to provide heating during winter months.

Lower winter fuel demand associated with higher winter temperatures could reduce the number of households in fuel poverty.

The risk of damage to infrastructure from freezing weather and ice could be reduced during milder winters.

Higher summer temperatures could increase the demand for energy for cooling (air conditioning and refrigeration).

High temperatures during summer could increase sagging of electricity distribution cables.

The urban heat island could increase the demand for energy for transport to travel to cooler, rural areas for leisure.

Possible increases in storm frequency could increase the risk of damage to electricity distribution infrastructure.

Changes in precipitation and cloud cover could increase the potential for the use of solar power and biofuels.

Periods of increased rainfall and increased rainfall intensity during the winter could increase the risk of damage to infrastructure from flooding.

Reduced summer precipitation could increase the risk of subsidence during summer droughts, particularly on clay soils.

Reduced summer precipitation could impose constraints on power stations through limited availability of water for cooling during the summer.

Changes in the pattern of wind directions and speeds could change the dispersion of pollutants from power stations and industrial plants.

Possible adaptation responses

Use low emissions air conditioning, shading or natural ventilation to cool buildings in summer.

Improve prediction of impacts of storms and encourage ongoing maintenance, for example clearing trees near wires.

Respond to opportunities for West Midlands' manufacturing to contribute to electricity generation from renewable energy.

Use alternative technologies to reduce demand from water-cooled power stations in the summer.

Recommendations

The forthcoming Regional Energy Strategy needs to reflect potential climate change impacts and adaptation options.

There is a need to raise awareness of the use of energy in buildings with clients, customers, developers and builders, and the possible changes in demand as a result of climate change. However, this must be focused on specifics, particularly that alternative technologies need not cost more than those currently used.

More generally, there is a need to raise awareness of energy and climate change, perhaps through the linking it to the current trend for 'home and garden' programmes, and link this to financial incentives and regulations.

Energy suppliers and planners should consider using scenarios that describe possible changes in demand from winter space heating to summer cooling and develop appropriate plans.

Methods for improving the energy efficiency of buildings need to be considered e.g. supplementary planning guidance and procurement specifications, to minimise the increase in the use of energy as a result of climate change.

Energy suppliers need to consider the potential impacts of climate change on their distribution networks in order to assess the potential economic costs and ensure that the necessary investment is made in any changes required.

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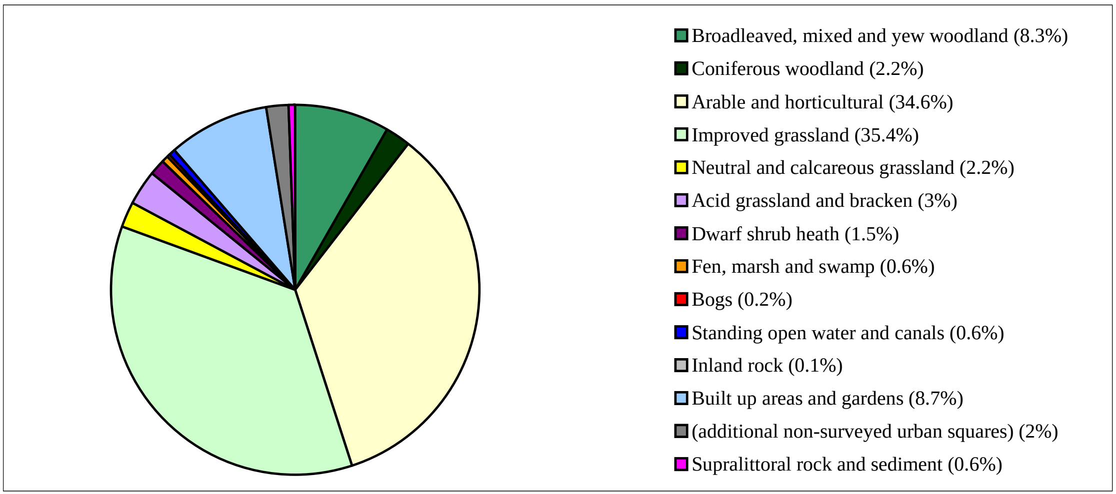
9. Land Use and the Built Environment

9.1 Context

Land use in the West Midlands is currently dominated by agriculture and forestry, with over 80% of the land area of the region used in this way. Arable and horticultural enterprises use 34.6% of land, and improved grassland accounts for 35.4%. Forestry covers 10.5% of land, of which the majority is broadleaved or mixed woodland. Land use in the region is shown in **Figure 9.1** below (National Statistics, 2002).

Figure 9.1 Land Use in the West Midlands, 1990



However, the region is not entirely rural, and these figures disguise significant regional differences. The east of the region, in the area around the Birmingham conurbation, is much more densely populated, with an average density of 28 people per hectare, compared to a national average of 3.6 (1991 population census). In these areas, much of the land is used for housing and industrial buildings. Half of the 2,079,000 dwellings and 40% of the 136,000 businesses in the West Midlands region are in the Metropolitan County of the West Midlands (National Statistics, 2002). There is also an increasing use of land for urban development. The most recent figures relate to 1997, and show an overall increase of 1,355 hectares in land used for urban development. Of this, 35% had been rural and 65% was already urban (the majority of which had been previously developed) (National Statistics, 2002).

The main regional policy for land use is the draft Regional Planning Guidance (RPG), which is currently available in draft form for consultation (WMLGA, 2001). One of the major priorities in the draft RPG is the regeneration of urban areas. The following bullet points outline the ten priorities of the draft RPG (the text in brackets refers to the policy titles):

1. To make the Major Urban Areas of the West Midlands increasingly attractive places where more people will choose to live, work and invest (Urban Renaissance);
2. To secure regeneration of the rural areas of the Region (Rural Renaissance);
3. To support the diversification and modernisation of the Region's economy whilst ensuring that opportunities for growth are linked to meeting needs and reducing social exclusion (Balance of economic growth across the region and regeneration areas);
4. To improve significantly the Region's transport systems to a quality comparable to that of competitor regions (Developing accessibility and mobility);
5. To ensure the quality of the environment is conserved and enhanced across all parts of the Region (Conserving and enhancing the environment);
6. To retain the Green Belt but to allow an adjustment of boundaries where this is necessary to support urban regeneration (Green Belts and Urban Renaissance);
7. To support the cities and towns of the Region to meet their local and sub-regional development needs (Meeting development needs beyond the Major Urban Areas);
8. To promote the development of a network of strategic centres across the Region (The development of a network of strategic town and city centres);
9. To promote Birmingham as a 'World City' (Developing Birmingham as a World City); and
10. To create a joined up multi-centred regional structure where all areas have distinct roles to play (The development of the Region).

In spatial terms, it is particularly the outward movement of people and jobs away from the major urban areas which is increasingly recognised as an unsustainable trend and one which provides the region with a key challenge. The trend is seen to be leading to pressures on the environment, to be increasing the need for car-based travel, to be having little benefit for rural areas and creating dangers of abandonment and greater social polarisation within the region. (WMLGA, 2001)

This policy is supported by others favouring the location of economic growth opportunities in the Major Urban Areas (Policy SS3A), the encouragement of Birmingham as a 'World City' (Policy SS9), and the focus on planning policies for urban areas. The draft Regional Planning Guidance suggests that development should be concentrated in the Major Urban Areas, and aims to exceed the national target of 60% for new development on brownfield land by 2008, with a regional target of 65% by 2011 (Policy CF5). This is further enhanced by a policy offering no opportunity for development of the Green Belt for housing development, although development would be considered for selective employment opportunities and for park-and-ride schemes (Policy SS6). Particular foci for development are the Urban Regeneration Zones in East Birmingham and North Solihull, North Black Country and South Staffordshire, North Staffordshire, Coventry and Nuneaton, and West Birmingham and South Black Country.

However, the draft Regional Planning Guidance also recognises the needs of the rural areas of the region, and offers support for rural regeneration through expansion of the local economy in strategic towns and enhancement of the transport infrastructure to allow access from rural areas. There is also support for the Rural Regeneration Zone proposed by Advantage West Midlands, which covers large parts of Herefordshire, Shropshire and western Worcestershire.

Finally, it is worth noting one point on the inclusion of the impacts of climate change in the draft Regional Planning Guidance. Policy QE14 states that "development plans and other strategies should take into account the land use implications of the predicted climate change scenarios for the West Midlands."

9.2 Social and Economic Change

As is the case with all the 'hot issues', climate change will be one of only a number of changes exerting influence on land use and the built environment. **Table 9.1** provides information on possible future socio-economic changes (UKCIP, 2001a). In addition, it seems likely that the changes in land use will be driven by changes in a range of other sectors, particularly housing, industry, transport, agriculture and tourism. However, other sectors have not been considered explicitly in this section. Quantitative information on the potential changes in land use under the two scenarios is given in **Appendix D**.

Table 9.1 Land Use and the Built Environment in the UKCIP Socio-Economic Scenarios

Local Stewardship	Tight planning controls over the countryside and the need to preserve land for agricultural production leads to denser urban development. Growth is concentrated within existing towns and smaller cities. Government policy encourages the conversion of urban land to natural vegetation. There is general migration away from the larger cities and a corresponding growth of small and medium-size towns more suited to a smaller-scale local development path. The distinction between countryside and towns is preserved. Planning favours mixed residential and commercial development and decentralisation. As a result, overall transport volume decreases. Improving the quality of housing is a political priority for social as well as environmental reasons (energy efficiency). However, efforts are limited by budget constraints. Investments in transport infrastructure are low as the demand for mobility remains stable.
World Markets	The planning system is weak and is not used to counter-act wider social and economic trends. New housing development will take place along the main transport lines leading to London, in the Midlands, the North West and the South of England. High investment in the built environment drastically improves the quality of the housing and transport infrastructure. The turnover of office and residential buildings increases. There is more rapid adoption of innovative technologies (e.g. information technologies).

Under the Local Stewardship scenario, urban development would become more dense, and would be concentrated in towns and smaller cities. Although unspecified at a regional level, in the West Midlands this could include some of the towns on the margin of the Birmingham conurbation, such as Coventry, Solihull and Wolverhampton, as well as those further away such as Newcastle-under-Lyme and Stoke-on-Trent, Shrewsbury and Hereford. Under this scenario, there would be limitations in budgets but the planning system would be strong, supporting the political, social and environmental motivation to improve the quality of the built environment, which could drive development of both rural and urban regeneration zones.

In contrast, the World Markets scenario would not exert strong limitations on the location of built development. Therefore, housing development would tend to take place along the transport corridors. In the West Midlands, this could include Telford on the M54, Newcastle-under-Lyme and Stoke-on-Trent, Stafford and Coventry on the M6, Worcester on the M5 and Leamington Spa and Warwick on the M40. The quality of buildings in this scenario is high. This could help to contribute to some of the regeneration objectives in the region outlined in the draft Regional Planning Guidance (WMLGA, 2001).

9.3 Potential Impacts of Climate Change

9.3.1 Increased average winter precipitation and increased number of intense winter precipitation events

The increased rainfall expected under the climate change scenarios is likely to increase the risk of flooding over the winter months. Land currently considered to be at risk of flooding is mapped by the Environment Agency (see **Figure 2.7**), and this can be seen by those anticipating a change of land use, particularly for housing development. However, the maps only reflect present risk, and do not take account of potential climate change. The draft Regional Planning Guidance (WMLGA, 2001) states that "development should not be permitted if … it would be at unacceptable risk of flooding … [or] otherwise unacceptably increase flood risk" (Policy QE11). Houses and buildings are at particular risk from flooding, because the costs associated with a flood can be high. A case study of the costs of flooding on property is detailed in Section 11.3. However, land used for recreation, agriculture or other uses may also be flooded, with potentially high costs for the user. The risk of flooding should be fully considered in development plans, and it might prove to be necessary to leave some land undeveloped and uncultivated to accommodate regular flooding.

In urban areas, the risk of flooding is increased if there is inadequate drainage. On undeveloped land, water is able to soak through the surface. However, in built environments much of the land is covered with tarmac or concrete, which does not allow the water to soak through. Therefore, the development must have sufficient drainage to prevent water accumulating on the surface and causing flooding. One of the main problems with current drainage systems is that during periods of prolonged or intense rainfall, the capacity of the drainage system is exceeded and water backs up from the drains to flood the surrounding area. In order to minimise the risk of flooding under the climate change scenarios it will be important for developers to consider increased average winter precipitation and increased risk of storms in planning developments. Capacity to cope could be increased by resizing some of the pipes used in the drainage system of existing developments and using larger pipes in new developments. Another alternative would be through the use of Sustainable Drainage Systems (SuDS), although it will be necessary to compare the ability of these drains to cope with climate events with the increased maintenance requirements. It could also be necessary to re-evaluate the design standards for urban drainage. The following case study indicates some of the issues associated with urban flooding in Birmingham. Assessment of the potential costs of flooding in property is given in Section 11.3.

Land Use and the Built Environment Case Study 1: Urban Flooding in Birmingham
As an example of possible adaptation to climate change, this brief case study provides an overview of the measures being implemented by Birmingham City Council in response flooding in urban areas. Birmingham has a unique topographic position being on top of a dome at the headwaters of a number of catchments. The city is vulnerable to high intensity, short duration storms in summer, which differ considerably from the type of flood event which often makes the headlines along the River Severn for example. The difficulty for the City Council is in the prediction of these flood events as this relies on the accuracy of weather forecasts, and quite often, the events occur at very short notice leaving the City Council and residents with little warning. The problem results in flash floods which often exceed the historic design limits of drains and culverts. In response to the issue the Council has instigated a number of actions. Works have been undertaken to the River Rea that is a major ordinary watercourse. Where particular hardship has been suffered the Council has also undertaken a number of schemes to provide some increased protection against flooding. Secondly a flood co-ordinator has been appointed to help individuals and groups prepare for future flooding, to liaise on proposed works and to engage more widely with the public on their concerns in specific locations across the city. Thirdly the Council is working with the Met Office on a research project to determine whether it is possible to provide better weather warning to match local conditions.

9.3.2 Reduced summer precipitation

The main risk from reduced summer precipitation relates to the potential impacts of subsidence on the built environment. Subsidence is particularly likely on clay soils, which shrink in dry conditions. This situation is thought to be exacerbated by trees, which extract water from the already dry soil. Buildings with foundations in such soils are at risk of damage. Figures for the particularly dry summer of 1995 found that subsidence-related insurance claims in the UK were up £197 million compared to 1994 and up £143 million compared to the average for the previous three years (Palutikof et al., 1997). **Table 4.6** suggests that similar conditions could occur in one in every ten years by the 2020s and in one in every two years by the 2080s.

9.3.3 Increased winter temperatures

As discussed in Section 7 on agriculture, warmer winters and the increased concentration of carbon dioxide may increase the rate of growth of agricultural crops and forestry. Agriculture may offer an opportunity for short rotation coppice, such as willow, for use as a source of renewable energy. On a slightly longer-term basis, the management of woodland for the production of timber could be important to the region’s economy. This is enhanced where the timber is sold locally. Milder winters may enhance the productivity of this sector of the economy, in line with Policy QE7 of the draft Regional Planning Guidance (WMLGA, 2001). It will be important to consider both the economic benefits of the forestry and associated industries, and potential environmental and social opportunities, for example for biodiversity or recreation.

Increased winter temperatures could have positive effects on the built environment through reduced damage caused by cold weather. In particular, the milder conditions could reduce the number of burst pipes. During the mild winter of 1994/5, UK insurance claims made for damage from burst pipes was £47 million lower than over the previous winter, and £127 million lower than the average for the preceding three winters (Palutikof et al., 1997). However, in interpreting these benefits, it is important to note that they rely on increased mean temperature, while there may still be significant damage resulting from a single spell of cold weather.

In contrast to the potential benefit above, the increased winter temperatures could also increase the growth of mould in houses (UKCIP, 2001b). This is already a major source of respiratory illness, and could be a particular problem in the tenth of housing already declared unfit for living in the West Midlands. The potential risk will depend on the degree of investment in housing. Under both the Local Stewardship and World Markets scenarios there is high investment in housing, although budget constraints limit this in the former scenario.

9.3.4 Increased summer temperatures

As mentioned elsewhere in this report, the increased temperatures predicted for the summer months are likely to be felt most strongly in the urban areas due to the urban heat island effect. Climate change could exacerbate the urban heat island effect. The trend towards urban densification and use of brownfield land for building encouraged in the draft Regional Planning Guidance (WMLGA, 2001) could add to discomfort. On the other hand, green spaces in the urban areas could help to counteract the urban heat island effect, and also provide outdoor space for recreation. The balance between competing demands for land, and particularly methods for extending the amount and quality of open space in urban areas, will need to be considered as part of development plans in order to prevent limiting climate change adaptation options. This consideration should also take account of a potential increase in demand for rural accommodation if the temperatures in the cities become uncomfortable.

Higher temperatures could reduce building comfort, in homes, offices, factories and shops. Although it might be possible to compensate for this using air conditioning or mechanical fans, both of these increase energy use, so are likely to raise costs and contribute to climate change. The potential change in the demand for electricity for cooling was discussed in Section 8.3.3. Alternatives to mechanical cooling include using shading from trees and blinds, and natural ventilation, which can be seen as both adaptation and mitigation measures. These have been used in the new Arup offices in Birmingham, as discussed in the box below.

Land Use and the Built Environment Case Study 2: Arup Associates' Campus

Arup Associates, an engineering consultancy firm, was closely involved in the design of their new offices at Blythe Valley Business Park in Solihull. Although they had considered buying the land, they eventually opted for a twenty year lease for the building, and therefore the design and budget had to be agreed with the site developer. There were a number of design specifications, including an open plan workspace to encourage communication, flexibility of use, and natural ventilation.

During the design phase, Arup undertook modelling to ensure that the natural ventilation offered maximum comfort and minimum energy use. Modelling of the local weather conditions was also used to ensure that the ventilation worked equally well during winter, which has been a problem in other natural ventilation schemes.

The most efficient way to meet requirements for space planning and site utilisation was to opt for a 24 metre deep floor plan, far greater than the 12-15 metres limit normal for naturally ventilated buildings. Using the modelling, it was found that to make natural ventilation work it was necessary to eliminate direct solar gain, reduce requirements for artificial light, and provide sufficient internal thermal mass to make use of night time cooling. The thermal mass cools as the temperature falls overnight, and heats much more slowly than the surrounding air during the daytime, helping to keep the air cooler for longer.

As a result, there are large windows, with openings at the top and bottom to allow maximum daylight and ventilation. However, there are louvred timber shutters to control solar glare. The required thermal mass is provided by concrete floor and ceiling panels, which are also part of the distinctive style of the building.

The success of the scheme is now being monitored using sensors built into the concrete flooring, although initial indications from those using the building suggest that it is working well.

9.3.5 Reduced cloud cover

The combination of increased summer temperatures and more hours of sunshine is likely to increase demand for outdoor leisure and recreation. This effect is briefly considered Section 8.3.3 in relation to energy demand for transport and in Section 10.3 in relation to cycling and walking, but would also increase demand for undeveloped land, parks and play-areas, and sports facilities. Although the West Midlands has over 21,000 hectares of formal open space and more than 1700 sports pitches, the continuing demand for new development has resulted in a steady loss of these amenities (WMLGA, 2001). Furthermore, the draft Regional Planning Guidance expresses concern that this trend could continue under policies aimed at increasing urban capacity. On the other hand, with policies such as those suggested in the Local Stewardship scenario, the planning controls would balance denser urban development with conversion of urban land to natural vegetation.

The increased demand for outdoor leisure could also have potential benefits for the West Midlands. There may be opportunities for developing tourism and recreation, particularly in the more rural areas in the west of the region. This could provide inward investment in areas of need but would need to be matched by appropriate infrastructure and transport alternatives.

9.4 Policy Considerations

The draft Regional Planning Guidance (RPG) sets out the main priorities for spatial development over the next 20 years, as outlined in Section 9.1. The draft RPG already contains policies on climate change e.g. development in the flood plain. However, this is a starting point and more consideration needs to be given to how climate change could affect the spatial development of the region, for example as follows:

- Where and how can more green, open spaces and wetlands be developed to benefit both the region’s population and biodiversity?
- Where and how can more forestry and woodlands be developed - again to benefit both the region’s population and biodiversity and contribute to the economic development of other sectors such as tourism and leisure?
- How can built developments be designed and implemented that can adapt to climate change? How can the performance of buildings under climate change conditions be improved?
- How can increased flood risk be managed?

9.5 Summary and Recommendations

Potential impacts and opportunities

Increased winter precipitation and precipitation intensity could make more land unusable or of limited use due to risk of flooding.

Urban developments without adequate drainage could be at increased risk of flooding during periods of intense winter rainfall.

Buildings could be at increased risk of damage from subsidence of clay soils during periods of low rainfall in the summer.

Changes in climate variables could result in greater opportunities for forestry and may increase land used for trees.

Agricultural responses to changes in climate may increase or decrease amount of land used for agriculture.

Increased winter temperatures reduce damage to the built environment, particularly from frost.

Milder winter temperatures might increase the growth of mould in houses.

Higher summer temperatures in the urban areas could increase the demand for rural living.

There may be an increased demand for green, open spaces in urban areas, especially in warm summer months.

Increased temperatures in urban areas, particularly during the summer, could require various cooling strategies to be considered.

Higher summer temperatures could increase the demand for outdoor activities and require more land for outdoor recreation and leisure.

Possible adaptation responses

Land at risk of flooding could be left undeveloped, or could include open spaces to encourage drainage.

Larger diameter drains or sustainable urban drainage systems could improve capacity to cope with intense winter precipitation.

More open spaces could be included in urban planning to provide local opportunities for outdoor leisure.

Natural ventilation could be used to reduce the discomfort of high summer temperatures.

Recommendations

The development of plans and policies should involve consideration of the potential changes in land use that may be appropriate in response to potential climate change in the region.

Given the life of buildings, design standards may need to be re-evaluated to take account of the potential impacts of climate change.

It would be useful for policy makers to have a visual picture of the potential impacts of climate change in order to make it easier to incorporate it into policies.

There is a need to convince policy makers that climate change and the adaptation options have economic consequences. There may be a need to link this not only to the Regional Planning Guidance, but also the Regional Economic Strategy.

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10. Transport

10.1 Context

Due to its geographical position in the centre of the country, the West Midlands is at the heart of the national transport infrastructure. Travel can take place on the ground, on water or in the air, and these modes are both complementary and substitutable in different circumstances.

Surface transport consists primarily of road and rail travel, but also includes cycling and walking. The road infrastructure in the West Midlands includes a number of motorways, particularly the M6 running from the M1 and the east of the region north to Glasgow, the M5 past Birmingham to Bristol and the South West, and the M40 and M42, which skirt the eastern edge of the region. The M6 is one of the main roads in the Ireland-UK-Benelux Road Link, which involves a number of upgrades along the route, and includes the construction of the Birmingham Northern Relief Road, likely to take until at least 2005. This has attracted particular attention as the UK's first major toll road, although there are no plans to introduce further toll roads in the region. There are a number of other economic changes that may influence the use of road transport in the region. In particular, the government is currently planning to introduce a distance-based lorry road user charging scheme in the UK from 2006. The plans are still at a relatively early stage, but consultation indicated that a distance-based charge would be preferred to a time-based charge. In recognition of the other charges currently paid by hauliers, in particular through vehicle excise duty and fuel duty, the charge would be offset by reductions in other duties. As well as the links with other regions, local transport is also important. This is particularly emphasised in the Regional Transport Strategy (WMLGA, 2001), which aims to increase the number of journeys made in 'alternative' transport and not in cars.

Congestion in the Birmingham conurbation is particularly problematic, and there is concern that the increasing congestion threatens the economic development of the Major Urban Areas in the region. In order to counteract this, the draft Regional Planning Guidance (WMLGA, 2001) suggests support for expanding transport capacity. The West Midlands Multi-Modal Study commissioned by the government and published in 2001 suggested that £7.5 billion of investment will be required over the next 30 years to alleviate congestion in the region. A possible complement or alternative to this would be to use some form of congestion charging similar to that introduced in London at the start of 2003. Birmingham, in line with many other UK and international cities, has adopted a 'wait and see' policy on introducing congestion charging. Although the London scheme is still relatively new, it would appear to have been fairly successful in reducing congestion and increasing traffic speeds (although this in turn indicates a lack of success in raising revenues), and such schemes might therefore become more attractive to cities like Birmingham.

The main rail route through the region is the West Coast Main Line, which runs from London to Glasgow and Edinburgh. Main stations on this line in the West Midlands are in Stafford, Wolverhampton, Birmingham, Coventry, and Rugby. This route is currently undergoing a significant programme of improvements, linked to the introduction of tilting trains. The improvements aim to reduce journey times and delays and increase freight and passenger numbers, although they have recently been put back to budget overspend.

Because the region is land locked, there are no ports in the region. However, there are a large number of canals, a legacy of the region's industrial heritage. Although these were historically central to freight transport, they are now primarily used for leisure purposes. The use of canals for transferring water is considered in Section 6.3.5.

Air transport focuses primarily around Birmingham International Airport, although there is also a smaller airport at Coventry. Birmingham International Airport is currently the second largest regional airport after Manchester, with over 20 carriers serving more than 50 destinations, including a small number of long haul destinations. The number of passengers using the airport is increasing over time, with an average annual growth rate of around 10% per annum. Coventry Airport is much smaller, and did not have any scheduled services in 2000. However, it is important for freight, although traffic has fallen recently. Three other airports in the West Midlands "are considered to have potential for accommodating commercial activity" (Department of Transport, 2002): Wolverhampton Business Airport, Wellesbourne in Warwickshire and RAF Cosford in Shropshire. An option proposed in the consultation for the Air Transport White Paper, which is discussed below, is to develop a new airport between Rugby and Coventry. The potential benefits of this airport depend on the assumptions made, particularly its relationship with Birmingham, but could include improved access by public transport and a reduction in the number of people affected by noise. However, it would have significant land use implications. Outside the region, East Midlands Airport at Castle Donington and Manchester Airport to the north of the region are the most easily accessible.

The future development of air transport in the region will be determined not only by social and economic trends, but also by the proposals contained within the Air Transport White Paper due to be published in 2004. In order to inform the White Paper, there is currently a national consultation on alternative development options (see Department of Transport, 2002). Six alternative development options are discussed in the consultation papers, each of which will have a different impact on the development of air transport in the West Midlands and consequently on the effects of climate change. The first four options indicate the relationship between development in the West Midlands and elsewhere in the UK, while the last two consider development within the region. These options are described more fully in the consultation papers, but are described broadly in **Table 10.1**.

A further discussion that is taking place as part of the consultation for the Air Transport White Paper concerns the use of economic instruments to internalise the external costs associated with aviation. Although regulation has been used in the aviation sector, particularly to limit noise, there have not been many moves towards economic instruments, as there has been in other sectors. This is primarily limited by the international nature of air transport and the associated international laws, particularly the Chicago Convention. Despite these limitations, it is possible that a tax or permit scheme could be introduced to limit the environmental and climate change impacts of aviation. Introduction of aviation taxation could be expected to change demand for air transport not only in the West Midlands, but across the UK.

Table 10.1 Scenarios in the Consultation for the Air Transport White Paper

National 'Growth' Scenarios	
RASCO (Regional Air Studies Co-ordination) Reference Case	Existing policy of meeting increased demand continues, with new runways built to meet demand in the South East.
UK Wide Constrained	Air transport is restricted across the UK, leading to loss of some services and increased air fares.
South East Constrained	Growth in air transport in the South East is limited, leading to likely increases in transport from the West Midlands.
Facilitating Growth	Growth is not only permitted, but actively encouraged, resulting in new runways at a number of airports.
Local 'Spatial' Scenarios	
Fly Local	Growth is encouraged at a larger number of smaller airports, including Birmingham and Coventry.
Concentrated Growth	Growth in the West Midlands would be concentrated at Birmingham.

10.2 Social and Economic Change

As in the other 'hot issue' sections, **Table 10.2** outlines those parts of the socio-economic scenarios developed by the UK Climate Impacts Programme relevant to transport (UKCIP, 2001). Figures for the potential changes in passenger-kilometres and modes of transport in the two scenarios are given in **Appendix D**.

Table 10.2 Transport in the UKCIP Socio-Economic Scenarios

Local Stewardship	The transportation sector is affected by a major slowdown in the growth of trade and the demand for mobility. This reduces need for investment in infrastructure. Transport costs rise sharply due to high energy prices and policies which internalise environmental costs e.g. congestion charging. Passenger transport is still dominated by private cars but public road and rail transport structures are extended. Alternatives such as car sharing, cycling and walking increases. Cars based on low emission technology (fuel cells, electricity, hybrids) are commonly used.
World Markets	Housing development creates a need for new investments in infrastructure, especially in transport. New roads are built to meet the increased demand for passenger transport. Traffic is efficiently managed using new control systems. The quality of water, energy and communication infrastructure will improve significantly.

As outlined in Section 10.1, the West Midlands' transport system is of significance not only for transport within the region, but also as a centre for national transport.

Under the World Markets scenario, investment in transport infrastructure would increase, with an accompanying increase in the quality of the infrastructure. This could have significant benefits for the West Midlands. Although the region has a wide network of nationally important routes, some of these are ageing and capacity constraints are being felt in some areas, particularly on the rail network and showing itself as congestion on the M6 (WMLGA, 2001). Future investment could also enhance the effects of current work, particularly on the BNRR.

However, it is likely that investment under the World Markets scenario would be in private transport, especially to link housing developments. This could generate problems for lower income groups and limit successes in rural regeneration to a small range of socio-economic groups.

The Local Stewardship scenario also predicts dominance of private transport, but accompanied by a growth in public transport infrastructures. In the West Midlands, this investment in public transport would fit with the priorities of the draft Regional Planning Guidance (WMLGA, 2001) and the desire to integrate communities in urban and rural areas. However, the scenario also indicates that the balance between public and private transport would take place within the context of a major slowdown in demand for travel. This could impact on the region in a number of ways. Demand for international services from Birmingham International Airport could fall, reducing not only the environmental impacts, but some of the broader social and economic advantages associated with the airport. While generated using different motivations, this compares to the UK-wide Constrained scenario in the Air Transport Consultation Paper, with growth at the airport limited close to current capacity. There could also be implications for the major tourist destinations such as Stratford-on-Avon and Warwick although this will depend on the relative changes in foreign and domestic tourism. Lower demand for travel could also help to reduce pressure on the region's road network.

10.3 Potential Impacts of Climate Change

The following section outlines some of the potential impacts of climate change on transport. However, the choice of transport mode and fuel has impacts on the emissions of greenhouse gases contributing to climate change. The impacts of transport on climate change and mitigation of these impacts is not considered in this study.

10.3.1 Road

Heavy rainfall could increase the risk of delays from roads blocked by floods and embankment slippage. Although main roads have been designed to withstand incremental changes in weather and have generally been over-specified to cope with such variations, they do not have such ability to cope with more extreme weather events, such as increased incidences of heavy rainfall. On the other hand, older roads that are maintained less frequently may have poorer foundations and drainage. Therefore, there may be more damage to these roads from even incremental increases. On these roads, increased rainfall might increase the run-off and wash away structures and foundations. A case study of the costs for transport associated with flooding is developed in Section 11.4.

The potential increase in the number of intense winter precipitation events could add extra pressure to the drainage systems on roads. The current design specifications suggest that the drainage system will cope with a summer thunderstorm lasting 15 or 20 minutes. However, a longer-lasting storm, or a number of storms without significant time between them, could overload a system built to current specifications. This could cause water to flood onto the carriageway as the drains became full.

Road surfaces may become buckled and weak during periods of high temperature. In the summer of 1995, which was unusually warm, roads were subject to 'bleeding' as the materials used in the surfacing melted. This led to an increase in the rate of deterioration of the road surface, and even resulted in an amendment of the British Standard specification for the road surfacing programme (Palutikof et al., 1997). High temperatures also cause expansion of the steel and concrete used in some roads and bridges. In concrete roads, typically constructed some time ago, many of the expansion joints have failed. This could increase the maintenance requirements in order to minimise travel disruption. However, the impacts on the transport infrastructure will be critically affected by the design specifications.

One possible positive effect of milder winter temperatures is the decreased maintenance required to counteract the effects of low temperatures. In particular, local authorities undertake salting or gritting of road surfaces to prevent ice formation on road surfaces in freezing conditions. The time and budget dedicated to this might be reduced if the number of days of freezing weather falls. The number of accidents resulting from skidding on untreated roads might also decrease.

Analysis of the hot summer of 1995 indicated that car use tends to increase in hot summers as people travel for leisure (Palutikof et al., 1997). This may also be true of walking and cycling, but the dual increase could result in more pedestrian and cyclist accidents. In addition, it might be that in warm weather, driver concentration is reduced. A survey of drivers found that 9% felt that warm weather increased drowsiness (Palutikof et al., 1997) and research on a highway in very high temperatures (over 24°C) found that there was an increase in the number of accidents (Stern and Zehavi, 1990). To compensate for this, drivers might make more use of air conditioning. However, this reduces the fuel efficiency of vehicles, and would add to the emissions of greenhouse gases. In order to address these effects it may be necessary to further develop road safety programmes with this in mind, to raise awareness of the higher numbers of pedestrians and cyclists and the risk of drowsiness.

10.3.2 Rail

The decrease in summer rainfall could result in soil shrinkage, particularly of clay soils, which could in turn affect the stability of rail structures. Where bridges, tunnels, cuttings or embankments are affected, additional structural support could be needed to counteract the effects of the shrinkage. On the other hand, the wetter winters may increase the risk of landslips when previously dry land becomes saturated and unstable.

The increased average winter precipitation could cause problems for the ballast and subgrade used in the foundations of roads and railways, in particular for railways since it is not protected by a sealed top layer. Increased rainfall can wash the smaller particles from the structure, reducing its cohesiveness, and its strength when put under pressure. The performance of the ballast is also dependent on the support layers below. When the soil is saturated, the strength of the overlying ballast is reduced. Although the risks associated with this differ according to the particular site, the importance of adequate drainage is fundamental (TRL, 2002).

Flooding also causes problems for the rail network. Standing water on the tracks conducts the electricity in a way that mimics a train, so that the flooded area shows up as an unexpected train on the control systems. Therefore, in order to maintain safety, engineers are required to attend sites to check that flooding is the cause of the confusion. This is likely to be most problematic in those areas identified as particularly at risk of flooding (see **Figure 2.7**) and can result in significant delays.

In addition to flooding, the progress of trains is also hampered by leaves falling onto the line, since traction and breaking becomes more problematic. Although the link between climate change and leaves on the line has not yet been established with certainty, it may be that the higher proportion of carbon dioxide in the atmosphere increases the leaf cover of trees, and therefore increase the number of leaves falling in autumn. If these fall onto rail tracks, trains could suffer delays.

Increased temperatures may be associated with buckling of rails. In order to minimise the risk, speed restrictions are imposed on the trains and rails are manually ‘de-stressed’. This adds to journey times and increases the time spent by rail engineers on routine maintenance. As mentioned in Section 8 on energy, higher temperatures also increase the sag of the cables used on electric lines. This can be particularly dangerous if the loose cables get caught on the pantographs (the framework connecting the cables and the train), damaging rolling stock and trackside equipment.

In freezing weather, points at rail junctions are kept free of frost by using point heaters. Milder winter temperatures will reduce the number of days below freezing point, and therefore will reduce the need for point heaters. A decrease in the number of frost days should also reduce the rate of deterioration of subgrade, although it is not clear whether higher summer temperatures will reduce performance (UKCIP and EPSRC, 2003).

The milder winter and warmer summer weather could encourage people within the West Midlands and outside it to look for more tourism and leisure options in the region. This links to the discussion of land use in Section 9.3.5. This could increase the demand for all types of transport, particularly road and rail to access some of the more rural areas of the region. In order to adapt to this without encouraging much greater use of private cars, it will be necessary to consider how best to support and develop public transport systems, including rural rail links, as an alternative method of transport for leisure travel.

10.3.3 Walking and cycling

Milder weather might encourage more walking and cycling, as people take advantage of the warmer temperatures. This might yield a number of social and health benefits, but will also have implications for the necessary infrastructure. More cycle lanes and footpaths might need to be built, particularly in order to minimise the risk of road accidents involving pedestrians and cyclists, which have been shown to be more likely in warmer weather. It may also lead to tourism opportunities, particularly along the parts of the National Cycle Network that pass through the region.

10.3.4 Air

The likely impacts on air transport are similar to those for road transport, since most of the impacts relate to the effects of climate on the infrastructure. As with road transport, fewer days below freezing will reduce delays associated with de-icing runways. There is currently significant use of de-icer for aircraft to allow them to take off. Fewer days with freezing temperatures would reduce the use of de-icer, and the associated delays and water pollution. However, high temperatures in summer might increase the risk of damage to the runway surface, resulting in the need for more frequent maintenance.

A number of climate factors, such as wind speed, wind direction and air temperature, also affect aircraft during take off. In particular, as air temperatures rise, air density falls, thereby reducing the amount of lift that can be obtained from the aircraft wings. This effect could become a problem if air temperatures rise above 25^{o}C to 30^{o}C, depending on the type of aircraft, and also varies according to the disposable load of the aircraft, length of runway and air density

(Palutikof et al., 1997). Lift is necessary at all stages of a flight, but sufficient lift is critical during take-off because runway length limits the distance available to achieve take-off speed. Air density depends not only on temperature, but also pressure, and therefore, the effects of higher temperatures will be more acute at runways at higher altitude. For example Birmingham is at 98m whereas Heathrow is only at 25m. A further potential problem for Birmingham is that the runway is relatively short, 2,600m compared to 3,800m at Heathrow. This reduces the scope for accommodating reduced lift, and could require airport operators and airlines to consider alternative adaptation. Birmingham International Airport is already considering the extension of the existing runway and this is included as part of the development strategy in its current master plan (Department of Transport, 2002). However, this has been driven by demand predictions and does not seem to have taken into account the effects of climatic change.

The unpredictability of the British summer is often blamed for the number of people taking holidays abroad, particularly in the Mediterranean. However, if weather in the summer months became more settled and warmer, there might be a substitution towards domestic holidays. This would be even more likely if areas traditionally visited for holidays, including parts of the Mediterranean, suffered increased disruption or discomfort from changes in the climate. The change in demand for holiday travel would have an impact on the aviation industry through a decrease in the demand for international flights, but an increase in demand for domestic flights. This is supported by the experience of the warm summer of 1995, when spending on international tourist flights fell by £12 million, but an extra £1.2 million was spent on domestic flights (Entec UK Ltd., 2002). At a regional level, the increase in domestic flights might be lower because the central position within the UK and the transport links to other regions facilitate journeys by car or train. Birmingham International Airport already has a lower proportion of domestic flights than the average for airports outside London: 27% of air traffic movements compared to 49% (Department of Transport, 2002).

10.4 Policy Considerations

The regional economic development strategy supports the development of the region's transport infrastructure as a key means of encouraging economic development. The draft Regional Planning Guidance also contains the Regional Transport Strategy (RTS). The RTS sets out transport priorities for the region, including reducing the need to travel and supporting the move towards more sustainable and integrated transport modes, improving capacity, particularly in urban areas, and managing demand and development. The RTS also lays out the priorities for investment in specific transport projects. However, at present this does not include consideration of the potential impacts of climate change. This should be incorporated into the RTS to ensure appropriate planning for potential climate changes.

10.5 Summary and Recommendations

Potential impacts and opportunities

Flooding during periods of intense winter rainfall could damage the foundations of roads, railways and runways.

Increased winter precipitation and precipitation intensity could increase the risk of flooding on roads and runways with poor drainage.

Likelihood of landslips in railway cuttings could increase due to increased rainfall during the winter months.

Flooding on railways can mimic the effect of a train and increase maintenance and safety requirements.

Increased summer temperatures may increase the risk of tarmac on roads and runways melting.

Milder winter temperatures could reduce the need to grit roads, with fewer road accidents from ice.

Higher winter temperatures could also reduce the requirements to deice aircraft and runways.

There could be a reduced need for railway point heaters in winter months.

Higher summer temperatures could increase accident risk as driver concentration is reduced.

Reduced summer precipitation could result in damage to infrastructure from soil shrinkage and subsidence.

High temperatures could increase buckling of rails and sag of overhead electricity cables on railways.

A higher growth rate of trees, in response to higher temperatures and increased carbon dioxide, may increase the problems of leaves on the railways.

Higher temperatures and reduced summer cloud cover could increase the number of leisure journeys by road.

There could be a possible substitution from foreign holidays if the climate of the West Midlands becomes more attractive relative to other destinations, reducing demand at Birmingham Airport.

Warmer summer temperatures and reduced precipitation could encourage more walking and cycling, for work and leisure.

Leisure travel could increase the number of trips from the cities and towns to the country, particularly during warm summer months.

Higher summer temperatures could reduce aircraft lift during taking off at Birmingham Airport.

Possible adaptation responses

Risk of flooding should be incorporated into planning the construction and maintenance of foundations for roads, railways and runways.

The capacity of existing and new drains should be increased to cope with greater risk of flooding.

Driver awareness of walkers and cyclists and recognition of potential drowsiness should be improved to minimise the risk of accidents, especially in warm weather.

Public transport systems should be developed to support increased demand for rural leisure travel.

Recommendations

There is a need to tie climate change impacts and adaptation into the Regional Transport Strategy (part of the Regional Planning Guidance) and the Regional Economic Strategy. This should include the potential impacts of higher temperatures on infrastructure, driver concentration and road safety, as well as the potential impacts of more extreme rainfall events, that could give rise to increased flooding, on infrastructure and economic disruption.

It is also necessary to consider the impacts of climate change on the construction and drainage of roads and railways.

There is also a need to consider the climate change impacts in the analysis of the alternative development options in the Air Transport White Paper, particularly in comparing expansion of Birmingham International Airport and a possible new airport at Rugby.

Further research could be useful in establishing a transport emissions inventory for the region, not only including road transport but also rail and air transport.

This inventory could also be used to assess the contribution of transport emissions to air quality under potential future climate conditions. This would combine air quality modelling and monitoring with climate predictions to allow responses for improving air quality in the region.

In order to encourage public transport there is a need to 'climate proof' new developments, particularly to ensure that they are not too hot in the higher summer temperatures and that there is sufficient protection from increased winter precipitation.

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11. Costing the Impacts of Flooding

11.1 Introduction

The following section provides three case studies indicating the potential costs of the damage associated with a climate change related weather event. Each case study uses historical data from the floods in Autumn 2000, a 1-in-50 year event. The World Markets and Local Stewardship scenarios are then developed to assess how these costs may change in the 2020s. The impacts of the floods are considered in three areas: agriculture, property and transport.

The costs demonstrate the potential financial implications of a flooding event. It is not known how often this kind of event could occur in the future, but it is likely that similar events will happen more frequently (see **Table 4.6** for the predicted changes in probabilities of four climatic events). However, if flooding becomes more frequent it may improve the opportunities to reduce costs through adaptation measures as outlined in Sections 6 to 10 of this report, and to establish situations in which flooding could be beneficial, e.g. for biodiversity in wetlands (see Agriculture Case Study 1). As is discussed in other sections of this report, other climate extremes will become more likely. These will also have costs, for example hotter summers could increase the costs of road maintenance. However, this section only considers the potential costs associated with a single flooding event. Finally, the estimates presented here do not offer a total cost of one flooding event, but only include the potential costs to agriculture, property and transport respectively. Therefore, the costs to other sectors of the economy are not included.

11.2 Agriculture

11.2.1 The impact of the floods in autumn 2000

The impact of the floods on agriculture at a national level were identified in *Dossier of Chaos* produced by the National Farmer's Union (NFU, 2000).

To estimate the impacts on farmers of the floods, the Flood Hazard Research Centre (FHRC) applies a methodology that appears to be as described in the guideline for productivity loss included in the UKCIP Costing Methodology guidelines (UKCIP, forthcoming). The methodology uses the total budget approach, which assesses the impacts on the budgets of farmers - including both negative and positive impacts of flooding. The cost or benefit to producers of a climate change impact is given by the change in net income between the ‘with’ and ‘without’ climate change scenarios.

The approach can be used to value small changes in combinations of inputs and outputs, and is not restricted to valuing the total loss or gain of those inputs and outputs. Thus, it has the advantage that it can deal with changes in the mix of inputs and outputs, inclusive of investment expenditures.

In order to estimate the total impact on farmers, it is necessary to identify both the impact on crop production and the impact on prices.

Impact on crop production

The NFU (2000) estimated the impacts of the Autumn 2000 floods as follows:

- Potato crops - 30% unharvested nationally;
- Sugar beet damage resulting from crops rotting in the ground;
- Cereals - up to 50% of the crop not planted;
- Dairy - impacts on milk collection and forage stocks;
- Livestock - poor lambing, damage to fencing and high straw prices; and
- Horticulture - 25% increase in costs of harvesting vegetables.

The impact on the West Midlands has been estimated based on average impacts per hectare for potatoes and wheat for the UK as a whole as shown in **Table 11.1**, following FHRC (2002). The aggregate UK estimate for agricultural damages arising from the October/November 2000 floods was £90 million based solely on potatoes and wheat.

This takes account of the following:

- Potatoes - A reduction in potato yield of 54,755 ha based on 7,000 ha with 100% crop loss; 7,000 ha with 70% crop loss and a 7% increase in crop leavings to 24% from 17%;
- Wheat Yield - An estimated fall in wheat yield of 0.6t/ha;
- Cropping Effect - A drop in gross margin based on the crop changes induced by the flood event in the area, of £190/ha on 423,000 ha;
- Extra Seed Effect - An estimated extra seed cost of £5 million; and
- Positive price effect of £100 million on wheat. In essence, because of the reduction in supply the price of wheat increases and hence farmers are partly compensated for the reduction in yield by an increased price per unit of crop.

For the West Midlands, this resulted in an indicative estimate is £6.7 million, or 7.48% of the national total. These impact cost estimates are presented in **Table 11.1**, below.

Table 11.1 Impacts of Autumn 2000 Floods on Agriculture

	UK				West Midlands	
Crop	**Total Cost (£)**	**Hectares damaged**	**Damage per hectare (£)**	**Area UK (ha)**	**Area (ha) (1)**	**Total cost (£)**
Potatoes	35,000,000	54,775	639	612,500	21,000	1,200,000
Wheat - yield effect (2)	70,000,000		42	1,660,000	167,000	7,042,169
Wheat - cropping effect	80,000,000	423,000	189	1,660,000	167,000	8,048,193
Extra seed effect (2)	5,000,000		3	1,660,000	167,000	503,012
Positive price effect	-100,000,000			1,660,000	167,000	-10,060,241
Total	**90,000,000**					**6,733,133**

Notes: (1) Based on 1997 data for potatoes

(2) Damage per hectare costs are calculated as an average damage per hectare in the UK

Blank spaces correspond to data that is not applicable

11.2.2 Vulnerability to future flood events

The vulnerability of agriculture to future climate change impacts will principally depend on the following:

- land use changes associated with planning zoning;
- pricing regimes for agricultural products; and
- food security policy.

Agricultural values will be determined principally by the pricing regimes, people's tastes, the openness of domestic markets to international competition, and income levels.

The data on impacts associated with the Autumn 2000 flood event allowed us only to cost impacts related to crops. Impacts on livestock were not identified, and therefore the estimates presented here have to be seen as representing the lower bound. As a consequence, the estimation of future costs presented in this sub-section also excludes potential cost due to the impact on livestock.

In order to estimate the potential impacts of climate change-induced flood incidence on arable agriculture it is necessary to establish the types of crops impacted, the area of crops impacted, the impact on the yield of the crop, the impact on prices and the impact on crop mix. We consider the impact of flood events in the West Midlands only on potatoes and wheat, as these were the only crops for which data on the above determinants were available in relation to the 2000 flood event.

We combine the crop scenarios generated by the Regional Climate Change Impact and Response Studies (REGIS) project (Holman et al, 2002) with the UKCIP socio-economic scenarios for the 2020s to develop estimates of crop yields, crop prices and subsidies over time and changes in land use. With reference to prices and subsidies, potato crop price scenarios were not available, so as a proxy the price variation in sugarbeet was used. No subsidies exist in the UK market for potatoes at the current time.

11.2.3 World Markets (WM) scenario

Under the World Markets scenario, agricultural prices are assumed to decrease rather than increase, as inefficiencies in production are reduced resulting in increased yields and price reductions as a consequence. Innovation is assumed to be high, with biotechnology developing quickly. As a consequence of the innovations, crop yield increases are highest under this scenario. Gross margins are assumed to vary with prices, as are seed costs.

Positive price effects of the sort identified following the Autumn 2000 floods were judged not to be relevant given the assumption of free trade made in this scenario. There may in fact be some short-term price impacts, but these would be removed as supplies from other countries come in to the UK to meet demand.

11.2.4 Local Stewardship (LS) scenario

To estimate the impact on agriculture of a flood event in the 2020s under the Local Stewardship scenario it was necessary to take the Regional Sustainability scenario under the REGIS project and apply it to the cost data given above. The REGIS report did not cover the Local Stewardship option, thus it was necessary to take the closest proxy to give indicative estimates of impacts.

Under the Regional Sustainability scenario, product prices for wheat and sugarbeet (the proxy taken for potatoes) both rise by 20 percent up to the 2020s. Yields for both wheat and potatoes are held constant. The positive price effect is also assumed not to apply under the Local Stewardship scenario for the 2020s. However, in reality there could be some effect if imports were limited.

A summary of the results of this analysis is presented in **Table 11.2** below. As can be seen from the table, under the World Markets scenario the impact is greater than in 2000 but less than under the Local Stewardship scenario. This can be explained by the fact that the Local Stewardship scenario has a greater increase in crop price than the World Markets scenario, although yields rise less.

Climate change related flood events may have significant impacts on agriculture. It must be noted that the costs reflected below are only partial cost estimates - they only reflect the impacts on two types of crop. Other important impacts, including impacts on livestock health, are difficult to cost but may be significant. The figures also represent the costs of a single flooding event on the crops concerned, and the number of such events may increase.

Table 11.2 Summary of scenarios for agricultural damages in the West Midlands (£m)

	2000	WM 2020s	LS 2020s (*)
Potatoes	1.20	1.37	1.46
Wheat	5.53	17.50	18.97
of which (for wheat)			
Yield effect	7.04	8.05	8.53
Disruption to cropping	8.05	9.05	9.83
Extra Seed effect	0.50	0.40	0.61
Positive price effect	-10.06		
Total	**6.73**	**18.88**	**20.43**

(*) LS uses Regional Sustainability of REGIS as a proxy

11.3 Property

The impacts of flooding on property can be seen from two main perspectives: (1) the direct impact of the flooding on property in terms of structural damage and (2) the reduction in the value of the property attributable to the negative impacts of a recent flood event. One risk in considering the latter effect is that the expected impacts of flooding on property in the future might be included implicitly. This implies that a risk factor for flood damage is included in calculating the value of the property. This may well be the case, and would lead to double counting. Therefore, this section only considers the structural costs and does not include the impact on property prices further. However, it is possible that the monetary impact may be higher if flood risks are not accounted for in the property value.

11.3.1 The impact of the floods in autumn 2000

The Environment Agency has collected data at an aggregate level of the flood impacts on property, which were presented in the FHRC (2002), in combination with property damage information obtained from the Association of British Insurers (ABI).

Data on the number of impacted properties for England and Wales are available for the 2000 riverine floods by region, drawing on FHRC (2002). These data are presented in **Table 11.3** below. The number of properties flooded in the 'low' estimate are based on actual reported data, whereas the 'high' data include an allowance for underestimation, which is most notable in the case of Kent.

Table 11.3 Properties Flooded in England and Wales During 2000 Floods

	Number of properties flooded	
	Low	High
Midlands	**3,025**	**3,025**

North West	239	244
South West	570	570
Thames	1,104	1,104
Wales	1,688	1,692
Southern	2,319	2,400
North East	1,997	1,997
Anglian	99	99
England and Wales	**11,041**	**11,131**

Clearly, the impacts on the Midlands as a whole were quite a significant part of total flooding damages in England and Wales. To estimate the damages in the West Midlands, it is possible to scale according to land area. The West Midlands consists of 13,004 square kilometres, or 45% of the land area in the Midlands as a whole. Thus, as a lower bound we take an estimate of 45% of total properties flooded in the Midlands were in the West Midlands - i.e. 1,368 properties were damaged in the 2000 floods. This may well be an underestimate, as of five towns with over 100 properties flooded in the Midlands region only one was in the East Midlands (Hatton). The towns in the Midlands region with over 100 properties flooded are shown in **Table 11.4**. Using this distribution as the basis of an upper estimate, we can estimate that 2,668 properties were flooded in the West Midlands.

Table 11.4 Locations in the Midlands with over 100 properties flooded

Location	Number of properties flooded
West Midlands	
Shrewsbury	230
Bewdley	140
Bridgnorth	200
Stourport	505
East Midlands	
Hatton	144

It is possible to estimate the cost of this damage, drawing on the Association of British Insurers (ABI) estimate of a cost of £51,208 per property (FHRC, 2002). It is assumed that this unit cost can be applied across the UK as a whole and to the West Midlands. It should be noted that since the ABI unit cost does not consider the willingness to pay of affected parties to avoid flood damage, it must be treated as a lower bound of the true cost to individuals, including factors such as trauma of damage to domestic property and business premises. Taking this value, we can estimate a lower bound for property damage in the West Midlands attributable to the 2000 flood event of £70.1 million. An upper bound, derived using the sample of the 1,219 properties in the worst affected areas can be estimated, yielding a damage cost of £136.6 million.

11.3.2 Vulnerability to future flood events

In order to make estimates of the future impacts of climate change-induced flood event incidence it is first necessary to establish the number of properties that are potentially vulnerable to different dimensions of a flood event. The extent to which damage might be expected to result from any such exposure must then be determined and a unit cost value given for that damage.

The exposure of domestic property to flood risk principally depends on:

- population size;
- average household size;
- spatial planning policy relating to new build construction;
- building design specifications and their ability to withstand flood risk;
- household insurance policy related to properties at flood risk; and
- other flood protection measures adopted.

The value of domestic property will primarily be determined by average household income levels and the supply of properties to the market in relation to the numbers of new households demanded.

To estimate the impact of a flood event in the West Midlands, it is necessary to take into account the changing demographic nature of the population and changing income levels. The former will impact on the number of properties damaged. **Table 11.5** outlines some of the underlying assumptions of the World Markets (2020s WM) and Local Stewardship (2020s LS) scenarios when applied to the West Midlands. Another assumption is that house construction does not adapt to changing climatic conditions - if for instance new houses are constructed outside flood plain areas this will reduce the costs of the flood event in the 2020s.

Table 11.5 Assumptions in Scenario Analysis

				Households affected	
Scenario	**Population**	**H/hold size**	**No of h/holds**	**Low**	**High**
2000	5,300,000	2.4	2,208,333	1,368	2,668
2020s WM	5,617,094	2.2	2,553,225	1,582	3,085
2020s LS	5,435,897	2.6	2,090,730	1,295	2,526

Under the World Markets scenario, population in the West Midlands is anticipated to rise to 5.6 million by the 2020s. This is estimated to coincide with a reduction in average house size to 2.2 persons, thus leading to a rise in the number of households in the West Midlands to 2.6 million from a baseline in 2000 of 2.2 million. GDP per capita is also expected to rise from £10,500 in 2000 to £24,000 by the 2020s, and taking the assumption of a linear relationship between incomes and prices this leads to an increase in the unit damage cost from the estimate of £51,208 for 2000 to £117,047 in the 2020s. Thus, under the World Markets scenario a damage cost estimate in the West Midlands for the 2020s for a similar flood event to that experienced in Autumn 2000 would be between £185.1 million and £361.1 million.

Under the Local Stewardship scenario, population in the West Midlands is anticipated to rise to 5.4 million by the 2020s. This is anticipated to coincide with an increase in average house size to 2.6 persons, thus leading to a reduction in the number of households in the West Midlands to 2.1 million from a baseline in 2000 of 2.2 million. GDP per capita is expected to rise less dramatically than under the World Markets scenario - to £15,000 by the 2020s. Taking the assumption of a linear relationship between incomes and prices, this leads to an increase in the unit damage cost from the estimate of £51,208 for 2000 to £73,154 in the 2020s. Thus, under the Local Stewardship scenario a damage cost estimate in the West Midlands for the 2020s for a similar flood event to that experienced in Autumn 2000 would be between £94.7 million and £184.8 million.

Table 11.6 presents the damage cost estimates for the West Midlands for the World Markets and Local Stewardship scenarios.

Table 11.6 Estimated Property Damage Costs in West Midlands under WM and LS scenarios

	Households affected		Unit	Damage cost (£m)	
Scenario	**Low**	**High**	**Cost (£)**	**Low**	**High**
2000	1,368	2,668	51,208	70.1	136.6
2020s WM	1,582	3,085	117,047	185.1	361.1
2020s LS	1,295	2,526	73,154	94.7	184.8

The scenario analysis indicates that damage costs are likely to be higher in the 2020s under the World Markets scenario. This is driven by assumptions regarding increased population (mainly driven by immigration), reduced average house sizes (reflecting the current trend towards smaller household units) and increased income levels. Under the Local Stewardship scenario household units are assumed to increase in size and neither income nor population increase as dramatically as under the World Markets scenario.

11.4 Transport

The impacts on transport of flooding fall into a number of areas, as outlined in Section 10.3. Roads may be blocked by floods, in which case passenger vehicles have to divert from their chosen course. Roads may also be flooded but passable thereby increasing journey times. In this case, both the impact on the direct vehicle running costs incurred by the road user and the impact on travel time must be taken into account. The impacts are on both market goods (the cost of petrol etc.) and on non-market goods (time) and hence, drawing on the UKCIP guidelines (UKCIP, forthcoming) we can estimate the value of the diversion. In addition to road transport, other parts of the transport network may be impacted by a flood event. However, this case study is restricted to road transport.

11.4.1 The impact of the floods in autumn 2000

To estimate the impact of the October-November 2000 floods on the West Midlands, we have assumed that the impact is similar to that experienced across the country, and hence interpolate from the aggregate data presented below. However, in practice the West Midlands, and areas within the region, may be more or less susceptible to flooding damage than the average.

For the whole UK, data on the impacts on roads in England and Wales of the Autumn 2000 floods were obtained from the FHRC report and scaled to take account of Scotland and Northern Ireland.

Posford et al. (2001) also provide estimates of increased distance and time due to the closure of A-roads and motorways. This data is provided in **Table 11.7**.

Table 11.7 Percentage Increase in Time and Distance on Major Roads as a result of Flooding

		A roads (%)	Motorways (%)
Increase in distance	Mean	22.3	23.9
	99.5 percentile	81.0	57.8
Increase in time	Mean	34.7	57.5
	99.5 percentile	81.1	124.0

UK

The total cost to England and Wales of the major road disruptions during the Autumn 2000 floods were estimated by FHRC to be approximately £72.9 million, including vehicle costs, value of time lost, and a willingness to pay multiplier for stress and anxiety. Scaling up on the basis of population size to include Scotland and Northern Ireland, and including a multiplier of 2 for the knock-on effect on congestion and subsequent time losses on roads to which the disrupted traffic has been diverted, (as suggested by FHRC, 2002) we arrive at an estimate of total damages due to road disruption of £194 million (in 2000 prices).

West Midlands

For the West Midlands, it is possible to gain an indicative estimate of the costs of major road closures by scaling down the UK cost data on the basis of population. This leads to a cost estimate for the 2000 floods damage to major roads for the West Midlands of £17.5 million.

A recent study showed an estimate of £24.2 million for the UK of B-road closures during the Autumn 2000 floods based on road closures in the Oxfordshire region (Metroeconomica, 2002).

Scaling this value to the West Midlands region on the basis of population, we estimate a cost of £2.2 million for B road closures resulting from the Autumn 2000 flood event.

We estimate the economic costs of the transport damages relating to A-roads, motorways and B-roads of the Autumn 2000 flood event at £19.7 million. This clearly does not reflect all the damages to transport attributable to the floods, notably it does not include railway disruption.

11.4.2 Vulnerability to future flood events

The susceptibility of transport to disruption from flooding depends on:

- the location of modal transport infrastructure in relation to the flood risk area;
- the design of modal infrastructure (e.g. drainage capabilities etc.);
- the design of future vehicles;
- the volume of transport using potentially impacted transport routes; and
- the existence of alternative transport routes.

The values that can be attributed to transport disruption will be determined by the following factors:

- the nature of the goods and services that are being distributed by transport routes vulnerable to disruption by flooding; and
- spatial patterns and volume of business and leisure-related travel.

We need to consider the possible influence of these factors in determining transport related costs that could be attributed to future flood events, and how they will vary between the socio-economic scenarios. Our starting point in this exercise is the data on disruption lengths and associated costs that were derived from the costing methodology applied to the Autumn 2000 floods, reported above.

The UKCIP socio-economic scenarios give estimates of the number of passenger kilometres per annum expected in the mid-2020s by scenario. The percentages per mode of transport are also given.

The annual passenger kilometres are:

- 1990s 690 billion
- 2020s World Markets 1,200 billion
- 2020s Local Stewardship 700 billion

The estimates of road transport impact costs for the West Midlands, under the different assumptions regarding passenger kilometre growth and the socio-economic scenarios are outlined in **Table 11.8** below for all roads. These costs include additional vehicle operating costs, i.e. the costs of diverting around a flood, and additional ‘opportunity costs’ to delayed passengers of lost work or leisure time. A factor has also been included to allow for increased congestion as a result of the flood event. The future costs were calculated by adjusting the costs of the 2000 floods, described above, to take account of changes in GDP per capita and passenger kilometres travelled.

Table 11.8 West Midlands Road Transport Disruption Costs - all roads (£m)

A Roads	Passenger km	GDP/ca	Cost (£m)
2000	690 billion	10,500	19.67
2020s WM	1200 billion	24,000	78.19
2020s LS	700 billion	15,000	28.51

The disruption cost of flooding in 2000 was estimated at £19.67 million for the West Midlands. From the figures above, there would be some increase in costs for a similar event in the 2020s under the Local Stewardship scenario, to £28.51 million, largely due to an increase in GDP per capita. However, under the World Markets scenario there would be a huge increase in costs, because of an increase in GDP per capita combined with a significant increase in passenger kilometres traveled. Under this scenario, the costs of transport disruption would be £78.19 million.

11.5 Bibliography

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Posford, Meteorological Office, and JB Chatterton Associates (2001) *Research to Determine the Impact of Severe Weather: Part II*

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12. The Potential Impacts of Climate Change in Europe

Following on from the assessment of the potential impacts of climate change on the five 'hot issues' in the West Midlands, this section considers the potential impacts of climate change at a European level. This section considers potential climate change impacts on a wide variety of sectors and issues in order to provide a broad context. While the majority of this study has focused exclusively on the West Midlands, it is important to recognise that the impacts on this region will depend in part on the impacts elsewhere. This was noted in particular in Section 6 relating to the dependency of the water supply in the West Midlands to resources in neighbouring regions. At a European level, climate change impacts could affect the competitiveness of the West Midlands. For example, if the impacts on particular industrial sectors of the West Midlands are small relative to the impacts on competitor regions, there may be an improvement in comparative advantage.

12.1 ACACIA

The Europe ACACIA Project drew together the research material on potential climate change impacts across Europe (Parry (ed.), 2000). The overall conclusions were that:

- the balance of impacts of climate change will be more negative in southern than northern Europe;
- primary sectors, such as agriculture and forestry, will be more affected than secondary and tertiary sectors, such as manufacturing and retailing; and
- more wealthy regions and sectors will be less adversely affected than more marginal and poorer ones.

The likely effects of climate change in Europe were assessed for the following sectors:

- Water resources;
- Soil and land resources;
- Ecosystems;
- Forestry;
- Agriculture;
- Fisheries;
- Insurance;
- Transport, energy and other industries;
- Tourism and recreation;

- Human health;
- Coastal zones; and
- Mountain regions.

Recognising that there is still much uncertainty in this area and more research needs to be done, the following sections give brief descriptions from the report of the main impacts for these sectors.

12.1.1 Water resources

Climate change is only one of the pressures facing water resources in Europe over the coming decades. The main climate change related impacts could include the following:

- an increase in annual streamflow in northern Europe, with a decrease in the south;
- an increasing range of flows in maritime and Mediterranean areas, as precipitation becomes concentrated in winter. Peak flows could alter as snowfall is replaced by rainfall and snowmelt shifts from spring to winter. This could affect much of eastern and mountainous Europe. The far north and east of Europe would be relatively unaffected;
- a general increase in the risk of summer drought, particularly in the south;
- an increase in flood risk throughout Europe;
- a decline in river water quality; and
- changes to river flows and increased flooding could have adverse effects on navigation.

The most vulnerable regions are those in southern Europe that have the greatest water resource pressures and could experience a substantial increase in demand.

Water supply in the UK is mainly a regional or inter-regional issue and so there is unlikely to be any direct competitiveness issues in this area. However, where water resources could be adversely affected in other European regions, this may in turn affect production of water dependent goods and services e.g. food and drink. This could then become a source of comparative advantage for the West Midlands if it is in competition with the region, either for inward investment or product markets. This would depend on adequate resources being available in the West Midlands in the future.

12.1.2 Soil and land resources

Climate change could affect soil and land both directly (e.g. reduction in soil moisture and increasing erosion) and also indirectly (e.g. land use changes). The main climate change impacts could include the following:

- an increase in land degradation process such as salinisation, peat wastage and soil erosion due to more arid conditions; and

- increases in the frequency and size of crack formation in soils with high clay content. This could alter pollution pathways and increase building damage through subsidence.

The most vulnerable regions are:

- those most vulnerable to salt related problems including coastal or inland lowlands (including the Great Hungarian Plain), river deltas, areas downstream from saline marine sediments in which badlands have developed e.g. southern Spain and Italy, and areas where drainage requirements of irrigation are being ignored;
- those with peat soils due to shrinkage from drainage and drying, particularly in the coldest regions e.g. Iceland and north facing high latitude high altitude slopes;
- those with thin soils with a low stone cover e.g. Iceland, southern Europe, Lesbos and northern Europe (on glacial deposits); and
- those with cultivated fields on sloping land as they are sensitive to intense and long duration rainfall. The loess soils of northwest France through Belgium and Germany and into eastern Europe are particularly vulnerable.

12.1.3 Ecosystems

Most northern and western European ecosystems are temperature limited, while eastern and southern ecosystems depend more indirectly on soil moisture. Higher temperatures and higher concentrations of carbon dioxide could increase ecosystem productivity. Again climate is not the only determining factor on changes to ecosystems. Land use is changing rapidly in Europe e.g. agriculture and settlement patterns and this is just as likely to continue to have a significant effect on ecosystems. The main climate change impacts for ecosystems could include the following:

- a northward displacement of boreal forests, northward expansion of broad leaved temperate forests in eastern Europe and a likely expansion of frost intolerant species from the northern Iberian peninsular into the British Isles;
- an increase to the frequency and severity of fires in the Mediterranean region;
- loss of species in some areas due to changes in biodiversity; and
- some changes to habitats could threaten migrating bird populations.

The most vulnerable regions are generally those with moisture limited ecosystems and include

- continental temperate Europe e.g. Hungary and Ukraine,
- the Mediterranean where increased incidences of fire may be the main problem, and
- parts of southern Spain where desertification could be amplified by climate change.

The West Midlands has opportunities to enhance the biodiversity value of the region. This will require management and investment to enhance habitats.

12.1.4 Forestry

The diversity of tree species in Europe probably means that there is ample capacity to adapt to changing temperatures and precipitation. However, changes to the frequency and scale of extreme events e.g. fires and droughts (Mediterranean, continental Europe and western Europe), floods and storms could result in significant losses. The main climate change impacts could include the following:

- continuing increase in growth rates. This may support the spread of deciduous tree species;
- reduced productivity and profitability in northern European forests due to increased precipitation and rain days and reduced snow cover and soil frost. More frequent wind damage could disturb the pattern of forest production leading to increased costs and interruption to timber markets; and
- an increase in some insect and pest populations but this will depend on the change in predator species.

The most vulnerable forests are:

- those at the polar and alpine timberline (Finland, Norway, Russia and Sweden);
- those in the Atlantic region on coastal areas on sandy soils with low water holding capacity e.g. Jylland in Denmark;
- those at risk from summer drought e.g. lowland northwestern and southwestern Germany, Poland, Czech Republic, Slovakia and northern France; and
- those in the Mediterranean region due to reduced summer precipitation and increased fire risk.

Expansion of forestry in the West Midlands could increase the opportunities for export of both wood and products manufactured from wood. However, most UK forest products tend to be used locally within the region or UK.

12.1.5 Agriculture

Patterns of agricultural production are affected by a wide range of factors including economic, cultural, political, technological and environmental. Agriculture is temperature limited in northern Europe, moisture limited in parts of eastern and southern Europe and restricted by high rainfall along the Atlantic coast. Temperature, sunshine and precipitation are the main climate factors affecting agricultural production. The main climate change impacts could include the following:

- a northward expansion of suitable cropping areas due to warming, a reduction of the growing period for cereals and an increase in the growing period for root crops. Higher concentrations of CO_2 would enhance plant productivity;
- changes to livestock systems due to increases in extreme events and changes to pasture and forage crops;
- the introduction of new crop species and varieties, higher crop productivity and expansion of suitable growing areas in northern Europe; and

- lower harvestable yields, higher yield variability and a reduction in suitable areas for traditional crops in southern Europe due to increasing water shortage and extreme weather events.

Changes to crop types and agricultural practices could help to mitigate the negative effects of climate change in some areas. The most vulnerable regions are northern and southern Europe (see above).

The ACACIA report presented the conclusions from the CLIVARA project. This was an integrated assessment of the potential impacts of climate change on agriculture across Europe. A series of crop models were run to assess climate change impacts on crop development, growth, yield and yield quality. The following sections present the main conclusions for a range of crops.

Wheat

The application of various crop models for wheat produced the following conclusions:

- The application of a wheat crop model using sites to represent central England indicates that the combined effect of changes in the mean and variability of temperature, solar radiation and precipitation will have little effect on the mean or variance of regional wheat yield;
- The results of a simulation for Spain indicate that the largest negative effect could be for water-limited yields in the southern regions (up to 30% yield reductions). Northern and western regions are affected positively and the central region would not experience significant yield change;
- The results for Hungary suggest that mean yields will worsen in the future and more frequent droughts will increase risks; and
- Other models were run for Finland and Denmark. Mean yield in southern Finland increases slightly, while yield reliability improves. Mean yields would increase in Denmark.

Soya Bean

The model for Spain showed the largest negative effects to be in water-limited southern regions. The northern and western regions are affected positively and the central region wouldn't experience significant yield change.

Grapevine

The model for national and continental simulations shows an improvement in production.

Potato

Modelling of potato yield suggests the following:

- Simulations show that yields tend to increase but less so in southern Europe. Early sowing and early varieties tend to increase yields;
- For the UK different results are obtained from different scenarios - one showing small yield losses across most of England and Wales with increases in Scotland

and another showing small increases in most areas except in the south and southeast of England;

- Denmark could experience increases in yields;
- There could be a substantial northward shift in potato yields in Finland; and
- In Hungary, potato cultivation could shift towards the southwest and higher elevations.

No information has yet been obtained on the comparative position of the West Midlands with regards to these crops and export/import activity but the following general conclusions can be made. Decreases in yields elsewhere in Europe could present opportunities for export of West Midlands produce but this would depend on the level of activity, and infrastructure to support it, and the economic viability of the activity. Increases in yields elsewhere could reduce opportunities for export or increase imports in some cases. Effects will also depend on socio-economic changes, as discussed in Section 7.

12.1.6 Fisheries

The importance of marine fisheries as an economic activity in Europe has been steadily declining. Young fish are highly sensitive to changes in water temperature. However, resource scarcity due to overfishing and environmental change are threatening most European fisheries with collapse. The main climate change impacts could include the following:

- changes in aquatic biodiversity and fish production. The most vulnerable species are those with juvenile stages in freshwaters e.g. migratory salmonids, alewives and sturgeon species. Productivity could increase in the north due to temperature increase but changes to ocean circulation currents in the North Atlantic could lead to fisheries collapse; and
- changes to fisheries diversity and productivity could affect the development opportunities for coastal communities and could lead to conflict between aquatic resource users.

The most vulnerable regions are:

- the Baltic Sea due to increased freshwater runoff causing productivity to continue decreasing; and
- in the south higher evaporation and lower rainfall could lead to an increase risk of ecosystem failure.

12.1.7 Insurance

This sector is sensitive to changes in extreme weather events, particularly impacts on property damage. Countries across Europe manage natural hazards in different ways including the use of insurance. The main climate change impacts could include the following:

- major impacts from coastal flooding or from windstorm damage in northwest Europe. In some areas of Europe the insurance industry does not provide cover e.g. for standing crops or flooding; and

- low risk of insolvency for the European industry but regional insurers may be at risk.

It is likely that the insurance industry would use a number of mechanisms to manage the increased risk from potential climate change impacts including pricing, limitation and risk transfer.

The most vulnerable regions are:

- coastal especially western Europe due to any increased storms and flooding,
- northern, central and eastern Europe due to winter damage (and to a lesser extent western and southern Europe);
- central and southern areas due to increased periods of extreme high temperatures, droughts and increased risk of forest fires and subsidence (particularly the UK and northern France);
- river plains due to inundation;
- valleys and urban areas due to flash funding; and
- alpine areas due to flash flooding and landslides.

12.1.8 Transport, energy and other industries

Transport infrastructure could be affected by increases in extreme events such as flooding. This in turn could cause disruption to other economic activities that depend on transportation e.g. deliveries. However, reductions in snow fall and ice could reduce winter disruption. Energy demand could change from heating in the winter to cooling in the summer e.g. air conditioning. These sorts of impacts could also be experienced in the UK, and have been outlined in Sections 8 and 10. The most vulnerable areas are:

- those with infrastructure in low lying areas. In the UK 40% of manufacturing industry is located along coastlines and estuaries. The proportion is higher in the Netherlands. Many petroleum refineries and power stations are located at the coast and sea level rise could have some impact on offshore oil and gas production. It is estimated that around the Mediterranean there were 73 petroleum plants, 28 metallurgical plants and 86 chemicals plants that were at risk. The importance of the coastal zone to Mediterranean countries varies. It is less important in Spain and France than Italy but in Greece as much as 90% of the population live within 50kms of the coast and all major industrial centres are close to the coast;
- river valleys, as they often provide lines of communication; and
- river and estuary crossings especially those exposed to high winds.

Transport disruption due to climate change elsewhere in Europe e.g. flooding and temperature related disruption could adversely affect the economics of export from the West Midlands. Conversely, winter warming could reduce disruption due to snow and ice.

12.1.9 Tourism and recreation

Tourism is a global industry and subject to changes in preference. Climate is one of the factors that determines the choice of tourist destinations. The main climate change impacts could include the following:

- stimulation of tourism and recreational activities in northern Europe due to higher temperatures and a lengthening of the tourist season;
- a risk of reduction in visitor numbers to winter resorts due to less reliable snow cover, especially at lower altitudes;
- an increase in the sea bathing season and locations due to higher sea temperatures; and
- an increase in the frequency of summer extreme high temperature periods in southern Europe could reduce the attractiveness of some Mediterranean locations. This could benefit other areas as people could choose to visit slightly cooler locations or take their holiday nearer home.

The most vulnerable regions are:

- coastal zones e.g. Venice, due to rising sea levels;
- islands e.g. lower lying islands in the Mediterranean;
- mountainous areas with winter tourist resorts;
- tourist areas; and
- the Mediterranean.

If tourism was developed sufficiently within the West Midlands it could benefit from the reduced attractiveness of some European destinations. This could include increased visitors and local people taking their holidays in the region.

12.1.10 Human health

Climate change could pose a risk to human health for a variety of reasons although there is little clear evidence that health has changed due to recent observed warming trends. More research needs to be done.

The main climate change impacts could include the following:

- increases in heat stress related illnesses, reduction in cold related illnesses;
- increases in water related illnesses due to increased flooding. Floods can also give rise to psychological conditions such as post traumatic stress disorder especially amongst children who can become very sensitive to extreme events;
- a northward expansion of some diseases e.g. tick borne encephalitis; and
- exacerbation of the current trend of increases in incidences of food borne diseases.

Again, these are similar to the potential impacts in the UK.

The most vulnerable populations are:

- those without access to appropriate health information;
- those in absolute and relative poverty; and
- the rising average age of the European population due to longer lifespans could expose people to an increase in years with disability. This could be exacerbated by climate change e.g. heat related conditions. Elderly populations have increased disproportionately in coastal areas and hence may live in areas at greater risk from flooding.

12.1.11 Coastal zones

Sea levels have risen around much of Europe and climate change is one of the pressures on coastal zones. The main climate change impacts could include the following:

- increases in flood risk for low lying coastal zones and increased erosion for cliffs and beaches. Any increases in storminess would exacerbate these impacts; and
- degradation of saltmarsh and intertidal habitats. The Baltic and Mediterranean coasts are most vulnerable as they have a low tidal range. Under the High Emissions scenario (Hulme et al., 2002), these area could virtually disappear by the 2080s.

Adaptation options include appropriate defences but these could further threaten coastal ecosystems. However, working with natural processes such as managed retreat or realignment could enhance ecosystems.

The most vulnerable areas are:

- The Baltic and Mediterranean, coastal wetlands and ecosystems and islands.

12.1.12 Mountain regions

Mountain hydrology could be affected by climate change. The mass of glaciers could be reduced due to higher temperatures affecting the availability of water further down the valley. The snowline rises by 100-150km for every degree of warming. This would have consequences for runoff into river basins and winter tourism. Rockfalls, mudslides and avalanches could increase due to shifts in permaforst and increased precipitation. Temperature specific mountain species may face competition from more temperature tolerant species.

12.1.13 Conclusions

By and large these impacts are similar in nature to those that could be experienced in the UK, although the extent to which they are experienced could differ. Little is known as yet about the relative scale of these potential impacts across European regions and whether they could be a source of comparative disadvantage or advantage. This will depend on the nature of the competition between regions in Europe and globally. More work needs to be done to assess the comparative position of the region with the rest of Europe. This would allow the potential impacts of climate change in the region to be compared to those elsewhere in Europe. For example, much of the food consumed in the West Midlands comes from outside the region.

Therefore, if arable farmers in the West Midlands were competing with producers in areas in which climate change has significant negative impacts on soil and land resources, grain production in those regions could fall, reducing the strength of the competition for arable farmers in the West Midlands. Unfortunately, information on competition was not available for this study. However, this could be a source of further work to make the assessment of potential impacts more robust.

12.2 Bibliography

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Parry, M.L. (ed.), *Assessment of the Potential Effects and Adaptations for Climate Change in Europe: The Europe ACACIA Project*, Jackson Environment Institute, University of East Anglia, Norwich, UK, 2000, 320pp.

13. Summary and Recommendations

13.1 Introduction

This section provides a summary of the key issues in the report. It outlines the potential climate change impacts at a broad level, and also for each of the five 'hot issues'. Opportunities resulting from these changes in climate, key policy considerations and possible adaptation responses are suggested for the five 'hot issues' only. Finally, some recommendations are made, relating to both the 'hot issues' and to broader issues.

13.2 Summary of Key Climate Change Impacts for the West Midlands

Climate change could result in a number of important impacts in the West Midlands. However, climate will not be the only change occurring during the 21st century. Social, economic and technological changes will also occur in the region and these changes need to be considered alongside possible climate change in order to plan for the future.

In general the following climate change impacts could occur:

- Increased temperatures and different patterns of rainfall could lead to changes in the demand for, and availability of, water. A significant proportion of the region's water is supplied from reservoirs in Wales, which has a wetter climate. Drier summers could result in lower flows in the region's rivers, with negative impacts on biodiversity and water quality, and an increase in the demand for water for irrigation, garden watering, industry (especially food and drink) and the public. However, whether these impacts actually occur will depend on the success of implementing an effective regional water strategy and measures to address supply and demand issues;

- Increased temperature could change the demand for energy, with a reduction in demand for winter space heating and an increase in the demand for cooling in the summer. Reduction in winter space heating demand could help to reduce incidences of fuel poverty in the region, although this will depend on future energy costs and housing conditions. Use of natural ventilation, shading, and green spaces for cooling may be able to meet any increased demand for cooling but these measures will need to be incorporated into building design;

- There are plans to expand the amount of energy produced from renewable sources in the region. Reduced cloud cover and hence increased sunshine may increase the opportunities for certain renewable energy e.g. solar based technologies;

- Increased temperatures and less cloud might encourage people to spend more time outdoors, with possible health benefits from increased physical activity but risks of skin damage or heat exhaustion on very hot or bright days. People may decide to take more local holidays rather than travel abroad, especially if other destinations such as Southern Spain and France experience more negative climate change impacts e.g. reduced water availability and increased fires. The West Midlands has many attractive destinations and these may need to be developed and extended to attract visitors and respond to increased demand;

- Increased temperatures and carbon dioxide levels and a longer growing season could benefit certain agricultural and horticultural crops and trees. This could benefit agriculture but potential opportunities are closely linked to consumer demand. Forestry and woodland could be extended in the region. This may have benefits for related activities e.g. the renewable energy and leisure sectors;

- Higher temperatures could increase the urban heat island effect in Birmingham. Policies in the draft Regional Planning Guidance aim to concentrate development in existing urban areas and develop Birmingham as a 'World City'. Denser development may exacerbate the urban heat island effect and require adaptive measures for development layout to be built into the spatial development process in the region. If these adaptive measures are not taken then comfort in buildings could be adversely affected leading to a reduction in productivity amongst office based workers and discomfort in domestic dwellings;

- Wetter winters could lead to increased recharge of regional water supplies e.g. aquifers and hence increased availability of water and also provide the opportunity for providing enhancement of certain habitats e.g. wetlands, that are under-represented in the region; and

- Wetter winters and extreme precipitation events could also increase the risk of flooding and hence economic and social disruption in the region. Flood risk is dependent on a number of factors e.g. land use (transport, housing, agriculture etc.), soil type, availability of drainage and level of flood protection. Flood risk can be reduced through a number of actions e.g. reducing development in the floodplains, water storage and flood management. Urban areas may experience flooding from drainage systems that are inundated during extreme events. A focus of the draft Regional Planning Guidance is to concentrate development in previously developed urban areas. Capacity of existing drainage systems may need to be increased to take into account possible future climate.

In addition to the wide ranging potential impacts indicated above, a number of more specific impacts were identified for the five 'hot issues'. A summary of these is given below.

13.2.1 Water management

The main climate change impacts on water management could be as follows:

- Increased winter precipitation and precipitation intensity could increase flood risk on major rivers such as the River Severn;

- Urban drainage systems, in particular those in Birmingham, may not be able to accommodate intense precipitation in the winter, impacting on design, capacity and maintenance requirements of these systems;

- Increased winter rainfall could have potential benefits of winter recharge to reservoirs and groundwater such as the Shropshire Groundwater Scheme;

- There are concerns over greater winter recharge further increasing rising groundwater under Birmingham during winter months;
- Changes in the seasonal pattern of rainfall could require changes to water resources operational practices in river regulation (River Severn) and direct supply reservoirs;
- Low summer rainfall could result in further low flow problems and water quality deterioration in the region's rivers and the need for greater flow regulation from existing reservoirs or groundwater;
- Reduced precipitation over the summer could result in increased water demand and stress on resources for water supply management and from direct abstractions from rivers for irrigation, navigation and industry, in particular in the drier Vale of Evesham area;
- There could be increased demand for irrigation due to higher soil moisture deficits in the summer. The CCDeW study for the Midlands suggests that this increase could be as much as 23% under some climate change and socio-economic scenarios by the 2020's;
- Where water surpluses over the winter months can be controlled, this may represent an opportunity for attracting investment from other parts of the UK where more extreme water shortages are predicted (e.g. the South East); and
- Water trading opportunities may arise between individual farms with potential surplus water stored during periods of increased precipitation.

13.2.2 Agriculture

The main climate change impacts on and opportunities for agriculture could be as follows:

- Increased precipitation and precipitation intensity during the winter could limit the use of land for agriculture due to an increased risk of flooding;
- Reduction in quality and quantity of grass caused by lower rainfall and higher temperatures during summer may require feed for livestock to be supplemented;
- There could be a reduction in yields of fruit, vegetables and cereals that do not have as much water during growing period;
- Some crops may flourish due to higher temperatures and increased carbon dioxide in the atmosphere;
- Changing climate condistions could make it possible to grow alternative crops, including crops for energy;
- Water available for spraying, irrigation and livestock may be restricted during drier summers;
- Higher summer temperatures and reduced cloud cover could increase the risk of heatstroke and sunburn for livestock in open pasture;

- Higher average winter temperatures could reduce problems for livestock in freezing weather;
- Higher winter temperatures and fewer days of freezing weather affects vernilisation of winter cereals and formation of flower buds on some fruit trees;
- Milder winter temperatures and higher atmospheric concentrations of carbon dioxide may result in more lush growth during winter, which could in turn create more straw;
- Higher temperatures could increase the risk of pests and diseases in arable and horticultural crops; and
- Higher temperatures and reduced cloud cover could increase the demand for outdoor leisure and tourism, which could create opportunities for diversification.

13.2.3 Energy

The main climate change impacts on and opportunities for energy could be as follows:

- Milder temperatures could reduce demand for energy to provide heating during winter months;
- Lower winter fuel demand associated with higher winter temperatures could reduce the number of households in fuel poverty;
- The risk of damage to infrastructure from freezing weather and ice could be reduced during milder winters;
- Higher summer temperatures could increase the demand for energy for cooling (air conditioning and refrigeration);
- High temperatures during summer could increase sagging of electricity distribution cables;
- The urban heat island effect could increase the demand for energy for transport to travel to cooler, rural areas for leisure;
- Possible increases in storm frequency could increase the risk of damage to electricity distribution infrastructure;
- Changes in precipitation and cloud cover could increase potential for the use of solar power and biofuels;
- Periods of increased rainfall and increased rainfall intensity during the winter could increase the risk of damage to infrastructure from flooding;
- Reduced summer precipitation could increase the risk of subsidence during summer droughts, particularly on clay soils;
- Reduced summer precipitation could impose constraints on power stations through limited availability of water for cooling during the summer; and

- Changes in the pattern of wind directions and speeds could change the dispersion of pollutants from power stations and industrial plants.

13.2.4 Land use and the built environment

The main climate change impacts on land use and the built environment could be as follows:

- Increased winter precipitation and precipitation intensity could make more land unusable or of limited use due to risk of flooding;
- Urban developments without adequate drainage at increased risk of flooding during periods of intense winter rainfall;
- Buildings could be at increased risk of damage from subsidence of clay soils during periods of low rainfall in the summer;
- Changes in climate variables could result in greater opportunities for forestry and may increase land used for trees;
- Agricultural responses to changes in climate may increase or decrease amount of land used for agriculture;
- Increased winter temperatures could reduce damage to the built environment, particular from frost;
- Milder winter temperatures might increase the growth of mould in houses;
- Higher summer temperatures in the urban areas could increase the demand for rural living;
- There may be an increased demand for green, open spaces in urban areas, especially in warm summer months;
- Increased temperatures in urban areas, particularly during the summer, could require various cooling strategies to be considered; and
- Higher summer temperatures could increase the demand for outdoor activities and require more land for outdoor recreation and leisure.

13.2.5 Transport

The main climate change impacts on transport could be as follows:

- Flooding during periods of intense winter rainfall could damage the foundations of roads, railways and runways;
- Increased winter precipitation and precipitation intensity could increase the risk of flooding on roads and runways with poor drainage;
- Likelihood of landslips in railway cuttings could increase due to increased rainfall during the winter months;
- Flooding on railways can mimic the effect of a train and increase maintenance and safety requirements;

- Increased summer temperatures may increase the risk of tarmac on roads and runways melting;
- Milder winter temperatures could reduce the need to grit roads, with fewer road accidents from ice;
- Higher winter temperatures could also reduce the requirements to deice aircraft and runways;
- There could also be a reduced need for railway point heaters in winter months;
- Higher summer temperatures could increase accident risk as driver concentration is reduced;
- Reduced summer precipitation could result in damage to infrastructure from soil shrinkage and subsidence;
- High temperatures could increase buckling of rails and sag of overhead electricity cables on railways;
- A higher growth rate of trees, in response to higher temperatures and increased carbon dioxide, may increase the problems of leaves on the railways;
- Higher temperatures and reduced summer cloud cover could increase the number of leisure journeys by road;
- There could be a possible substitution from foreign holidays if the climate of the West Midlands becomes more attractive relative to other destinations, reducing demand at Birmingham Airport;
- Warmer summer temperatures and reduced precipitation could encourage more walking and cycling, for work and leisure;
- Leisure travel could increase the number of trips from the cities and towns to the country, particularly during warm summer months; and
- Higher temperatures could reduce aircraft lift during taking off at Birmingham Airport.

13.3 Summary of Key Policy Considerations for the West Midlands

Potential climate change needs to be considered in a number of regional strategies and policies including the following:

- The Regional Economic Development Strategy - climate change could present some important opportunities for growth in a number of sectors e.g. food and drink (linked to agriculture), tourism and leisure and environmental technology. Climate change could also lead to some negatives impacts on the region’s assets and infrastructure e.g. increased risk of flooding and storm damage;

- Regional Planning Guidance (RPG) - climate change could affect the location, form and performance of developments and patterns of land use;
- Regional Transport Strategy (part of the Regional Planning Guidance) - climate change could affect the demand for mobility within and through the region. Transport infrastructure could also be affected by changing climate conditions e.g. reduced need for winter maintenance and increased damage from flooding and higher temperatures; and
- Regional Water Resources Strategy - climate change could change the demand and availability of water. The regional water resources strategy has begun to consider the potential impacts of climate change.

Although these are the key strategies that could be affected by climate change, other strategies and policies will need to consider the potential impacts of climate change including those related to energy, waste management, water quality, biodiversity and emergency planning.

A discussion of policy considerations for each of the five 'hot issues' can be found in the 'hot issues' sections. These consider the need for incorporating the potential impacts of climate change into the policies, particularly where this may conflict with one or more of the stated priorities of the current plan.

13.4 Recommendations

A number of recommendations were made for each of the 'hot issues' in the sections above. In particular, it was suggested that in each of these areas there was a need for further research, a need to incorporate climate change impacts into policies and plans, and a need to raise awareness about potential impacts. The recommendations for the 'hot issues' are repeated below.

13.4.1 Water Management

- There is considerable research and investigation on the impact of climate change on water management in the West Midlands, so the recommendations here are based on the need to improve key gaps in our understanding. Some of this has already started e.g. climate change has been considered as part of the regional water resources strategy. Water companies are also assessing water resources investment needs as part of the asset management planning (AMP) process. They have received guidance from the Environment Agency on how to consider climate change in this process.
- One key challenge will be the ability to influence long term 'no regrets' investment decisions on water management (resources and flood prevention) schemes, to ensure effective adaptation to climate change. The challenge involves the management and communication of uncertainty from climate and socio-economic change scenarios. UKCIP launched a key report on managing uncertainty and risk in climate change in May 2003. The communication of risk and uncertainty in water management will be particularly important for the non-specialist.

- A key communication challenge for the wider public in the West Midlands is to explain that potential water shortages may arise from climate change, while at the same time, advise on potential flood risk and surplus water scenarios.
- Most of the key water management policies and strategies relevant for the West Midlands take into account climate change and present recommendations for the application of climate change factors in planning and investment studies. A possible exception identified in this scoping study is the implication of climate change on the canal network, and a recommendation is that British Waterways give further consideration to climate change in future canal management and water resources development strategies.

13.4.2 Agriculture

- There is a need to raise awareness amongst farmers about the potential future changes in climate, the effects of the impacts, and how to maximise opportunities. This awareness raising should also be extended to others in the agricultural supply chain and to consumers.
- Support mechanisms for opportunities need to be integrated into regional plans, especially the Regional Planning Guidance.
- The close links between the impacts on agriculture and other sectors, particularly water management and land use, need to be emphasised. This should also be the case for developing policy, with agriculture seen as part of the wider supply chain, especially linking to the Food and Drink Cluster of the Regional Economic Strategy.

13.4.3 Energy

- The forthcoming Regional Energy Strategy needs to reflect potential climate change impacts and adaptation options.
- There is a need to raise awareness of the use of energy in buildings with clients, customers, developers and builders, and the possible changes in demand as a result of climate change. However, this must be focused on specifics, particularly that alternative technologies need not cost more than those currently used.
- More generally, there is a need to raise awareness of energy and climate change, perhaps through the linking it to the current trend for ‘home and garden’ programmes, and link this to financial incentives and regulations.
- Energy suppliers and planners should consider using scenarios that describe possible changes in demand from winter space heating to summer cooling and develop appropriate plans.
- Methods for improving the energy efficiency of buildings need to be considered e.g. supplementary planning guidance and procurement specifications, to minimise the increase in the use of energy as a result of climate change.

- Energy suppliers need to consider the potential impacts of climate change on their distribution networks in order to assess the potential economic costs and ensure that the necessary investment is made in any changes required.

13.4.4 Land Use and the built environment

- Consideration should be given to the potential changes in land use that may be appropriate in response to potential climate change in the region.
- It would be useful for policy makers to have a visual picture of the potential impacts of climate change in order to make it easier to incorporate it into policies.
- There is a need to convince policy makers that climate change and the adaptation options have economic consequences. There may be a need to link this not only to the Regional Planning Guidance, but also the Regional Economic Strategy.

13.4.5 Transport

- There is a need to tie climate change impacts and adaptation into the Regional Transport Strategy (part of the Regional Planning Guidance) and the Regional Economic Strategy. This should include the potential impacts of higher temperatures on infrastructure, driver concentration and road safety, as well as the potential impacts of more extreme rainfall events, that could give rise to increased flooding, on infrastructure and economic disruption.
- It is also necessary to consider the impacts of climate change on the construction and drainage of roads and railways.
- There is also a need to consider the climate change impacts in the analysis of the alternative development options in the Air Transport White Paper, particularly in comparing expansion of Birmingham International Airport and a possible new airport at Rugby.
- Further research could be useful in establishing a transport emissions inventory for the region, not only including road transport but also rail and air transport.
- This inventory could also be used to assess the contribution of transport emissions to air quality under potential future climate conditions. This would combine air quality modelling and monitoring with climate predictions to allow responses for improving air quality in the region.
- In order to encourage public transport there is a need to ‘climate proof’ new developments, particularly to ensure that they are not too hot in the higher summer temperatures and that there is sufficient protection from increased winter precipitation.

In addition to those recommendations specific to the ‘hot issues’, a number of more general and cross-cutting issues are described in this section. These recommendations are a combination of the authors’ views and those put forward at the ‘hot issues’ workshop.

13.4.6 Policy proofing

In order to assess the potential impacts of climate change on key regional policies and strategies they should undergo a climate change appraisal to highlight the key issues and responses. There could be a number of stages to this appraisal process:

- An initial scoping, objectives led, qualitative assessment to highlight key issues;
- A more detailed assessment, if required for specific strategies, could include application of UKCIP tools and techniques e.g. risk, uncertainty and decision making, economic evaluation and scenarios; and
- The most detailed assessment might require the use of higher resolution climate modelling and use of downscaling e.g. flood risk assessment and management, water resource availability, agricultural production and air quality.

A methodology, with accompanying guidance, should be developed that specifies when to apply these three levels of assessment for developing policy. This could help to address a concern voiced at the third workshop that fully considering every local policy from scratch would waste significant resources.

13.4.7 Further specific research for the West Midlands

Data and information on current and potential climate change could improve the understanding of the nature of potential climate change and its impacts and hence the effectiveness of planning. A number of actions could assist this:

- Development of a set of climate change indicators to assess whether, and if so to what extent, climate change is happening;
- Improved observations and data for higher resolution modelling of future climate conditions; and
- Measurement of climate change impacts.

The climate change indicators could include key climate variables such as temperature, precipitation, wind speed and humidity. Impact areas to be measured could include the following:

- flooding occurrences;
- low river flows;
- changes in habitats and species;
- changes in agriculture e.g. growing season, type of crops grown, yields and pests;
- changes in water demand and availability;
- changes in energy demand;
- costs associated with climate change, not only losses due to flooding and storms but also opportunities e.g. changes in tourism and leisure patterns;
- change in building and development design and implementation; and
- climate change related health impacts.

Further research should be considered into the requirement for the development of higher resolution models to assess more detailed changes and impacts. Additional sectoral assessment on potential climate change impacts should be carried out using more detailed modelling techniques to assess crop yields, water resources and quality, increase in flood risk, energy demand, impacts of transport infrastructure and changes to land use and spatial development for example.

13.4.8 Provision of sectoral information

In a number of the workshops, a need for further information was identified. This would involve specific information for the particular sector on the expected changes in climate, possible ways in which to respond to these changes and sources of information and support. This could encourage individuals and organisations to take action as their understanding of options improved.

13.4.9 Further sector involvement

This study has engaged a wide range of individuals and organisations in developing this report. The choice of ‘hot issues’ was made during this consultation, but there were a number of other issues identified that were not included as ‘hot topics’. These sectors are also important in the region, and may benefit from discussion of potential climate change impacts.

- The finance sector should be engaged for a view on the potential market in the West Midlands for the possibility of water trading and on the potential costs to business of increased flood risk in the region (including insurance);
- Biodiversity and the impact of climate change has been a cause of particular concern nationally, and it would be useful to consider in more detail the threats, opportunities and changes possible in this sector in the West Midlands;
- The heritage sector should be consulted for key concerns and policies on the impact of climate change on key heritage features; and
- Information on the potential impacts of climate change on health should be considered to improve understanding of effects at an individual level and facilitate planning in the health sector.

Appendix A : The First Workshop

Introduction

This appendix provides a summary of the workshop held on Thursday 6th March by Sustainability West Midlands. The workshop was attended by over 30 people representing a range of organisations, including business, NGOs and pressure groups, local government, and regulatory bodies. The workshop was a key part of the scoping study to consider the impacts of climate change in the West Midlands, and the beginning of collective involvement in the study and the wider process.

Objectives

The objectives of the workshop were two-fold. Firstly, the discussions aimed to draw on the experience of those attending to identify the priorities associated with climate change in the region. The purpose of this was to allow Entec to select a small number of 'hot issues' to consider in more detail in the scoping study. Since there has already been a pre-scoping study undertaken that presented an overview of all the relevant issues, this study will select a case study approach in order to add some depth to the assessment of priorities for the West Midlands. The second aim of the workshop was to allow a number of people from different organisations to hear about the project and to discuss their own experiences and thoughts with others.

Content and method

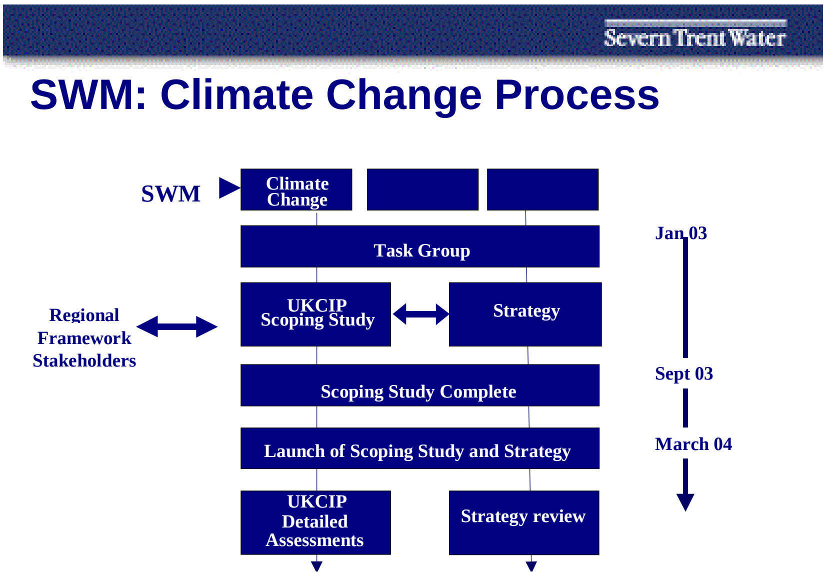
Programme

The morning started with a number of presentations, followed by a series of group discussions and feedback sessions. A summary is given below.

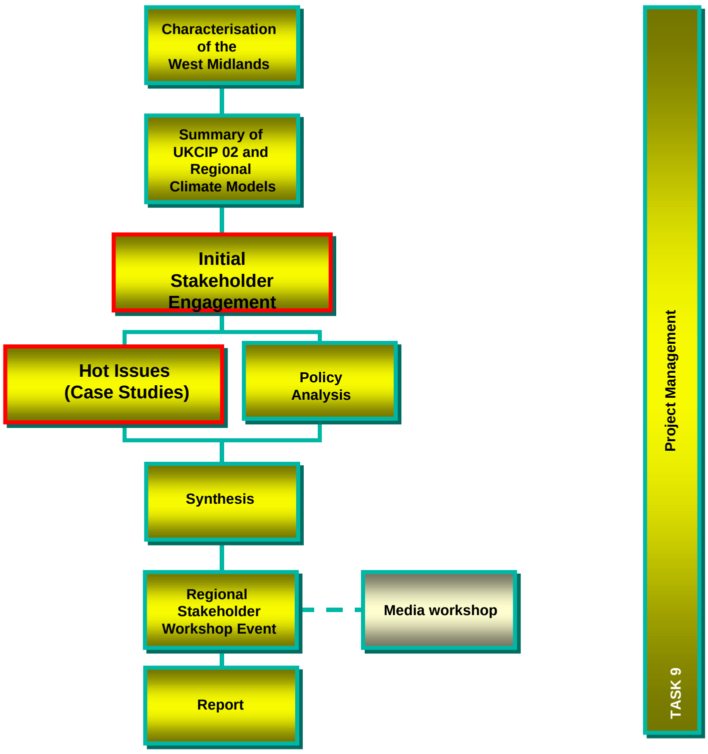
Introductory presentations	Claire Bridges	Welcome
	Charlotte Harper	The Wider Strategy
	Chris Hughes	Overview of the project
		Characterisation of the region
	John Thornes	Climatology of the region
Group discussions	Clarifying the issues	
Feedback		
Group discussions	Managing the issues	
Feedback		

Context

In Charlotte's presentation, she outlined the twin track approach within which the current project fits. A copy of the slide showing this approach is given below.



The current Entec project fits in the 'UKCIP Scoping Study' box. Within this project, the workshop came as one of the first tasks, as shown in the following diagram, which outlines the flow of the scoping project.



‘Hot Issues’

In no particular order, the topics that came up as ‘hot issues’ were transport, energy, agriculture, water resources, and land use and the built environment. In all of these topics, the impact of climate change on the sector, and the sector on climate change, were seen as important. Each topic will also consider the differences between urban and rural areas.

Transport

The West Midlands is central to the national transport infrastructure, as well as having international links. As with the other topics, transport influences the extent of climate change, but changes in the climate will affect transport infrastructure and alter choices.

Energy

This was based on the recognition of the West Midlands as a centre for traditional manufacturing industry based on the use of carbon fuels. Therefore, climate change itself will impact on the energy use requirements, but there might also be opportunities for the development of innovative energy products.

Agriculture

Since agriculture still represents a relatively important sector of the West Midlands economy, and is a crucial influence on the economy, society and environment of rural areas, this also was chosen as a ‘hot topic’. For this study, agriculture includes horticulture and silviculture as well.

Water Management

It is anticipated that climate change will have a significant impact on the availability and distribution of water. This topic will consider the water resources of the region, as well as the consequences of broader water issues, including both flooding and drought.

Land Use (inc. Built Environment and Regeneration)

This topic will consider climate change impacts in relation to the land use planning system, regeneration strategy and land use composition of the region.

Other issues identified

Other issues that were raised, but were not decided as ‘hot topics’ (at this stage) are listed below. However, these issues will be considered whether they cut across the ‘hot topics’ above, and are being considered by the Climate Change Task Group as the subject of further study.

- Housing
- Biodiversity
- Tourism
- Effects of climate change on the industrial structure of the region
- Health

Appendix B : The 'Hot Issues' Workshop

Introduction

This appendix provides a summary of the workshop held on Tuesday 13th May by Sustainability West Midlands. The workshop was focused around the five 'hot issues' identified in the first workshop:

- Water Management;
- Agriculture;
- Energy;
- Land Use and the Built Environment; and
- Transport.

The workshop was attended by over 30 people with specific interest and knowledge in one of the 'hot issues'. These individuals are named in Appendix E, along with those who attended one of the other workshops.

Information was sent out to those attending prior to the workshop focusing on their particular 'hot issue'. These briefing papers were specific to the 'hot issue', and included the following information:

- A headline summary of the current situation in a few bullet points;
- The current priorities incorporated into regional or national plans, policies and strategies. Together with the summary of the current situation, this now forms the 'Context' part of Sections 6 to 10;
- The socio-economic scenarios for future change. These are in this report as Tables 6.1, 7.1, 8.1, 9.1, and 10.2;
- A summary of potential climate changes; and
- Prompts for discussion.

The prompts for discussion set out a range of questions as follows:

- Is the 'hot issue' characterisation accurate? Does anything need to added or deleted?
- Is the accompanying strategy or policy appropriate? Does it highlight the most important issues? Does it reflect the current change that is planned?
- Are there any other plans or policies that will affect the 'hot issue'?
- What is the level of uncertainty i.e. what could change the planned changes (population change, consumer demand, EC and UK policy making, economic

factors, natural processes, unexpected large scale change e.g. foot and mouth, climate change)?

– How can we learn from other sectors?

– Can you think of a case study to illustrate climate change impacts (including opportunities) for the ‘hot issue’?

– What recommendations should we make e.g. what plans, policies and processes should we seek to influence, is there a need to carry out further research, should we be setting up new processes, is there a need to invest in appropriate change to respond to the challenges and capture opportunities? Can we be specific about these?

Agenda

10.00	Meet for coffee
10.30	Introduction and objectives
11.00	Group discussion
12.30	Lunch
13.30	Group discussion
15.00	Plenary session
15.30	Thanks and close

Outputs from the day

Answering the discussion questions above was intended to help identify gaps, threats and opportunities but most importantly to help formulate specific recommendations. There were a number of issues, ideas and recommendations made during the workshop discussions. In order to inform the study, the points of consensus and particular priority are included where appropriate in sections 6, 7, 8, 9 and 10. In addition, some of the recommendations from the workshop related to mitigation and therefore did not fit within the scope of this project. However, these comments have been passed on to Sustainability West Midlands to inform the development of the regional climate change strategy.

Appendix C : The Third Workshop

Introduction

This appendix provides a summary of the discussion at a regional workshop held on 13th June 2003. Three hundred people were invited, with over 30 attending. The main objective of the workshop was to inform the integration of this study into the regional climate change strategy. Therefore, much of the discussion focused on further needs for research or consideration within the West Midlands. The discussion took place in groups, which aimed to include a range of interests and knowledge.

The invitation to the workshop included the agenda (shown below) and a very brief outline of the key messages from the five 'hot issues'. These aimed to provide an overview of the possible issues that could prompt discussion of how these should be included in the development of a West Midlands climate change strategy. The main points from the discussion are listed below.

Agenda

09:30 Welcome and Introduction

09:50 Scoping Study Overview

10:15 Climate Change in the West Midlands

10:45 Coffee

11:15 Action Planning Workshop

This involved breaking into a number of smaller groups to discuss the 'Agenda for Action' for climate change in the West Midlands

12:15 Feedback from group discussions

12:45 Lunch and Close

Main points from the group discussions

The main points from each of the group discussions are listed below. Some of the first comments came up in a number of the groups. These comments will be used to inform the development of the regional strategy from this study.

- We need to link the West Midlands strategy to the strategies from other regions;
- The strategy will need to integrate mitigation into the adaptation focus of this study;
- It will be important to consider natural areas and the relationship to climate change in the strategy to balance the discussions of energy and transport in this study. This should also link to landscape management;
- There are a number of regional anecdotes about responses to changes in climate. The strategy needs to use stories and numbers to demonstrate possible impacts;
- It would be best to 'climate-proof' regional plans and then check local plans against that, in order to make it as easy as possible to incorporate climate change into plans;

- The basis of the regional strategy must be in sustainability, and should not focus on future scenarios, which are too extreme;
- Other sectors, particularly finance, health, and contingency planning, need to be considered more fully;
- The regional authorities need to consider how to get the climate change message to the public, by developing simple messages and examples of action with current benefits to capture wider interest;
- There is a need to discuss climate change with the wider media, developing ‘off-the-shelf’ stories that can be used during news droughts. Perhaps there should also be a regional figurehead;
- One further area for consideration could be the implications of integrating more fully into Europe, linking economic forecasts to the impacts of climate change. This could also assess potential inward migration if other parts of Europe become uncomfortable to live in; and
- There should be an implementation toolkit, considering a range of options from regulation to market-based instruments.

Appendix D : Indicators in the UKCIP Socio-Economic Scenarios

The following tables relate to the 'hot issues' and indicate the quantitative information used in the UKCIP socio-economic scenarios (UKCIP, 2001). They provide alternative indications for the whole of the UK in the 2020s, based on a continuation of current trends as well as the World Markets and Local Stewardship scenarios.

Agriculture

	Mid-1990s	**2020s (linear)**	**World Markets**	**Local Stewardship**
Total agricultural area (ha)	18, 500, 000	17, 500, 000	16, 500, 000	19, 000, 000
Of which under agricultural production	18, 000, 000	17,000, 000	16, 000, 000	18,750, 000
Of which other (set aside, roads, etc.)	500, 000	500, 000	500, 000	250, 000
Value of agricultural goods	£12 billion	£8.2 billion	£15 billion	£15.8 billion
Value of agricultural goods per agricultural area	£700/ha	£500/ha	£950/ha	£800/ha
Pesticide usage	3.8 kg/ha	*No stable trend*	3.0 kg/ha	1.5 kg/ha
Synthetic nitrogen fertiliser usage	1.6 Mt N/year	1.4 Mt N/year	1.5 Mt N/year	1.2 Mt N/year
Agricultural subsidies (CAP and national, part of GDP)	0.49%	*No stable trend*	0.16%	0.8%
Agricultural subsidies (CAP and national, at constant prices)	£3,000 million (large variations)	*No stable trend*	£2,400 million	£7,100 million
Of which related to agri-environment schemes	£120 million	*No stable trend*	£250 million	£2,000 million
Organic farming (% of area under agricultural production)	1%	*No stable trend*	3%	40%
Yield of milk per cow	5,500 litres/hd/ year	7,000 litres hd/ year	8,700 litres/ hd/ year	6,200 litres/ hd/ year
Yield of wheat per hectare	7.7 t/ha	9.4 t/ha	9.8 t/ha	7.0 t/ha
Production (% output) Farm crops	40%	42%	45%	47%
Livestock	60%	58%	55%	53%

Energy

There is no quantitative information given in the UKCIP socio-economic scenarios report on use, generation or demand for energy.

Land Use

	Mid-1990s	2020s (linear)	World Markets	Local Stewardship
Land Use (%)				
Agricultural	75%	72.5%	71%	76%
Forest, woodland and other	10%	11%	11%	9%
Urban and not specified	15%	16.5%	18%	15%
Land use changing to urban use (p.a. 1995-2025)	13, 000 ha/ year	*No stable trend*	24,500 ha/ year	3, 000 ha/ year
Of which re-used land	6, 500 ha/ year	*Increasing*	12, 000 ha/ year	3, 000 ha/ year
Of which formerly developed land	6, 500 ha/year	*Decreasing*	12, 000 ha/year	--

Transport

	Mid-1990s	2020s (linear)	World Markets	Local Stewardship
UK passenger transport (passenger kilometres)	690 billion km/ year	1100 billion km/ year	1200 billion km/ year	700 billion km/ year
UK passenger transport (%)				
Air	1%	1%	2%	0.5%
Rail	5.5%	3%	3.5%	10%
Road (public)	6.5%	4%	6%	15%
Road (individual)	87%	92%	88.5%	74.5%

Water Management

	Mid-1990s	2020s (linear)	World Markets	Local Stewardship
Water demand (% change)	+ 0.2%/year	+ 0.5%/year	+ 1%/year	- 0.5%/year
Public water supply (volume)	20, 000 Ml/day	23, 000 Ml/day	27, 000 Ml/day	17, 000 Ml/day
River quality (% classified as good)				
Biologically	93%	*Improving*	90%	95%
Chemically	63%	*Improving*	60%	75%

Appendix E : Consultees During the Study

Sustainability West Midlands Steering Group

Claire Bridges	Sustainability West Midlands
Charlotte Harper	Severn Trent Water
Brian Waters	Sustainability West Midlands
Colin Wilkinson	Royal Society for the Protection of Birds
Michelle Colley	UK Climate Impacts Programme
Richenda Connell	UK Climate Impacts Programme
Chris Crean	Friends of the Earth
John Firth	Severn Trent Water
Jackie Lawrence	Warwickshire County Council
Julia Brown	Birmingham City Council
Tony McNally	ProEnviro
Caroline Bedell	Country Land and Business Association
Richard Davies	Marches Energy Agency

Others involved in the study

Liz Alston	Worcestershire County Council
Molly Anderson	Environment Agency
Fran Austins	West Midlands Regional Assembly
Stephen Baker	South Staffordshire Water PLC
Duncan Bardsley	Carbon Trust
Maurice Barlow	Solihull Metropolitan Borough Council
Sue Blakeley	Birmingham City Council
James Bradley	Government Office for the West Midlands
David Clarke	Government Office for the West Midlands
Susan Cooper	Birmingham City Council
Elizabeth Cox	National Trust
Julie Coxon	Sandwell Metropolitan Borough Council
Annette Daykin	British Waterways
Tracy Dexter	Warwickshire Energy Efficiency Advice Centre
David Elliot	Department of Health
Jonathon Felton	Countryside Agency
Mark Felton	English Nature
Tracey Fletcher	World Wildlife Fund
Ruth Green	National Forest Company
Francesca Griffith	Herefordshire Nature Trust
Colin Hagan	Freight Transport Association
Mike Harley	English Nature

John Harrison	Shropshire County Council
Adrian Hilton	Wolverhampton City Council
Paul Horcombe	Severn Trent Water
Jonathan Horsfield	Warwickshire County Council
David Howatson	Government Office of the West Midlands
Lynette Jones	Wyre Forest District Council
Terry Jones	Sandwell Metropolitan Borough Council
Nick King	Environment Agency
John Kings	University of Birmingham
Susan Manns	Advantage West Midlands
Lynn Melling	Warwickshire Energy Efficiency Advice Centre
Justin Milward	Woodland Trust
Jenny Moreton	Worcestershire County Council
Gordon Selway	Transport 2000
Peter Shirley	West Midlands Wildlife Trusts
John Sidebotham	Centro
Amanda Smith	English Heritage
Roger Stone	Country Land and Business Association
Paul Tame	National Farmers' Union
Sandy Taylor	Birmingham City Council
David Thew	West Midlands Regional Assembly
Mike Thompson	Advantage West Midlands
David Ward	Birmingham City Council
Richard Wood	Herefordshire County Council
Nick Young	Countryside Agency

Appendix F : Glossary

Terms in *italics* are found elsewhere in this Glossary.

Aerosols		Airborne solid or liquid particles, with a typical size between 0.01 and 10μm that reside in the atmosphere for at least several hours. Aerosols influence the *climate* directly through scattering and absorbing radiation, and indirectly through the formation and optical properties of clouds.
Anomaly		Deviation or departure from the normal or average order or form.
Anthropogenic		Resulting from, or produced by, human beings.
Anticyclone		A slow moving high pressure system commonly termed a 'high'. Winds light and variable with clockwise winds in the northern hemisphere, calm in middle of the system. Brings generally settled weather, warm and sunny in summer, in winter cold, frosty or foggy
Aquifer		Layer of permeable rock, sand or gravel which allows water to pass through it and which if underlain by impermeable material, holds water to form a saturated layer or water table.
Aspect		The direction in which a thing faces, particularly applied to slopes in relation to the sun on account of its effect on settlement and plant growth
Atmosphere		The gaseous envelope surrounding the Earth, comprising almost entirely of nitrogen (78.1%) and oxygen (20.9%), together with several trace gases, such as argon (0.93%) and *greenhouse gases* such as carbon dioxide.
Birmingham Temperature Series	BTS	Meteorological data collected in Birmingham for over 200 years, yielding almost identical results to the *Central England Temperature* series.
Biodiversity Action Plan	BAP	The UK Biodiversity Action Plan was published in January 1994 in response to Article 6 of the Biodiversity Convention. Following this, three types of Action Plans have been developed which set priorities for nationally important and locally important habitats and wildlife, Species Action Plans, Habitat Action Plans and Local Biodiversity Action Plans.
Bleeding		Separation of road surfacing materials leading to reduced and variable skid resistance and tendency for tyres to pick up binder or aggregates from the road.
Brownfield land		Land that has been previously developed. This may be urban or rural, but excludes land or buildings used for agriculture or forestry purposes. It also excludes parks, recreation grounds and allotments. Contrast to *greenfield land*.
Carbon cycle feedback		This occurs where changes in the climate induced by increased carbon dioxide concentrations in the atmosphere lead to environmental changes that release more carbon dioxide. For example, a study carried out at the Hadley Centre found that under some scenarios for increased CO_2, this led to trees in Amazon being replaced by grassland, thereby releasing the CO_2 previously held in the trees and exacerbating the climatic warming.
Carbon dioxide	CO_2	One of the principal *greenhouse gases*.
Central England Temperature	CET	Temperature data representative of the triangular area with corners at Preston, Bristol and London. The series is the longest instrumental climate record in the world and has been used to demonstrate a number of climate changes.
Climate		The 'average weather' described in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organisation (WMO).

Climate change		Statistically significant variation in either the mean state of the *climate*, or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or to *external forcings*, or to persistent *anthropogenic* changes in the composition of the atmosphere or in land use.
Climate Change Levy	CCL	A tax introduced in 2001 on the industrial use of energy, with rates varying according to the type of energy used.
Climate model		A numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes, and accounting for all or some its known properties.
Climate prediction		An attempt to produce a most likely description or estimate of the actual evolution of the climate in the future, e.g. at seasonal, inter-annual or long-term time scales.
Climate projection		A projection of the response of the climate system to emission or concentration scenarios of *greenhouse gases* and *aerosols*, or *radiative forcing* scenarios, often based on simulations by *climate models*. As such climate projections are based on assumptions concerning future socio-economic and technological developments.
Climate scenario		A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships, that has been constructed for explicit use in investigating the potential consequences of anthropogenic *climate change*.
Climate variability		Variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events.
Convective cellular clouds		Discrete clouds, generally taller than they are wide. Uniform base, with widely variable tops, with turrets of cloud projecting above the main mass. They form only when the atmosphere is unstable.
Cyprinid		Belonging to a family of fish (Cyprinidae) including carp, tench, roach, rudd, and dace. Tolerant of a lower standard of water quality than Salmonidae. See *salmonid*.
Deterministic		A process, physical law or model that returns the same predictable outcome from repeat experiments when presented with the same initial and boundary conditions, in contrast to *stochastic* processes.
Disposable load		This is the weight that an aircraft carries in passengers, freight and fuel. It does not include the aircraft prepared for service weight (the aircraft, fuel and crew).
Diurnal		occurring daily, once every 24 hours (compare to *seasonal*)
		occurring during the day (compare to *nocturnal*)
Emission scenario		A plausible representation of the future development of emissions of substances that are potentially radiatively active (e.g. *greenhouse gases*, *aerosols*), based on a coherent and internally consistent set of assumptions about driving forces and their key relationships.
External forcing		A set of factors that influence the evolution of the climate system in time (and excluding natural internal dynamics of the system). Examples of external forcing include volcanic eruptions, solar variations and human-induced forcings such as changing the composition of the atmosphere and land use change.
Extreme weather event		An event that is rare within its statistical reference distribution at a particular place. Definitions of 'rare' vary from place to place (and from time to time), but an extreme event would normally be as rare or rarer than the 10th or 90th percentile.
Fluvial		Riverine, pertaining to rivers.

Green Belt		14 separate areas covering approximately 12% of the land area of England. They are located around urban areas to restrict sprawl, prevent neighbouring towns merging, protect the countryside and nature of historic towns, and encourage recycling of urban land.
Greenfield land		Land that has not previously been used for development, generally agricultural, parkland or natural. Contrast to *brownfield land*.
Greenhouse gas	GHG	Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds. The primary greenhouse gases are water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and ozone (O_3).
Greenhouse gas forcing		The effect of the *anthropogenic* emissions of *greenhouse gases* on the *climate*.
Grid		The co-ordinate system employed by *GCM* or *RCM* to compute three-dimensional fields of atmospheric mass, energy flux, momentum and water vapour. The grid spacing determines the smallest features that can be realistically resolved by the model. Typical resolutions for GCMs are 200 km, and for RCMs 20-50 km.
Gross Domestic Product	GDP	The total market value of all the goods and services produced within the borders of a nation or region during a specified period
Gross value added		The sum of total payment to factors of production, i.e. wages, interest, profit and rent. It is used as a measure of the contribution of a sector to the overall economy.
Intergovernmental Panel on Climate Change	IPCC	Intergovernmental Panel on Climate Change
Isohel		A line drawn on a map connecting points that receive equal amounts of sunlight
Isostatic		Relating to the equilibrium in the earth's crust such that forces tending to elevate landmasses balance forces tending to depress landmasses. Changes can occur as the pressures exerted by ice age conditions relax.
Knot		A measure of wind speed (also used widely in aviation and sailing) where 1 knot = 1 nautical mile per hour = 1.152 miles per hour or 1.85 kilometres per hour (note: this is the UK definition of knot, which differs fractionally from the international definition).
Managed retreat		Choice of water, particularly coastal, management that allows natural processes to continue with relatively little intervention.
Mean		The total of a group of values divided by the number of values. For example, the mean of the values 6, 9, 1, 7, 9 is 6.4.
Median		The middle value of a distribution arranged in size order. For example, the median of the group of values 6, 9, 1, 7, 9 is 7.
Mode		The most commonly occurring value in a distribution. For example, the median of the group of values 6, 9, 1, 7, 9 is 9.
Nocturnal		Occurring during the night (compare to *diurnal*)
North Atlantic Gulf Stream		Current of warm water that is moved from the Gulf of Mexico north across the Atlantic as cooler water from the Arctic sinks and moves in the opposite direction. It leads to significantly warmer conditions in the UK than in other countries at a similar latitude.
North Atlantic Oscillation		Defined as the pressure difference between the air over Iceland and the air over the Azores. If pressure is higher than usual over Iceland, it is colder in Europe during the winter and there is more rain in the Mediterranean. If pressure is unusually low over Iceland, there are more storms and precipitation in Europe, a milder winter and there is less rain in the Mediterranean.
Northern hemisphere		The half of the earth north of the equator.

Office of Water Services	OFWAT	This organisation is responsible for making sure that the water sewerage companies in England and Wales give a good quality, efficient service at a fair price. They are a government department led by the Director General of Water Services.
Parameter		A numerical value representing a process or attribute in a model. Some parameters are readily measurable climate properties; others are known to vary but are not specifically related to measurable features. Parameters are also used in climate models to represent processes that are poorly understood or resolved.
Photosynthesis		The process by which plants (and a number of other organisms) use sunlight, carbon dioxide and water to make carbohydrates. These carbohydrates are then used to provide energy for the plant to grow.
Physiography		The study of the physical features of the earth's surface
Planning Guidance Note 25	PPG-25	Local Planning Authorities are to ensure that flood risk is properly taken into account in the planning of developments to reduce the risk of flooding.
Precipitation		All forms of rainfall, whether solid (snow, hail, ice pellets, snow grains or hoar frost) or liquid (rain, drizzle, sleet, wet fog or dew).
Radiative forcing		The change in net vertical irradiance (expressed as Watts per square metre) at the *tropopause* due to an internal change or a change in the *external forcing* of the climate system, such as, for example, a change in the concentration of carbon dioxide, or the output of the Sun.
Real price		This is the price adjusted for inflation, and is usually used for data gathered over a number of years to allow comparison of prices over the period.
Relative humidity		A relative measure of the amount of moisture in the air to the amount needed to saturate the air at the same temperature expressed as a percentage.
Renewable energy		Energy captured using renewable sources. These include solar, wind, wave and biomass fuel power.
Resolution		The *grid* separation of a climate model determining the smallest physical feature that can be realistically simulated.
Salmonid		Soft-finned fish of cold or temperate waters. Of, belonging to, or characteristic of the family Salmonidae, which includes the salmon, trout, and whitefish. Requires high water quality. Compare to *cyprinid*.
Scenario		A plausible and often simplified description of how the future may develop based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections, but are often based on additional information from other sources, sometimes combined with a 'narrative story-line'.
Scoping study		Study in which the aim is to provide an introduction to the issues of most importance, defining the scope of the priority issues, rather than generating a detailed, technical analysis.
Seasonal		Occurring or related to a particular season of the year. When considering climate averages, seasonal variations can also be used to compare longer periods of time than *diurnal* variations.
Sky view factor		An index between 0 and 1 showing the amount of sky visible from the ground, where 0 indicates no sky visible (e.g. in a tunnel) and 1 indicates completely open sky.
Special Area of Conservation	SAC	571 sites across the UK, often linked to Sites of Special Scientific Interest, that are afforded the highest possible environmental protection.
Special Protection Area	SPA	These are similar to *SAC*s, but relate specifically to migratory and threatened birds and their habitats.
Sustainable Drainage System	SuDS	System of drainage concerned with rainwater runoff, which is designed to take account of people and the environment.

Specific humidity		The ratio of the mass of water vapour (in grams) to the mass of moist air (in kilograms) in a given volume of air.
Station		The individual site at which meteorological measurements are systematically observed and recorded.
Stochastic		A process or model that returns different outcomes from repeat experiments even when presented with the same initial and boundary conditions, in contrast to *deterministic* processes. See *weather generator*.
Topography		Description or representation on a map of all the surface features of an area, natural or artificial.
Total budget approach		Economic methodology that considers changes to the budget of an individual or organisation, including both costs and benefits.
Tropopause		The boundary between the lowest part of the atmosphere, known as the troposphere, and the highly stratified region of the atmosphere, known as the stratosphere. The tropopause is typically located 10 km above the Earth's surface.
UK Climate Impacts Programme	UKCIP	The UK Climate Impacts Programme (UKCIP) helps organisations assess how they might be affected by *climate change*, so they can prepare for its impacts and plan to adapt. Based at the University of Oxford, UKCIP was set up by the Government in 1997 and is funded by the Department for Environment, Food and Rural Affairs (Defra).
UKCIP98		A set of four *scenarios* of future *climate change* (to 2100) for the UK.
UKCIP02		An update of *UKCIP98* scenarios incorporating higher resolution results, estimates of changes to extremes of weather and sea level, advice on the possibility of rapid change, and guidance on how to handle uncertainty.
Uncertainty		An expression of the degree to which a value (e.g. the future state of the climate system) is unknown. Uncertainty can result from a lack of information or from disagreement about what is known or knowable. It can also arise from poorly resolved climate model parameters or boundary conditions.
Urban heat island		A climate effect occurring in built-up areas, particularly on calm, clear nights associated with *anticyclones*. The degree of effect depends on the *sky view factor*.
Value Added Tax	VAT	Tax on the final consumption of certain domestic goods and services.
Vernilization		Number of day degrees below zero required for winter cereals to move from vegetative stage to sexual maturity.
Weather generator		A model whose stochastic (random) behaviour statistically resembles daily weather data at a location. Unlike *deterministic* weather forecasting models, weather generators are not expected to duplicate a particular weather sequence at a given time in either the past or the future. Most weather generators assume a link between the precipitation process and secondary weather variables such as temperature, solar radiation and humidity.

Appendix G : Pre-scoping report

This appendix includes a copy of the pre-scoping report carried out by the West Midlands Climate Change Impacts Study in 2001 and used as a basis for this scoping study.

The Potential Impacts of

CLIMATE

CHANGE in the West Midlands

Pre-scoping Consultation Report March 2001

MIDLANDS ENVIRONMENTAL BUSINESS CLUB LIMITED

Severn Trent Water

UK Climate Impacts Programme

A report by the West Midlands Climate Change Impacts Study (WMCCIS)

Foreword

"Doing nothing is not an option. You may doubt some of the predictions and their likely impacts, but I suggest that a sensible analysis of the risks does not allow us to sit back and wait."

Peter Ewins F.Eng, Chief Executive The Met. Office

This statement is often used to draw attention to the immediacy of climate change and its far reaching effects. I make no apologies for using it. I believe we are facing the greatest environmental challenge ever experienced by modern civilizations. How we control the causes of climate change and adapt to its effects will determine the future structure of our society.

The Midlands Environmental Business Club and Severn Trent Water have jointly agreed to sponsor a study looking at the impacts of climate change on the West Midlands within the framework of the UK Climate Impacts Programme. This is the first report setting out the findings from a review of published information. We welcome your responses and thoughts.

We cannot be certain what tomorrow's climate will be, I suggest however that it is entirely reasonable for you to acknowledge that something strange is happening. I believe that in the West Midlands we have the determination to rise to the challenge, thereby ensuring that our children look back with gratitude at our efforts and not exasperation at our inactivity. This is not a problem for government alone, nor is it problem which should be the sole preserve of NGOs, businesses, or motivated individuals. There is a role for all.

It would be remiss if I did not take this opportunity to thank UKCIP for their advice, the members of the Steering Group for their continuing support and encouragement; and particularly Severn Trent Water's graduates without whose efforts this report would not have been possible.

Tony Lass
Cocoa Technical Manager
Cadbury International Ltd.
Chair of the West Midlands Climate Change Impacts Study Steering Group

Contents

Introduction

This report is the first publication to be released by the West Midlands Climate Change Impacts Study. It sets out a summary of the results to date following a wide ranging review of existing literature and documents, published information on the web, regulatory policies and legislation relating to climate change impacts.

This document does not intend to identify a definitive list of climate change impacts for the West Midlands, nor does it attempt to reach any conclusions regarding priority issues, responsibilities and actions. It is a record of views currently expressed by a variety of organisations and individuals based on informed judgements

This document has a number of objectives:

1. to provide a record of the work undertaken to date
2. to provide a baseline from which a formal climate impacts scoping study can be undertaken
3. to enable views and thoughts from a wider cross-section of key individuals and organisations in the West Midlands
4. to raise awareness of climate change impacts and the need to plan to adapt within the West Midlands

The WMCCIS will be placing greater relative emphasis upon regional economic and business activity than that currently seen in other studies. This is not to say that lower weight should be attached to traditional 'green' issues rather that we need to recognise that mitigation and adaptation strategies are required across all aspects of West Midlands society.

We have identified 15 sectors, with the business groups corresponding to the task groups established by Advantage West Midlands:

- Creative industries
- Built environment
- Ceramics
- Finance and banking
- Food and drink
- Health
- Environmental services
- Natural resources
- Leisure and tourism
- Transportation and the automotive industry
- Engineering
- Textiles
- Biodiversity
- Society
- Regulatory

A description of the sectors is given in Appendix 1: Sector Groups. These sectors were chosen for their specific relevance to the West Midlands.

Summaries of the key impacts and issues for each of these sectors are provided in this report. The results of the review of published documents etc., are set out in a technical paper (Technical Paper 1: Pre-scoping Information Review) which is available as a separate document.

At this stage we have not evaluated the impacts using downscaled regional information taken from the UKCIP climate change scenarios. The impacts identified in this report make use of general views of likely climate change impacts for the UK.

UK Climate Impacts Programme (UKCIP)

Cutting edge-science. Supercomputers. Advanced modelling. These are just some of the powerful tools and techniques used to understand how our climate is changing. But that is only part of the story. These changes will have very real effects on the UK. Organisations with responsibility for dealing with the impacts of climate change need to work together to assess how those changes will affect them. By undertaking studies to determine their vulnerability to climate change, business leaders, politicians and decision makers across the UK will be able to obtain the information they need to plan for a future with climate change. Armed with this information they will be able to make the very real changes to the way they work, live, think and develop, that are needed to adapt to climate change.

Climate change and its impacts will vary from one part of the UK to another. By undertaking studies at the regional level, organisations can find out how the specific interests, resources and assets of their region will be affected. They can also establish what steps they need to take to adapt to climate change in order to minimise the costs of anticipated impacts, and to position themselves to benefit from the opportunities that climate change might present.

Impacts on one sector could also influence the capacity of another sector to respond to potential impacts. A partnership approach is needed between those in different sectors to ensure a better sense of 'the big picture' of climate change impacts is achieved. By working together organisations can also get better value for money, combining their resources to obtain the information they need to prepare for climate change.

Launched by the Department of the Environment, Transport and the Regions (DETR) in April 1997, the UK Climate Impacts Programme (UKCIP) serves to help organisations get engaged in assessing what climate change means for them. UKCIP provides a common framework to co-ordinate and integrate study results. A number of studies are now underway, putting the UK at the forefront of tackling the global challenge presented by climate change at a regional level.

In its first three years of operation the UKCIP has stimulated the development of tools for climate impacts assessment. Use of common tools in studies is a key to integration. UKCIP has also been the catalyst for a range of regional and sectoral studies into climate change. These studies combine state-of-the-art scientific methods with real stakeholder engagement. Their results are influencing the way the private and public sector plan for a future with climate change.

Further information about the UKCIP can be obtained from their web site: http://www.ukcip.org.uk/ukcip.html

WMCCIS Programme

The West Midlands Climate Impact Study (WMCCIS), covering the regional planning area, is being undertaken by Severn Trent Water in partnership with the Midlands Environmental Business Club. The study is one of a number of regional and sectoral studies being prepared under the guidance of UKCIP.

The WMCCIS has differentiated itself from other regional studies by placing a greater emphasis on the impacts of climate change on regional economic activity in addition to covering the natural environmental resource issues. This approach has been welcomed by UKCIP.

The Study is seeking to stimulate debate within a wide range of organisations and groups reflecting the varied social, political, economic, environmental and cultural spectrum present in the West Midlands. Through this we hope to encourage ownership of climate change and responsibility for taking action to develop and implement mitigation and adaptation strategies.

This report is a first step towards understanding what climate change could mean to the West Midlands, how we may have to adapt, and what we must do to minimise any further climate change.

The WMCCIS will concentrate its activities upon:

- the completion of a comprehensive scoping report on the impacts of climate change in the West Midlands
- detailed impact assessments for selected topics in accordance with the framework developed for the purpose by UKCIP.
- the development of mitigation and adaptation strategies, with particular emphasis upon the opportunities for the West Midlands business community
- raising awareness of climate change within the West Midlands through an interactive communication exercise. (Please play your part in this process by completing and returning the consultation response sheet included with this document).

A phased approach has been adopted to the scoping report beginning with a pre-scoping review (this report) to be followed by a comprehensive scoping exercise. During April and May we will be reviewing the work to date and the responses to the consultation exercise to define the brief for the scoping report. It is likely that consultants will be appointed to assist with the following work:

- review the work undertaken to date
- provide a detailed regional downscaling of the UKCIP climate and socio-economic scenarios
- identify further work required to complete the scoping exercise taking into account the comments received from the consultation exercise
- undertake the additional scoping work
- recommend specific focus areas for the detailed impact assessments, adaptation and mitigation strategies
- produce a final scoping report for publication and consultation

The key milestones for the Study are:

WMCCIS launch	April 2000
Pre-scoping report	November 2000 - February 2001
Pre-scoping report launch	March 2001
Consultation period	April 2001 - May 2001
Consultation report	June 2001
Scoping Report	May 2001 - August 2001
Regional Conference	September 2001
Consultation period	September 2001 - October 2001
Consultation report	November 2001
Mitigation and Adaptation Strategies	January 2002 - June 2002

Has the climate changed over the last century?

The world is warming. Four out of the five warmest years ever recorded since records began in 1860 were in the last decade; with 10 out of 11 of the warmest years occurring after 1980. Average surface temperatures have increased by 0.6^{0}C over the past 130 years. Glaciers are retreating and, due primarily to the thermal expansion of sea water, global sea levels are rising.

In 1995 the United Nations Inter-governmental Panel on Climate Change concluded, "the balance of evidence suggests there is a discernible human influence on global climate change."

Recent extreme weather events around the world are changing perceptions.

The climate of the UK is changing. Our climate has warmed by about 0.7^{0}C over the last 300 years, with about 0.5^{0}C of warming occurring during the twentieth century. The total of cold days (average temperature below zero degrees centigrade) has fallen from between 15 and 20 per year prior to the C20th to around 10 per year over recent decades. The warm year of 1995 recorded 26 "hot" days above 20 degrees centigrade in Central England, the highest total in 225 years of daily measurements.

Annual rainfall totals across central and eastern England have increased slightly (+3%) since the 1930's. December rainfall totals increased by 38% and July totals fell by 31% over the same period. There has been an increase in summer dry spells. There has been no long term trend in the frequency of severe gales since 1881, but the 1990's experienced more gales than average. Recent research conducted by the Met Office for Severn Trent Water points to an increase in short duration, intense storms in the East and West Midlands.

Winters have become wetter and summers drier. Recent decades have seen an increase in the proportion of winter rainfall in intense storms.

There are no comparable long-term trends in annual precipitation, whether over England and Wales or over Scotland. Substantial variations in precipitation have nevertheless occurred. For example, winter precipitation in Scotland has increased in recent decades, while summer rainfall totals in England and Wales have been falling.

Global warming is also leading to rising sea levels with a typical rise of about 1mm per year, and a maximum relative sea level rise on the east coast of England of over 2mm per year.

This changing climate is having noticeable effects on our environment and on some of our economic activities. Aphids, butterflies and moths are active earlier in the spring. Swallows arrive earlier and oak trees leaf earlier. Gas consumption during the mild winters has fallen. Engineers, water managers, conservationists, architects, decision makers in many industries, will have to learn to plan for a range of future climates and weather extremes that may be quite different from those recorded in recent decades. Consumer attitudes are changing; they expect utilities, transport systems and service industries to deliver in extremes.

Why is climate change happening?

The industrial economy through its reliance on carbon-intensive energy has substantially altered the properties of the Earth's atmosphere. Atmospheric concentrations of greenhouse gases have risen by 50% in less than 200 years and there is increasing evidence to show that human influence is affecting the global climate. Due to the inertia in our energy systems and the long memory exhibited by the climate system, human-induced climate change will continue throughout this century. The implementation of the Kyoto Protocol may slow the rate of change, but will not reverse it.

Climate change has always taken place, it occurs naturally through the complex interaction of a variety of factors including: volcanic eruptions, changes in solar output or natural oscillations in the climate system such as El Nino. However, the increased rate of change that we are currently experiencing is for the most part, due to human activity as a consequence of significant increases in greenhouse gas emissions. It is this increased rate of change that poses the real threat to our society. To overcome these problems, we must adapt to the changes which are already occurring and do as much as we can to prevent any further impacts. Confidence in predictions of future climate is increasing, but uncertainties still remain, so we cannot be certain about the associated impacts. The level of confidence attached to climate predictions has to be borne in mind when assessing and adapting to climate change impacts.

What climate changes can your children expect in the West Midlands?

We expect the climate to continue to change during this century. Possible future climate changes for the Region based on the UKCIP climate scenarios (medium-high) and regional climate model include:

- Temperatures will increase. Annual mean temperatures show a warming of +0.5°C to +1.3°C by the 2020s, +0.8°C to +2.2°C for the 2050s and +1.1°C to +3.0°C for the 2080s.
- Variability in summer temperatures is expected to increase suggesting that we will have more frequent very hot summers. In contrast, the variability in winter temperatures is expected to decrease so we are likely to experience fewer very cold winters.
- The annual number of freezing winter nights has been predicted to be halved by the 2050s
- Overall the climate will become progressively wetter. However, this will not be evenly throughout the seasons as winter rainfall will increase, but summer rainfall will decrease. Annual precipitation increases by 2 to 5% by the 2020s, by 3 to 5% in the 2050s and by 2 to 9% in the 2080s. Winter precipitation is predicted to increase by up to 24% and summer precipitation reduce by 7 to 14% by the 2080s.
- The type of precipitation has been predicted to change towards an increase in both frequency and intensity of short-duration, extreme rainfall events.
- Within the West Midlands the trend will be towards milder, wetter winters and hotter, drier summers. This will be more pronounced in the south-east of the region than in the north-west

What effect will this have on Society, Business and the Environment in the West Midlands?

The following sections provide summaries identifying some of the key impacts and issues drawn from the review of published information on the web, regulatory policies and legislation. The results of the review of published documents etc., are set out in a technical paper (Technical Paper 1: Pre-scoping Information Review) which is available as a separate document.

Engineering industries

Engineering techniques could change in the future due to the rise in temperature caused by global warming, with conditions for employees working in the sector potentially becoming increasingly uncomfortable. The engineering sector will have to think of how to ameliorate these problems so that large costs for refrigeration and air cooling systems are not incurred and damage to goods that are produced is not involved. The West Midlands may be able to attract companies that potentially need to relocate from areas of the world which become less attractive due to climate change.

Engineering manufacturing locations within the West Midlands may well change their location in the future due to the increased risk of flooding in their current locations.

This should be considered when future investment is being planned as relocation may be a better option than investing heavily on an existing site at risk from flooding.

The engineering manufacturing base of the West Midlands is the car industry. Currently combustion engines and their components are being produced, but with the onset of measures to curb global warming and climate change, as well as efforts to save fossil fuel resources, the development of hydrogen cell technology could change all this. West Midlands companies should plan ahead to ensure that they are in a position to respond positively to a changing market.

It has been reported that the engineering sector may lose jobs in the West Midlands due to the climate change levy, which comes into force in April 2001. The aim of the levy is to encourage businesses to improve energy efficiency and promote the development of renewable energy sources. Companies which are energy efficient will not be so hard hit by this extra charge.

Transportation and the automotive industry

The scope of this sector took into account the potential impacts on the automotive industry, road networks and transport networks. This included detailed investigation into road, rail and aviation as sub-sectors.

As annual temperatures rise there will be a beneficial effect on road networks with less frost, reduced gritting bills and freeze thaw damage. Negative impacts arising from changing rainfall patterns will lead to more road closures, increased scour around bridge foundations and the potential for widescale disruptions to business. Higher temperatures will damage road surfaces and structures through the expansion of steel and concrete. Road construction and maintenance costs may increase.

Within the rail sector the focus is on providing an alternative to dependency upon road transport. Increased temperatures will affect the railtrack and associated structures. Flooding and trackside subsidence and slippage will be caused by increased precipitation. Disruption and delays caused by extreme weather conditions are also seen as likely impacts if mitigation or adaptation measures are not undertaken.

Climate change may create opportunities for an expansion of air transport following an increase in the tourism and leisure business in the UK. The use of air transport to move freight may also be a growth area. This needs to be contrasted with concerns regarding the effect of engine emissions and the need to develop more energy efficient propulsion systems. Greater dependency on air transport will result in increased costs during periods of extreme weather.

Further research is required into the potential impacts on the canal network within the region. The only reference in published sources suggested that higher temperatures would result in increased evaporation rates, lowering water levels in the canals. Opportunities to use the canal system to transfer water to meet regional demands for increased resources may be available.

The automotive industry in the West Midlands may have to develop new products to meet changes in vehicle design required as mitigation against climate change impacts.

There will be a need to cut emissions and reduce the effect of human induced climate change. There are many new developments in lower emission cars; hydrogen powered vehicles, fuel cells and hybrid vehicles, which could be utilized. There are more efficient design and production processes and cost savings to be made due to these efficiencies. These new designs present marketing opportunities for these more efficient cars. There is a general view that other means of transport should be available so that the negative impact of cars could be reduced. This would involve creating better transport networks and encouraging people to move into public transport and mass transit systems.

Medical and health

It is suggested that, through the varying climatic scenarios, there may be a major impact on public health over the next century. The major impacts are thought to centre on a change in vector borne diseases such as malaria, digestive disorders, and viral and bacterial infections. Food hygiene will require even greater attention. Other major effects of the change in climate may be a decrease in winter deaths as winters become milder, but more deaths caused by the effects of summer heat waves. Physical and psychological effects caused by extreme events (droughts, heatwaves, and floods) may become more prevalent. Higher temperatures are also associated with an increase in air pollutants resulting in a greater incidence of inflammatory eye diseases. Respiratory diseases caused by damp conditions may increase if damp conditions become more prevalent. Those caused by air pollution or increasing temperatures may also increase.

The scenario is not entirely negative however, the population may become less sedentary as the weather improves and outdoor pursuits become more attractive in the longer, warmer summers. Increasing use of energy efficient materials in homes and more effective heating should improve living conditions for those at greatest risk.

Whilst there is a large amount of information available on this topic, it tends to focus on the negative issues. There is a shortage of West Midlands based data, and all recorded impacts were extrapolated from international articles. Further study is needed on the positive effects of climate change on human health in the West Midlands, health care systems and on the future business threats and opportunities for the pharmaceutical industry.

Ceramics.

It is possible that the greatest impacts on the ceramics industry may arise from a change in the culture and life-style of those living in the West Midlands together with changes in the building construction and design. If temperatures rise, society may move towards a more Mediterranean or Antipodean lifestyle, with an increase in open-air events and facilities. The greater use of ceramics inside buildings and externally will provide significant business opportunities for the industry. The climate predictions suggest that there should be greater opportunities for solar energy as a viable option for residential and business users, increasing the demand for photo voltaic cells. The use of ceramics for internal and external flooring surfaces may increase.

The less advantageous aspects of the issue were considered to be possible increased costs of raw materials and final product transport due to increased taxes etc. which may be imposed to mitigate climate change impacts.

A review of existing information has been carried out to identify the effects that climate change may have on the West Midlands ceramics industry. Very little information relating to the UK industry was found with no references specifically concerning the region. Further research is required in this area.

Creative industries

This wide ranging sector includes telecommunications, IT, the media, marketing and advertising. Its all pervading links, touching on all aspects of life in the West Midlands, influencing society and business, will have a major role in influencing the cultural changes required to meet the challenge of climate change. It also should, perhaps be seen as a resource available for use by the other sectors to assist in the development of mitigation and adaptation strategies.

The industry is, by nature, both creative and innovative, brand imaging especially is becoming ever more diverse. Opportunities, therefore, exist for companies to present a "cleaner" "greener" image, in response to public concerns. The more vociferous these concerns become the more likely that the marketing and advertising industry will react, as other industries ask that they present them in a more positive "Green Light".

The challenge to those involved in this sector is to consider how the new technologies, together with inherent innovatory skills, can be harnessed to support the mitigation and adaptation strategies required by the other sectors. The telecommunications industry sees the impact of climate change as having a positive impact on business growth if reduced private transport creates greater opportunities for virtual offices and home working. A direct impact of climate change may be that overhead telecom lines may be more vulnerable to wind damage.

There was very little available information on this sector or specific issues relevant to the West Midlands. Further research is required in this area.

Environmental services

The scope of environmental services included assessing the potential impacts on waste water treatment, water supply and purification of drinking water, environmental consultants, solid waste management, pollution control and clean technology.

Water supply and purification will be affected in many ways by climate change. Decreasing raw water quality will result from an increase in heavy rainfall producing higher rates of soil runoff, flooding from urban areas bringing associated pollutants into the water environment and a rise in ambient temperatures could lead to an increase in algal blooms, which already interfere with water treatment. Increased ambient temperatures and decreased precipitation during summer months coupled with increased demand for water will affect water resource planning for utilities, the Environment Agency, conservation groups and other water users.

There may be new business opportunities for the pollution control and clean technology sector as tighter environmental standards, especially for emissions, will provide opportunities for the development of new technological solutions. The predicted climate change impacts may also enable the development of viable alternative renewable energy sources. Rising energy costs and restrictions on emissions from carbon based fuels will encourage the development of energy efficient plant and equipment.

Landfill design, operation and management will need to take into account climate changes. Increased precipitation will require different drainage systems, larger pumps and leachate treatment plants. Higher temperatures will affect the rate and production of landfill gas production, increased odour generation and increases in potential pest problems. Increased ambient temperatures will lead to faster rates of bio-degradation and may therefore facilitate alternative disposal methods e.g. composting on a commercial scale.

Municipal waste collection will be disrupted in low-lying areas affected by flooding. During hotter weather, waste collection will have to take place more frequently to compensate for the increase in the rate of decomposition.

There are many lessons to be drawn from the experiences and practices of waste management in other countries. Waste recycling and minimisation, controlling the production of waste at source are key areas for adaptation. Alternative technologies in use elsewhere may provide the West Midlands with tried and trusted transferable solutions.

Food and drink
This sector included the complete food chain from production, through processing, retail and finally, consumption.

Investigations highlighted a number of potential impacts to agriculture in the West Midlands. These tended towards alterations in growing periods and crop yields due to increased summer temperatures and a "longer" summer. There may also be a shift towards growing more winter crops. Also considered was the incidence of pests, loss of crops through extreme weather conditions such as drought and flood. This suggested the need for a change to drought resistant plants, better irrigation and land drainage and a basic change in farming methods to maximise output. There will clearly be a major revolution in agricultural practices with far-reaching affects on issues such as landscape and biodiversity. The role of genetically modified crops will need to be explored in an objective manner. There may be changes in the demand for different food types due to changes in eating habits, for example, more salads may be eaten.

The literature available concentrated almost entirely on the impacts on agriculture and marketing. Little was found reflecting possible changes to the food and drink processing industry nor with regard to retail operations and to changing consumer demands. This area requires further research.

Textiles

There is little published information regarding the potential impacts of climate change on either the West Midlands or the UK textile industry. This area requires further research.

Banking and Finance

The possible increase in extreme weather will affect homeowners as mortgage lenders may enforce inflated buildings insurance premiums on to those with properties in areas at risk of flooding. It has also been suggested that mortgage lenders may require homeowners to have an annual assessment of their property to ensure it will withstand extreme weather conditions.

It is expected that building and contents insurance premiums will be increased in areas at risk of flooding and extreme weather. Some insurance providers may even choose not to insure certain properties in high risk areas, e.g. within designated flood plains. Claims on health insurance polices may also rise as the summer become warmer and working conditions decline leading to increased stress. On the positive side new opportunities will arise for insurance providers as new businesses are developed in direct response to climate change.

Business banking may benefit from climate change as opportunities arise to provide funding for companies to invest in energy efficient equipment to minimise their consumption rates. However, banks may also lose business as some energy intensive industries may be forced to relocate to other countries as the cost of energy increases.

Built Environment

Climate change may impact on the built environment by increasing the costs due to construction disruption (flooding, high winds, increased rainfall), increased land purchase costs and development of brownfield sites. It is expected that changes in building specifications will occur and that Health and Safety legislation will also be amended. This will result in changes in codes of practice for the construction industry.

An increase in extreme weather events will lead to increased repair and maintenance costs for residential/commercial property owners with historic buildings being particularly vulnerable. Heave and subsidence events may become more frequent. Higher temperatures are likely to reduce winter heating bills but air conditioning may be required in the summer. Construction materials, such as concrete, sealants and coatings, may also deteriorate more quickly.

Infrastructure will have to be modified and design standards changed to cope with climatic changes. Underground network failure (water, gas, cable, and sewerage) could increase due to flooding or subsidence, and there is an increased risk to overhead electricity cables from extreme winds. Transport networks may also come under more stress due to extreme weather events including higher temperatures, resulting in greater repair costs.

The Climate Change Levy will encourage the development of renewable energy sources and buildings are likely to become more sustainable. New construction techniques and new building materials will be required, perhaps drawing on the experiences in other countries.

Leisure and Tourism

There is little published information on the effects of climate change on the tourism and leisure industries within the West Midlands, although it was possible to draw conclusions from studies looking at national impacts.

Family groups and short break holidays are identified as the most climate sensitive, with British holiday makers taking more spontaneous decisions over travel. The potential lengthening of the summer season, and a higher frequency of warmer drier days may lead to an increase in visitor numbers to rural locations and key attractions which includes Cannock Chase, Long Mynd, Wenlock Edge, Wyre Forest etc. This may have both positive and negative impacts on the region, as increased revenue and the demand for services will boost the local economy. However, negative impacts may arise through increasing pressures on local infrastructure and environmental systems, especially in sensitive areas.

Global impacts due to climate change may also affect tourist numbers visiting the UK. The global resurgence of malaria, dengue fever and cholera, which is predicted to affect parts of Europe, may reduce the popularity of Mediterranean holidays and therefore lead to increased visitor numbers in the UK.

Two underlying factors must also be considered. The impacts on tourism in the West Midlands are likely to be lower than those experienced in more popular holiday destinations such as coastal areas. The second factor being changes in the availability of free time or disposable income may override any climatic impacts.

Further investigations into the direct impacts upon the West Midlands region will need to be undertaken through communication with key tourism groups - the National Trust, local tourist agencies and key visitor attractions to assess the level of understanding and possible adaptation strategies.

Biodiversity

There is a significant amount of information available related to the impacts of climate change on biodiversity within the UK.

Species of regional importance including: Freshwater Mussels, Great Crested Newt and Twaite Shad are identified as vulnerable. Aqaulate Mere, the largest of the meres and mosses in Staffordshire and North Shropshire has been identified as being particularly vulnerable to excessive periods of drought or flooding. Habitat loss due to natural processes and changing agricultural practices may also impact upon biodiversity. Reductions in summer rainfall may have a significant impact on grassland areas, with an increased potential for summer fires, resulting in habitat destruction.

As temperatures increase migratory characteristics and diversity of species may be affected. There may be a loss of species at the southern end of their climatic range, and an increase in those at their northerly range. The potential impacts on the dispersal and reproductive behaviour of species are currently unknown.

Natural resources and energy generation

The scope for this sector included the impacts on water availability and quality, mineral extraction, primary land use and forestry. Energy generation from a wide range of sources including landfill gas, biogas, hydropower, wind, solar, nuclear and coppicing was also investigated.

There is limited information regarding the impact of climate change on mineral extraction. Research has suggested that the projected changes in temperature and rainfall are unlikely to result in significant technical problems for oil, gas, coal, industrial minerals and aggregate industries in the UK.

Tree growth is likely to increase giving rise to shorter rotation periods and a potential increase in timber production. However, earlier springs may lead to frost damage, warmer winters may effect seed fertility. Warmer summers and less cold winters may encourage diseases and pests. Timber quality may be affected by extreme weather events and changes in carbon dioxide levels.

The characteristics of the varied landscapes in the West Midlands will change, in response to new agricultural practices, land management, and new plant species.

Whilst there is a plethora of information about renewable energy, there is little which deals with the direct effect of a changing climate. It is however considered that climate change will have a generally beneficial effect on the financial viability of renewable energy. The opportunities for solar energy and biomas given the rise in temperature and longer growing season seem particularly attractive.

Regulatory

Although there is some overlap with other study areas, all areas of direct and indirect government were considered within the scope. The following areas were investigated: local authorities including local government association policies and Local Agenda 21, central government including the Environment Agency and the DETR, the Home Office, the Ministry of Defence and other regulatory organisations OFWAT, OFGEM etc.

Impacts on the Environment Agency are generally based around increased uncertainty of issues such as water quality and resources. In response to this the EA has identified the need to incorporate risk and uncertainty into their planning time frame for large scale projects. The Agency has identified that a move to time-limited licences would help ensure that abstraction licences reflect water scarcity. The likely increased risk of flooding has highlighted to the EA that there is a need for more comprehensive flood forecasting systems and improved flood defences. The Agency has identified the need to define more clearly the definition of "conservation". At present there is disagreement amongst various groups as to whether ecosystems should be maintained in their current condition, or allowed to evolve with the changing conditions. Finally, it has been recognised that climate change may bring with it more intensive use of recreational facilities. In response to this the EA are planning to develop a better decision making process for priority setting to meet the needs of the differing objectives of a number of competing users.

Contact with the MOD has established that at present they do not seem to have a policy on Climate Change, but are collating information from other sectors, such as agriculture and industry rather than conducting their own study.

An impact that has hit the local authorities recently is that of the Climate Change Levy. Whilst initially this may increase their costs, there is a clear incentive to reduce energy consumption, which will have both negative and positive effects on other sectors. The flooding in late 2000 highlighted the confusing situation regarding responsibility for land drainage and flood protection. The role of local authorities in co-ordinating action amongst a wide range of groups may become an increasing feature of adaptation strategies.

Society

Very limited information was available relating to the impacts of climate change upon society. Areas considered for investigation included religion and education. Much of the information was theoretical and focused upon wider social issues such as the consequences of flooding, and extreme weather conditions. A number of educational issues were identified, though impacts were national rather than regional.

Environmental education and awareness is supported by a number of proactive groups within the region. Climate change issues are included within the National Curriculum, however no evidence of inclusion within non-environmental higher education courses was identified. Groups such as: TIDE (Teachers in development education), the Global Citizen Commission and The Development Education Commission are currently promoting awareness of sustainability issues. It was not possible however to identify any clear linkages with current thinking regarding climate change.

The general focus of published information suggests that the most vulnerable in society, the poor, the elderly and the young will continue to be most at risk from the adverse impacts of climate change.

Further investigations into the direct impacts upon the West Midlands region will need to be undertaken through communication with specific educational bodies, religious communities and other welfare organizations.

What do we need to do? Mitigation and adaptation

Climate change is widely regarded as being the most pressing environmental problem facing our society. We will have to plan and adapt to this changing climate and adopt appropriate mitigation strategies. Adaptation and mitigation may present significant costs to businesses. However, if we start now it will be easier, less costly and of potentially greater benefit to the West Midlands. This of course assumes that we can make accurate predictions of climate change and its effect on society, business and the environment.

Individual sectors need to work together in an integrated manner to obtain a more realistic assessment of climate change. This will enable appropriate adaptation strategies to be developed which take account of the impacts and interactions across sectors and regions. We need to think carefully about the methods and tools used in carrying out detailed assessments to ensure that they are sufficiently robust to take into account the interactions across the sectors.

The following are just a few of the adaptation and mitigation responses that we may need to implement in order to adjust to the changing climate:

- **Biodiversity** - create wildlife corridors to assist the migration of species
- **Transport** - new road and rail construction techniques to overcome increased temperatures
- **Agriculture** - new crops to cope with changes in temperature, rainfall and longer growing seasons
- **Energy** - develop commercially viable renewable energy generation systems
- **Flooding** - improve flood defences to cope with the changes in rainfall, major changes will be required to urban drainage systems
- **Built environment** - develop new infrastructure and buildings to cope with extreme weather events
- **Health** - increased use in and variety of vaccines and a greater emphasis on hygiene as temperatures increase.
- **Health** -stricter import and quarantine laws at international entry points to control the entry of parasites and vectors able to survive in a changing climate.
- **Business** - improve working conditions to overcome higher summer temperatures
- **Business** - include climate change headroom in decision making
- **Business** - encourage innovation and creative approaches to problem solving, develop new markets

The accompanying Technical Paper (No. 1 Pre-scoping Information Review) contains a more extensive list of possible mitigation and adaptation strategies for each of the sectors.

Are there any opportunities for the West Midlands? Is it all doom and gloom?

It is apparent from the review undertaken that most commentators have concentrated their efforts in an assessment of the negative and adverse effects. Climate change will have significant impacts upon the West Midlands which need to be further assessed. In responding to these impacts we will need to implement policies which not only reduce the effects but also lead to reduced emissions to slow the rate of climate change. How we adapt will inevitably create opportunities for resourceful and innovative people and organisations to develop new products, exploit new demands, provide new services. Adaptation may also enable us to look at how we improve the quality of life for people in the West Midlands by improving the environment.

We should also not forget that climate change is a global issue. We all have a responsibility beyond our own region to consider what effect the actions we take will have on societies across the world. The West Midlands economy developed in the C19th and C20th to meet the needs of world markets. What opportunities are there to provide the products and services which others will need to help them adapt to climate change in the C21st?

Whilst reading this report you should be asking yourself a number of questions:

- Does it matter if I don't understand the science?
- Do I accept that changes to the climate are taking place?
- Is climate change having any direct affect on me, my family, my community, and my place of work?
- Are there any barriers (institutional, cultural, regulatory, financial) which prevent action being taken?

What happens next?

We would like your comments on this report, which should be returned using the attached response form to:

John Firth,
Strategies Manager,
Severn Trent Water,
2297 Coventry Road,
Birmingham,
B26 3PU

The closing date for responses is Friday the 18th May, 2001.

We welcome responses by email. The response form and further copies of this report and appendicies can be downloaded from Severn Trent Water's web site (www.stwater.co.uk) or requested by email from charlotte.harper@severntrent.co.uk.

The WMMCIS will consider all comments and may undertake follow-up contacts to discuss points raised in greater detail. Information relating to your current involvement and interest in climate change will be recorded and we will use the responses to assist in defining the brief for the formal scoping report. A report on the comments received will be prepared and circulated to all those who responded to this report.

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Appendices:

Appendix 1 Sector Groups

Creative industries	IT, communications and media
Built environment	urban drainage, building design, urban landscape (note this includes both the urban and rural built environment)
Ceramics	self explanatory
Finance and banking	financial services and institutions
Food and drink	agriculture, commercial fisheries, food processing and retail
Medical and Health	pharmaceuticals, health service, public health
Environmental services	waste management, water and sewerage, noise, dust, pollution control
Natural resources and energy generation	minerals, energy generation, forestry
Leisure and tourism	recreation and leisure
Transportation and the automotive industry	all transport sectors, automotive includes component suppliers as well as vehicle manufacturers
Engineering	all manufacturing not included within other study groups
Textiles	clothing, household (including carpet manufacturing) and industrial textiles
Biodiversity	self explanatory
Society	culture and education
Regulatory	local and central government, legislation, other regulatory bodies (eg Environment Agency)

The Potential Impacts of

CLIMATE

CHANGE in the West Midlands

Technical Paper 1:
Pre-scoping Information Review

THE MIDLANDS ENVIRONMENTAL BUSINESS CLUB LIMITED

Severn Trent Water

UK Climate Impacts Programme

A report by the West Midlands Climate Change Impacts Study (WMCCIS)

Information Review Methodology

All impacts identified by the pre-scoping study have been collated and tabulated in this appendix. Impacts have been grouped within sectors. A timescale and "receptors" that may be impacted upon have been identified for each impact as described below. Both positive and negative impacts have been identified.

Three timescale brackets were used as an indication of the how quickly the impact will occur. These are:
S = Short-term (0-5 years from now)
M = Medium term (5-10 years from now)
L = Long term (greater than 10 years from now)

Three impact receptors were also identified. These are:
B = Business
E = Environment.
S = Society

The position of the shading on the spreadsheet indicates the receptors affected and whether the effect is positive or negative.

It should be stressed that these shadings are not an indication of the severity of the impact e.g. where all three receptors are affected by an impact, it does not mean this is of greater importance than impacts that affect only one receptor. The shading merely indicates that there is an impact. The severity of the impacts will be established by future work.

Sector	Sub Sector	Impacts	Time scale until impact	Comments i.e. dependencies, uncertainties, other study areas it relates to etc.	Possible Adaptation Strategies	Business -	Environment -	Society -	Business +	Environment +	Society +
Creative Industries	Telecoms	Extremes of temperature resulting in underground cables affected by soil movement.	M	Similar to Built Envt - Infrastructure.	Flexible cabling	B	E				
Creative Industries	Telecoms	Wind damage of mobile telephone masts.	S	Similar to Built Envt - Infrastructure. Demand for mobile phones is set to increase and more capacity is required - c 28,000 masts in the next 5 years.	New designs	B					
Creative Industries	Telecoms	Development of improved technology - greater energy use.	S	Development of better communication technology for video/audio conferencing and internet access. Will use more energy but save transport costs. Teleworking and conferencing saved BT 180 m miles in one year.	Culture changes in organisations to make this occur	B	E		B		
Creative Industries	Telecoms	Development of electronic communication to reduce paper based information.	S	Paper savings - reduced transport costs.	Culture changes in organisations to make this occur				B	E	
Built Environment	Construction	Changes in environmental legislation could lead to changes in energy costs during construction work	S	Local Government Authorities	Use energy efficient methods of construction and encourage recycling.	B			B		
Built Environment	Construction	Increased riak of flooding results in Planning departments restricting development on flood plains	S	Banking/Finance, Insurance, LGAs,	Avoid building on flood plains. If unavoidable construct defenses and model likley impacts	B			B	E	S
Built Environment	Construction	Increased knowledge of location of flood plains could lead to difficulties in obtaining loans or insurance to carry out construction on these sites	S	related to banking and finance	Look to use alternative sites	B		S			
Built Environment	Construction	Increased insurance costs for engineers, builders and architects increase total	S	related to banking and finance		B		S			

		construction costs									
Built Environment	Construction	Extreme weather events lead to increased need for repairs	S	increased revenue					B		
Society	Society	Moves to reduce vehicle emissions leads to an increase in home working	S	depends on technology being available and accessible. Requires a company culture change and is dependant on other business sectors		B		S	B	E	s
Built Environment	Construction	Increased competition for suitable building/development sites will increase land purchase costs	S		Development of land previously thought 'unsuitable' i.e. Brown field sites.	B	E	S	B		
Built Environment	Construction	Increased risk to health and safety of workers on site from UV-B radiation	S	Health - increased skin cancer	Insist construction workers keep skin covered and use high factor sun protection creams	B		S			
Built Environment	Construction	Increased risk to health and safety of workers from flooding	S	Sudden flash storms can flood deep excavations	Develop new Health and Safety Policies	B		S			
Built Environment	Construction	Increased risk to health and safety of workers from high winds.	S	Scaffolding can become unsafe in high winds.	Develop new Health and Safety Policies. Provide better accommodation and facilities for workers	B		S			
Built Environment	Construction	Increase in temperature leading to increased mobilasation and volatility of chemicals in soil	L	Certain chemicals become more volatile in warm conditions.	Carry out thorough site investigation prior to construction to avoid unforeseen costs due to contamination. Change in COSHH. Redesign of containmnet systems	B	E	S	B		
Built Environment	Construction	Increased use of brown field sites encourages development of land remediation techniques.	S		Investment required to turn them back to use. Research into remedial techniques. Grants should be available to encourage investment				B	E	

Built Environment	Construction	British Standards for design and construction change to reflect changing conditions i.e. construction of homes which are more flood resistant and increased shrinkage of soils.	M	Homes more able to withstand flooding - could lead to a decrease in insurance claims					B		S
Built Environment	Construction	Changes in British Standards affects working practices, increasing construction time and design time as engineers are trained in the new standards.	M	Increase in cost cannot be wholly quantified.	On the job training	B			B		
Built Environment	Construction	Changes in British Standards lead to developments of new building technologies such as adaptive building envelopes and sustainable housing.	M		Increase investment to speed up development process.				B	E	S
Built Environment	Construction	Increased winter rainfall will reduce number of working days, increasing total construction times and increasing construction costs.	S		Increase use of prefabricated techniques, to reduce exposed construction time. Provide temporary shelter from climate on site. Develop technologies to enable faster construction	B					
Built Environment	Construction	Increased risk of extreme weather conditions leading to site delays e.g. flooding	S		Select sites prior to development, develop innovative site practices to deal with flooding	B					
Built Environment	Construction	Extreme weather may disrupt the use of plant in site activity, affecting site productivity	S		Increase use of prefabrication	B					
Built Environment	Construction	Increased site wastage of materials through damage from extreme weather events may effect profitability	S	Solid Waste Management	Minimise site storage by delivering vulnerable materials as required.	B	E		B		
Built Environment	Construction	Extreme weather events can destroy work in progress e.g.	S		Carry out safety checks at design stage to ensure	B					

		temporary structures			semi-completed structure can withstand high wind loadings.						
Built Environment	Commercial	Effects of Increase in frequency and severity of storms magnified in urban areas due to impermeable areas. Damage and repair costs increase.	S		Flood attenuation measures used - provide areas of temporary water storage i.e. car parks and playing fields which can flood, reduce amounts of impermeable areas by using grasscrete, or porous pavements.	B			B		
Built Environment	Commercial	Hotter summer temperatures magnified by urban heat island effect increasing discomfort to occupants.	M	Health, the degree of tempeerature change in the scenarios, building design etc.	Use of air conditioning equipment	B		S			
Built Environment	Commercial	More hospitals required to cope with increased patient numbers caused by extreme weather conditions	M	Health	Increased Governmental Funding			S			S
Built Environment	Construction	innovative building techniques required due to extreme weather events	L	will be longterm as company's firefight in the shortterm					B		
Built Environment	Residential	Restrictions on CO2 emissions could lead to increased energy costs for homeowners	S		Homeowners encouraged to purchase energy efficient boilers/household appliances	B		S		E	
Built Environment	Residential	Restrictions on CO2 emissions lead to reductions in fossil fuel use	M		Development of self-sustaining homes. Use of renewable energy for heating and lighting in domestic homes is increased.					E	
Built Environment	Residential	Flooding damage increases repair and maintenance cost for homeowners/businesses	S		Prevent building on flood plains. Provide appropriate flood defences. Live in moveable homes! Adaptation of homes to prevent flood damage - raise ground floor levels, power points above flood	B		S	B		

					levels, use of tiling rather than carpets, gr						
Built Environment	Residential	Insurance premiums increased due to claims from extreme weather conditions	S	Insurance	Better information on damage prevention, advance warnings, better weather forecasting. Better building standards			S			
Built Environment	Residential	Hotter summers lead to drying and shrinkage of clay subsoils. Subsidence and ground movement increases. Wetting of soil leading to Heave	S	Check on the geology of the West Midlands	Repair and Underpinning work will be required. Redecorate over surface cracking.	B	E	S	B		
Built Environment	Residential	Hotter summer temperatures result in enhanced plastic and rubber degradation (sealants, jointing, uPVC windows etc). Owners/occupiers spend more money on maintenance	M	UV-B solar radiation flux will increase, increasing the degradation of these materials. Other industries affected: Plastics manufacturers	Adjust product forms to ensure materials continue to perform to required standards. Maintain existing materials. 'Use only quality assured units (e.g. with kite mark)	B		S			
Built Environment	Residential	Hotter summer temperatures lead to degradation of external surface coatings	M	Paints are also affected by UV-B radiation	Renew coatings more frequently.	B		S			
Built Environment	Residential	Hotter, drier summers lead to decrease in interior comfort levels (air quality)	S	Health	Increased use of air conditioning, development of heat responsive glass, improve insulation. Use deciduous trees in landscaping to provide shade.	B		S			
Built Environment	Residential	Homeowners require increased wind protection and solar access due to wetter, windier winters.	M		Use mansard roofs when designing houses. Plant wind breaks. Deciduous tree allow solar access during winter.				B	E	S
Built Environment	Residential	Increased extreme weather events lead to changes in building regulations for	M		Homeowners have to spend money to retrofit their houses to meet with			S	B		S

		building regulations for existing homes.			their houses to meet with new building standards.						
Built Environment		higher temperatures lead to increased use of air cooling units	S	temperatures rising			E		B		
Built Environment	Residential	Increased frequency and severity of storms increases rate of fluvial erosion in certain areas. Properties lost. Increase in severity of Severn Bore	S		Construct coastal protection systems. Restrict new development. Allow managed retreat.	B	E	S			
Built Environment	Residential	Increased rainfall and winds will increase rain penetration into homes via e.g. failure of cavity wall insulation, guttering	M	Most premature degradation of building fabric is caused by moisture penetration.	Roofing and guttering must be capable of keeping rain from building fabric. Coat external walls to protect from penetration of rain Alter window seals, alter cavity wall insulation. Improve guttering design and size to cope with additio	B		S			
Built Environment	Residential	Extreme weather conditions cause concrete to carbonate more quickly and lead to cracking of surfaces.	M		Surface sealant	B		S	B		
Built Environment	Residential/Commercial	Increased risk of leaks through sealants (e.g. around windows and doors)	M		Sealants developed to withstand new climate	B		S	B		
Built Environment	Residential/Commercial	Decrease in need for winter heating	L		Seek new markets	B				E	S
Built Environment	Residential/Commercial	Increased use of energy for air condition in summer	S		Develop systems to keep buildings naturally cool in summer without need for air conditioning. photochromatic glass. Photovoltaic cells to power air conditioning units	B	E	S	B		

Built Environment	Residential/Commercial	Increase in theft from buildings with windows left open for ventilation	S	Insurance	Develop systems to keep buildings naturally cool in summer without need to open windows - photochromatic glass. Photovoltaic cells to power air conditioning units	B		S			
Built Environment	Residential/Commercial	Increase in noise in buildings with windows left open for ventilation	S		Develop systems to keep buildings naturally cool in summer without need to open windows	B		S			
Built Environment	Residential/Commercial	Extreme wind conditions cause damage to buildings, in some cases, structural failure	S		Change building regulations and design specifications to incorporate higher wind speeds. Increase strength of fixings on new buildings	B		S	B		
Built Environment	Residential/Commercial	Increase in wind speed causes damage to roofs	S		Replace roof on existing buildings. Design new building to be more aerodynamic to help minimise wind loads. Use mansard roofs instead of pitched roofs (lower part being steeper than upper part). 'Retro-strengthening and retrofitting of	B		S	B		
Built Environment	Heritage	Buildings of historical interest deteriorate faster due to harsher weather conditions. Hotter drier summers cause cracking, wetter colder winters flood the cracks and then when frozen, expansion of the crack occurs.	M	Tourism	Monitor regularly and maintain as necessary.	B		S			
Built Environment	Heritage	Buried monuments of historical / archaeological interest are lost due to flooding and as land slides occur, due to extreme weather conditions.	M	Tourism	Monitor regularly and maintain as necessary.	B		S			

Built Environment	Heritage	The construction of flood defence systems may result in the destruction of unknown and hitherto unrecognised archaeological remains.	M		Carry out in-depth desk studies and site investigations prior to commencing construction	B		S			
Built Environment	Materials	Increased degradation of timber through increased biological and pest attack.	M		Monitor regularly for early detection of new pests. Improve stringency of quarantine inspection. Treat the pests with pest killer.	B		S			
Built Environment	Materials	Acidic rain leading to increased risk of chemical attack on susceptible concrete / masonry structures and landscapes	S	acidic rain from increased levels of atmospheric carbon dioxide	Vulnerable concrete / masonry should be monitored	B	E	S			
Built Environment	Materials	Decreased risk of frost damage to concrete / masonry	S						B	E	
Built Environment	Materials	Increased risk of cracking of concrete / masonry structures due to seasonal ground movements	S		Improve design standards to minimise cracking. Monitor vulnerable structures. Ensure designs allow for movement	B	E	S			
Built Environment	Materials	Deterioration of limestone / sandstone caused by C02 concentrations	S	acidic rain	Resurface damaged stonework (aesthetic not structural)	B	E	S			
Built Environment	Materials	Increased corrosion of unprotected metal building components (e.g. bolts)	S		Monitor components at risk of corrosion. Apply coating to metals to protect from the elements. Development of new corrosive resistant materials	B		S	B		
Built Environment	Materials	Failure of existing fixings under extreme weather conditions	S		Improve design to Increase strength of fixings to cope with loads	B		S			

Built Environment	Materials	Increased risk of breakage of glass due to extreme weather conditions	S		Reduce impact from objects by using toughened / laminated glass	B		S	B		
Built Environment	Infrastructure	Increased river flows causing increased erosion to bridge structures.	S		Surveying and checking of structures	B		S			
Built Environment	Infrastructure	Increased risk to overhead power and telephone cables.	S	High winds and heavy snow falls bring down overhead cables.	Underground cables?	B		S			
Built Environment	Infrastructure	Increased sewer flooding from 'short sharp shock' rainfall events.	S	Ties in closely with sewage treatment.	Larger sewers? Provision of off line storage? Use of open spaces as detention ponds? SUDS?	B	E	S			
Built Environment	Infrastructure	Subsidence affecting roads and railway lines.	S	There is an expectation of more subsidence with more ground water from rainfall.	Surveying of structures, targetted investment, new types of tarmac	B		S			
Built Environment	Infrastructure	Higher temperatures affecting road surface life - especially with tar based surfaces.	S		New types of tarmac	B		S			
Ceramics	Demand	Increase in demand for floor tiles / pool tiles as people adapt their houses / lifestyles to suit the hotter temperatures in the summer months.	M	Leisure	Increase production and staffing levels. Diversify product to meet demand for alternative energy sources e.g. Photovoltaic panels in clay roofs		E		B		S
Ceramics	Raw Materials	Increase in the cost of water required during the manufacturing of ceramic products.	M	Natural resources	Investigate water conservation methods, sire water audits	B					
Ceramics	Staff	Decrease in the standard of working conditions during the hotter summer months - requirement for air conditioning	S	Health	Install air conditioning. Water dispensers	B		S			
Ceramics	Staff	Extreme weather conditions stop staff getting to work and transport of raw materials	S	Transport	Home working for some staff, Company Busses.	B		S			

		and finished product									
Ceramics	Economics	Climate change levy prompts a rise in energy costs	S		Energy efficient ways of working	B					
Ceramics	Raw materials	Increased cost of raw materials as transport taxes increase? Also of exporting products.	S	Transport	Investigate alternative transportation methods e.g. canals	B					
Ceramics	Economics	Climate change levy rebate if company makes clear energy efficiency improvements	S		Energy efficient methods of working. 'Renewable energy sources required for tax breaks associated and to reduce emissions				B	E	
Ceramics	Product	Development of roof tiles to withstand storm conditions	M	links to built environment - business opportunity	Make roof tiles bigger/heavier and apply BS standards to form and fitting				B		S
Banking and Finance	Banking	Mortgage rates increase for borrowers with property in flood risk areas (may make it harder to buy / sell some property).	S	links with insurance section			E		B		
Banking and Finance	Banking	Mortgage lenders require MOT for older houses at risk of damage from flooding and extreme weather	M	To assure lenders of the adequacy of the building to resist extreme weather conditions	Conduct regular checks and maintenance on property	B		S	B	E	
Banking and Finance	Insurance	Mortgage lenders enforce an increased buildings insurance premium on borrowers with property in flood risk areas.	S		Construct adequate flood defences to minimise risk	B		S			
Banking and Finance	Insurance	Insurance companies refuse to provide buildings and contents insurance for properties at risk of flooding	S			B		S			
Banking and Finance	Insurance	Insurance premiums for older properties are increased	S	To compensate for increased claims due to damage caused by extreme weather	Money for retrofitting of older properties made available through	B		S			

					government grants						
Banking and Finance	Banking	New business opportunities for banks arising from company's need to invest in technical measures to reduce greenhouse gas emissions. Loans will be required.	S	links to the clean technology market					B		
Banking and Finance	Banking	Brokers will undertake a new role: brokering deals between countries and companies trading in emissions credits.	S	is this bad for the environment - no incentive to cut back on emissions - merely buy up other coutnires share instead ?? post on CCF			E		B		
Banking and Finance	Banking	New climate change levies will decrease the profitability of certain energy intensive industries. Possibility that certain companies will relocate their operations to countries who do not implement such levies.	S	links with other industrila sectos - will be sectorially specific. Industry will suffer first - banks will see a delayed reaction. Jobs will go as businesses relocate, and then banks will see an effect once the business moves out of the	Sectorially specific	B		S			
Banking and Finance	Banking	Reduction in public saving as home owners have to use disposable income in repairing and retrofitting homes.		are we a nation of savers ? or are we a nation of borrowers - if borrowers, then banks will get more interest on loans							
Banking and Finance	Banking	As people become more environmentally aware, the public will expect banks to support ecological projects and have a 'greener' outlook before banking with them.									
Banking and Finance	Insurance	Health insurance claims increase	M	From Stress due to increased caused by deterioration of working conditions e.g. hotter factories during summer months	Better health education and care	B		S	B		
Banking and Finance	Insurance	New insurance markets develop as new business and industries emerge in response to climate change	M	e.g. offshore wind energy, new food processing, new agricultural activity					B	E	S

Food and Drink	Agriculture	Expansion in suitable growing areas (e.g. Winter wheat to northern latitudes)	L		Farmers and growers can adjust their production systems to accommodate a changing climate. This requires improved education esp. re: mitigation and time scales.				B		S
Food and Drink	Agriculture	Warmer climate leads to longer growing season allowing greater yields	M		As above				B		S
Food and Drink	Agriculture	Faster rates of crop development so shorter growing period	M		As above				B		S
Food and Drink	Agriculture	The above could lead to lower yields due to soil stress caused by a lack of resting between growing periods	M		Alter agricultural management practices. Strategy for maintaining soil conditions and development of drought tolerant crops - but what will their impact be on soil nutrient cycling ?	B	E	S			
Food and Drink	Agriculture	Higher CO_2 concentrations in the atmosphere lead to higher take up levels by plants and so grow more - i.e. improved growing conditions?	M	Depends on CO_2 levels increasing further with global warming					B		S
Food and drink	Agriculture	Yield reduced by hastened maturation caused by higher temperatures	M		Genetically modified crops	B		S			
Food and Drink	Agriculture	Less water availability leads to common drought conditions	S	Water demand/supply	Develop drought tolerant crops or change crop type planted. Improved irrigation methods. Genetically modified plants. Greater water storage. Greater use of groundwater where available	B	E	S			
Food and Drink	Agriculture	Higher CO_2 levels lead to	M	Natural Resources. Depends on CO_2 levels	Adoption of low emission				B	E	

		better water efficiency on plant growth		increasing with global warming	technology.						
Food and Drink	Health	Changed incidence of disease/food borne illness in warmer temperatures	S	Direct links to Medical subgroup - some diseases will increase, other decline in warmer conditions	Improvements re. food hygiene/storage et.al	B		S	B		S
Food and Drink	Agriculture/Health	increase in use of chemical pesticides to control increased incidence of disease	S	Links to water pollution, manufacturing & economics (increased production costs)	Use of resistant crops	B	E		B		
Food and drink	Agriculture	Extreme weather conditions cause loss of crop through drought or water logging	S		better extreme weather defences and farming techniques	B	E	S			
Food and Drink	Food	Improved growing conditions for imported food produce (e.g. citrus fruits and olives).	L	Decreased dependence on imported produce - impact on retail / manufacturing links to this service.					B		S
Food and Drink	Drink	Improved conditions for wine growing in W. Mids.	L	Depends upon warming effects - tourism & retail benefits					B	E	S
Food and Drink	Food	Fewer sources of fresh fruit as pests and fungi become more rife and equatorial areas more prone to drought.	L	Associated with Medical - health effects & society	Increase production of local fresh produce	B	E	S			
Food and Drink	Agriculture	Changes to soil micro-organisms & their associated activity due to variations in climatic conditions (esp. drought and extensive water logging). Significant implications on decomposition of organic matter and role of soils in the carbon cy	L		better farming and soil management techniques	B	E				
Food and Drink	Food	Environmental changes lead to fish migration	L		Monitor fishing levels and balance catch content better. Change consumer preferences for certain fish	B	E				
Food and Drink	Agriculture/Food	Potential for species loss and habitat migration through changes to climate	L	Biodiversity links	monitor species levels	B	E				

Food and Drink	Food (Fisheries)	Changes in abundance and species composition of phytoplankton/zooplankton in NE Atlantic & oceanographic changes (e.g. temp & water movement) will influence the abundance of commercially important fish.	L	is this the same thing as above ?	MAFF - Continuous Plankton Recorder study.	B	E				
Food and Drink	Agriculture / Horticulture	Loss of traditional seasons - variation in seasonal produce esp. flowers, bulbs & field vegetables.	L	Impact on tourism (e.g. attendance of traditional events), increases in unit costs, changes in diet.	Cultural change/acceptance through education.	B	E	S			
Food and Drink	Agriculture	increased temperatures lead to Increase water use due to extended drought and need for increased irrigation.	S	Links to water demand, use, increase in storage requirements and pollution. Costs of production likely to increase.	water conservations. drought resistant crops	B	E				
Food and Drink	Food	Higher temperatures could lead to handling/logistical problems re: food preparation (health) and transportation.	S	Links to tourism, energy use (increased refrigeration) and economy (society). Costs of production are likely to increase.		B	E		B		
Food and Drink	Food	Reduced supply areas through increased flooding or drought. This has implications for increased importation of food produce to meet consumer demand.	S	The reverse is also potentially true with European countries being affected - therefore UK exports could increase.	flood defenses and drainage. Water storage	B	E		B		
Food and Drink	Agriculture/food	Meat production could become more energy intensive due to need to curb heat stress in livestock (esp. intensive agriculture).	S	Increased unit costs of production - passed on to the consumer.	natural shade - opean air farming rather than battery	B	E	S			
Food and Drink	Agriculture/Food	Insurance premiums are likely to increase. This will mean that food stocks are not underwritten in high risk areas (esp. flooding/drought)	S	Insurance & society - esp. increase unit costs of production	Increases in imported food and subsequent impacts of UK economy. Flood defense	B		S			

Food and Drink	Food	Extremes of storminess in the spring and autumn (esp. if accompanied by severe flooding) are an unmitigated blight on all sectors of farming and will subsequently have a marked impact on production - e.g. Autumn 2000 and milk.	S	Links to health, society, manufacturing and retail. EU subsidies ? was there a milk distrubution problem in autumn 2000 ?	better planning	B	E				
Food and Drink	Agriculture	Potential competitive gain in crops like sunflowers, maize, fruit and vegetables if large parts of southern Europe become desertified	L	climate change in other counties	open to evolution and new ideas / ways of doig things				B		
Food and Drink	Food	Changes in consumer demands due to extended seasonal variation - e.g. salad crops & summer food produce	S	Links to tourism, transport and economy (society) and agricultural yeild					B		S
Local Authorities	Environment Agency	Increased uncertainty of future water resources	S	Closely linked to water resources sub-sector. *** check the p.c. ness of this statement - check is says the right message !!!	Scenario based approaches need to be used in water resource planning. Risk and uncertainty need to be incorporated into Agency planing time frames for large scale projects such as reservoir construction. A move to time-limited licences w	B	E	S			
Local Authorities	Environment Agency	Increased uncertainty of future water quality	S	Closely related to biodiversity sub-sector	The EA has plans to develop an Agency Nation Plan for Water Quality, an Agency strategy for the control of eutrophication and to review and revise the charging for discharges scheme.	B	E	S			
Local Authorities	Environment Agency	Increased uncertainty of flooding	S	Related to emergency planning	Better flood forecasting systems are needed	B	E	S			

Local Authorities	Environment Agency	Increased pressure to define "conservation" will we/they be perpetuating an atrificial environment - get english natures view ?	M	The EA needs to develop a better understanding of the concept of what should be maintained - i.e. should ecosystems and habitats be maintained in the original state prior to climate change or should habitats be allowed to respond and remai						E	
Local Authorities	Environment Agency	Increased opportunity for recreation and leisure	S	The agency needs to manage the water resources to meet the differing objectives of a number of competing users	Develop a better decision making process for priority setting. Manage the countryisde		E		B		S
Local Authorities	Local Authorities	Climate Change Levy - increase in energy costs	S	The increase in charges could be seen as an incentive to reduce usage	energy efficiency	B				E	
Creative Industries	Marketing	Moves towards energy management	S	Move made by the Institute may be reflected by its members					B	E	
Creative Industries	Marketing	Cost savings following liaison with the Corporate Environmental Advisory Service	S	Move made by the Institute may be reflected by its members					B		
Creative Industries	Marketing	new business due to new innovations and technology	S	depends on innovation and mitigation to cc					B		
Health	Temperature related	Deaths relating to cardiovascular diseases will decrease due to warmer winters	M	Life Insurance, Local Government, Demographics					B		S
Health	Temperature related	General winter deaths will decrease due to warmer winters	M	Life Insurance, Local Government, Demographics	Reducing fuel poverty will probably have a greater effect than climate change	B	E	S	B	E	S
Health	Temperature related	Winter storms will increase the incidence of cardiovascular mortality	M	Winter storms and heat waves both increase incidences	General improvement in health standards / education			S			
Health	Temperature related	Increased incidence of summer heat waves leads to heat cramps, mortality, fainting,heat exhaustion/stroke, psychological and behavioural adaptations	M	Tourism, agriculture, water supply, social and cultural, working practises	Monitor health indicators. Educate. Air conditioning, R&D to determine the extent to which populations will acclimatise	B		S			

Health	Temperature related	Potential for increased sunburn and skin cancer related illnesses	S		Improve education about limiting exposure, and improving skin and eye protection	B		S			
Health	Temperature related	Human populations evolve to surroundings and so can be expected to adapt to climate changes over the next 50 years	L		Educate						S
Health	Extreme weather conditions	Increased risk of people drowning in flood conditions	S	Urban Drainage (SUDS)	Flood alleviation schemes			S			
Health	Extreme weather conditions	Risk of electrocution/ burns/ skin irritation and carbon monoxide poisoning during flood cleanup operations	S		Educate on cleanup safety, PPE			S			
Health	Extreme weather conditions	Flooding can cause mental health problems, e.g. Post traumatic stress (PTSD)	S		Increased government/community support	B		S			
Health	Extreme weather conditions	Transport and communication disruptions lead to medical staff being unable to get to work,	S		Emergency planning / networks	B		S			
Health	Extreme weather conditions	Floods may disrupt water purification and sewage disposal systems, cause toxic waste sites to overflow and dislodge chemicals stored above ground	S		Engineering, urban planning, improved water systems and early warning systems	B	E	S			
Health	Extreme weather conditions	Increased risk of communicable disease after floods e.g. Leptirospirosis (Weils)	M		Surveillance, control studies, transmission dynamics, vaccines, protective technologies,	B		S			
Health	Weather	Increase in temperature may produce a Mediterranean climate, decrease effects of SAD, arthritis, bronchial diseases	M						B		S

Health	Extreme weather conditions	Increased drought conditions lead to discomfort and possible implications on health	S	Natural resources	Plan water resource strategies, educate on the need for water conservation	B		S			
Health	Air pollution related effects	Air pollutants are significantly higher when associated with increased temperatures leading to respiratory/inflamatory eye diseases. Also airborne allergens affecting those with asthma/ hay fever	S		Legislation to tighten air pollution, increased medical support. Awareness / education	B	E	S			
Health	Water and food borne diseases	Higher rainfall gives more likelihood of Cryptosporidium washoff from farm land to water courses	S	Water supply	New Technology and Development	B	E	S			
Health	Water and food borne diseases	Hotter summers cause increased salmonella	S		More refrigeration needed. Also education about food hygiene / safety	B		S			
Health	Water and food borne diseases	Bacterial/ virus gestation times will change with temperature change	M	Agricultural (livestock diseases)	Vaccines, education and hygiene	B	E	S			
Health	Water and food borne diseases	Warmer summer climate leads to more swimming leading to more water borne diseases e.g. viruses, bacteria, protozoa	S	Fisheries and Agriculture	Vaccines, education and hygiene	B	E	S			
Health	Water and food borne diseases	Increase in poisoning by shellfish (imported to region) after toxic algal bloom periods, promoted by high nutrient runoff after rains and warm temperatures	S	Requires particular combination of atmospheric and marine conditions.	Increased observation and reporting of algal blooms. Monitoring and regulation of fishing industry.	B	E	S			
Health	Water and food borne diseases	Decreased number of fresh food imports as climate initiated diseases and fungi affect foreign crops	L	Food and drink	Produce wider variety of crops	B		S			

Health	Vector and rodent borne diseases	International entry points such as airports may require new health related developments to help prevent entry of parasites and vectors able to survive in a changing climate and to treat resulting public health problems	S	Agriculture, ecology, demographics	Spray planes, have stricter import and quarantine laws, enhanced surveillance	B	E	S			
Health	Vector and rodent borne diseases	Change in seasonality and distribution of vector borne diseases	M	Agriculture	Increase immunisation programmes	B	E	S			
Health	Vector and rodent borne diseases	Reappearance of malaria in parts of region with standing/ stagnant water	M		Higher use of insecticides and pesticides. Expand vaccination programmes	B	E	S			
Health	Vector and rodent borne diseases	Distribution and activity of domestic pests (i.e.. flies, cockroaches and rodents) may change as a result of climate change	S	Agricultural	More insecticides/ pesticides	B	E	S			
Health	Vector and rodent borne diseases	Visceral leishmaniasis (important coinfection with HIV) and tick borne encephalitis (transmitted by sand flies) and Lymes disease may become endemic in countries bordering the Mediterranean. It may move northwards with increasing temperatu	M		Vaccination programme	B	E	S			
Business	Pharmaceuticals	More drug research will be needed to combat new strains and target new areas							B		S
Health	Pharmaceuticals	Increased demand for vaccinations as requirements increase for foreign travel (through changes in infected regions) and also due to changing UK requirements	M	Tourism and leisure	Licence more vaccine manufacturers and ensure stocks are up to date and of sufficient number	B		S			
Natural	Forestry	Growth rates will increase	M		Rotation lengths may need				B	E	

Resources					to be reduced						
Natural Resources	Forestry	Higher vulnerability to spring frosts as buds are likely to break earlier	S		New provenances or species could be planted to respond to the predicted warmer climate	B	E				
Natural Resources	Forestry	Problems with natural regeneration if seed fertility is reduced due to warmer winters	M		As above	B	E				
Natural Resources	Forestry	Increased incidence of disease due to higher populations of pests and pathogens	S			B	E				
Natural Resources	Forestry	Increased risk of wind damage	S	The assessment of wind hazard will need to take increased storminess into account and may require further modification as a result of reduced stability from increased leaf area.		B	E	S			
Natural Resources	Forestry	Change in wood quality	M	Wood quality could be affected by changing climate and CO2 concentration in a variety of ways, some beneficial, some detrimental. These include an increase in compression wood production in some species and higher wood densities.	Change in type and use of materials	B	E		B	E	
Natural Resources	Forestry	Increased opportunities for Agroforestry	S	This practice has been identified as increasing the potential to either store carbon or reduce anthropogenic carbon emissions						E	
Natural Resources	Forestry	Increased potential for biomass energy production	S	Pressure to reduce fossil fuel consumption may mean that there is an opening in the market for alternative fuel.						E	
Natural Resources	Renewable Energy	Increased opportunities due to pressure to reduce fossil fuel usage	S							E	
Natural Resources	Renewable Energy	Potentially more sites for wind farms due to increased wind speeds?	S							E	
Environmental Services	Sewage Treatment	Enhanced sewage treatment may be required to meet more stringent limits on	S	Falling river flows used to calculate discharge consent may require a tightening of limits.	Development of new treatment technologies	B	E			E	

		discharge consents		of limits.							
Environmental Services	Sewage Treatment	Increased requirement for nutrient removal	S	Low river flows in Summer encourage algal blooms so increase pressure for nutrient removal	Ferric salt dosing to precipitate phosphate.	B	E			E	
Environmental Services	Sewage Treatment	Increased P levels in sludges due to nutrient removal threatens agricultural recycling	S		Increase outlets to land restoration and develop alternative markets	B	E			E	
Environmental Services	Sewage Treatment	Increased sludge volumes due to nutrient removal by ferric dosing requiring treatment/disposal	S		Develop alternative markets for sludge use, develop alternative sludge disposal options, maximise use of biological nutrient removal	B				E	
Environmental Services	Sewage Treatment	Increased requirement for effluent sterilisation due to stringent microbial standards	M	Recreational pressures on Midland rivers may lead to their classification as Bathing Waters	Exploit re-sale value of high quality effluent e.g. for agricultural demand, promote partnership opportunities with British Waterways for water transport	B					S
Environmental Services	Sewage Treatment	Increased requirement for storm water settlement capacity resulting from pressure to remove Combined Sewer Overflows	S		Change in design standards for new works, extensions to existing works	B				E	
Environmental Services	Sewage Treatment	More efficient biological treatment due to increased temperature	S						B	E	
Environmental Services	Sewage Treatment	More frequent low summer flow and high winter flow to treatment works may exacerbate local problems at some small works	S			B	E				
Environmental Services	Sewage Treatment	Increased demand on digestor capacity due to waste disposal discharges	S		develop alternative sludge treatment e.g. adoption of sludge reedbeds at remote works	B					

					works						
Environmental Services	Sewage Treatment	Power failures due to extreme winds, soil movement etc. increases potential for works failure	S		installation of back up power supply, develop use of passive processes	B	E	S			
Tourism		Family and short break holidays are the most climate sensitive, warmer, dryer summers may lead to more spontaneous decisions	S	Related areas: Society Changes in availability of free time / disposable income may override any climatic impacts.	Develop tourist attractions / opportunities within the West Midlands region to attract day / short break tourists.	B	E		B	E	S
Tourism		Warmer drier summers may lead to increase in visitor numbers, may change visitor numbers and patterns	S	Related areas: Society, Built Env., Biodiversity Changes in availability of free time / disposable income may override any climatic impacts.		B	E		B	E	S
Tourism		Lengthening of summer tourism season	S	society, transport	Improve visitor centre provision at key recreation sites to encourage tourism.	B	E		B	E	S
Tourism		Increase in other countries' diseases i.e. malaria may lead to increased tourism in the UK, as popularity of affected destinations declines	M		UK tourist industry actively promote the absence of malaria etc. in UK to encourage increased tourist numbers.		E		B		S
Transport	general	Information Communication Technology (ICT) can reduce dependency on the need for travel during climate disruption	S	Technology, Infrastructure	Better telelinks and conferencing, working from home			S	B	E	
Transport	General	Rural areas infrastructure more dispersed and vulnerable to weather damage	S	Infrastructure, community / social	Better forward planning and infrastructure, Green Fleets programme	B		S			
Transport	Roads	Higher rainfall leads to increased flooding. Network failure increases due to increased number of road closures	S		Improve road drainage by providing ditches, swales, permeable pavements	B		S			

Transport	Roads	Higher rainfall leads to higher river flows. This results in increased scour around bridge foundations/piers. .	S	Built Environment - Civil Engineering - Bridge/Structures Design	More safety inspections will be required, maintenance costs increase	B			B		
Transport	Roads	Higher temperatures cause ponding (the binders used in tarmac rise to the surface). Rutting also occurs and additional repair work is required	S		Changes in road pavement design	B		S			
Transport	Roads	Higher temperatures lead to increased expansion of steel and concrete, possibly exceeding tolerances. Concrete expansion joints in roads may fail.	S			B					
Transport	Roads	Increased temperatures lead to less frosts, leading to less freeze-thaw damage to road surfaces.	S						B		
Transport	Roads	Less frosts reduce the amount of gritting required, reducing the annual gritting bills for the local councils.	M						B		
Transport	Roads	Roads designed for particular volumes of traffic. Traffic volumes expected to increase as tourism increase. Increased road maintenance required.	S	Impacts of Climate change on tourism	Revise standards for road design. Allow for increased traffic volumes when resurfacing. Improve the existing public transport facilities to discourage use of roads.	B					
Transport	Automotive	Requirement for reduced emissions , Climate change may result in different transport requirements	M	Engineering	New technologies. Clean car policies. New fuels used.				B		
Transport	Automotive	Increase in marketing for more efficient cars for consumers and for fleet cars			Sales and advertising campaigns. Fleet car policies						

Transport	Rail	High temperatures could increase buckling of tracks	S		ensure that the design life of the new tracks is sufficient and can cope with increased temperatures.	B		S	B		
Transport	Rail	Higher temperatures could result in air conditioning being required for all train coaches. Additional cost will be incurred to retrofit existing trains.	M		Specify that all new trains come equipped with air conditioning. Older trains can be phased out eventually.	B					S
Transport	Railways	Increased ground and surface water causing subsidence.	S	Similar to problems with the Built Environment.	Revision of design standards.	B		S			
Transport	Aviation	Dense fog/poor weather conditions could result in operation difficulties	S		Invest in modern technology	B		S			
Transport	Aviation	Reduction in emissions	M		Changes in operational measures to reduce fuel consumption, i.e. optimisation of cruise speed, towing aircraft to runways	B				E	
Transport	Aviation	Increased ground level pollutants i.e. ozone, nitrogen oxides associated with aircraft will rise as increased use of air transport.	M	Air pollution. health	Reduce air traffic		E		B		
Transport	Aviation	Severe weather conditions, such as storms or even worse will cause delays, diversions, cancellations	S	Business costs		B		S			
Transport	canals	Canals suffer from low water levels in summer without new supply options	S			B	E	S			
Natural Resources	Water availability	Reduced river flows and reservoir inflows during periods of drought leading reduction in water available	S	Reduced volumes of water available	development of new resources, water transfer schemes	B	E	S			

		for supply									
Natural Resources	Water availability	Increased risk of interruptions to domestic and other supplies during droughts and more stress during peak demand periods	S	Increased demand during hot/dry periods. May impact on public health and industrial activity utilising water in their production processes	Increased investment in infrastructure and new resources, demand management	B	E	S			
Natural Resources	Water availability	'Reduced volumes of water available for supply due to increased environmental demands	S			B	E	S			
Natural Resources	Water Availability	Wetter winters increase winter availability of water	S	Opportunities to store water for summer deficits, groundwater recharge					B		S
Natural Resources	Water Availability	Wetter winters could exacerbate urban drainage and structural problems due to rising water tables resulting from decreased industrial abstractions.	S			B		S			
Natural Resources	Water Availability	Higher temperatures could lead to increased demand and higher peak demands, leading to resource depletion, interruptions to supply	S		Increased investment in water infrastructure and resources, demand management	B	E	S			
Natural Resources	Water Availability	Increased variability in rainfall could lead to more droughts	S			B	E	S			
Natural Resources	Water Availability	Depletion of resources in summer due to longer growing seasons (increased irrigation) and increased evaporation	M		Improvement in effectiveness/water efficiency or irrigation systems, changes in crops grown	B	E	S			
Natural Resources	Water Quality	Poorer river quality from increased operation of storm overflows from higher intensity storms	S		Change design standards for storm storage. Install increased storage capacity. Increase treatment capability at	B	E	S			

					overflows						
Natural Resources	Water quality	'Lower ground water levels in summer could increase exfiltration from sewer leading to contamination of ground water from foul sewer.	M		Investment in sewerage infrastructure	B	E	S			
Natural Resources	Water Quality	Longer, drier periods in summer will increase pollutant levels in rivers following rainfall due to accumulated pollutants on surface	S			B	E	S			
Natural Resources	Water Quality	water quality may be adversely affected by changes in soil structure causing increased leaching , decreased adsorption	S			B	E	S			
Natural Resources	Water Quality	Potential increases in contamination by pesticides in water resources	S	changes in crops to adapt to climate change may result in increased pesticide and herbicide usage	Enhanced treatment of water for supply, management of pesticide use, development of alternatives e.g. biological control	B	E	S			
Textiles	Manufacturing	Financial Impact of climate Change Levy		job losses							
Textiles		Increase in temperatures may lead to people not wanting carpets	M	Tiles, laminate flooring and ceramic tiles may become more popular	Diversification or move into non textile floor coverings	B			B		
Textiles			M			B					
Textiles		increase in market for summer clothing and decrease in winter clothing	M	America has already seen this change		B			B		
Textiles		Change in materials grown for supply may mean a need to change raw material for	M	new market opportunities - Hemp in Canada as example					B	E	

		textile manufacture									
Environmental Services	Water supply and purification	poorer raw water quality due to flooding events	S			B	E	S			
Environmental Services	Water supply and purification	shortage of water resource in summer due to resource depletion and increased demand, potential restrictions on use	S	due to increasing temperatures and extended "summer" period	Demand management, water recycling and conservation initiatives, reduce leakage, abstraction management plans	B	E	S			
Environmental Services	Water supply and purification	wetter winters resulting in increased reservoir replenishment	S		Increase reservoir capacity to prevent overtopping and flooding. Opportunity for winter storage of water to meet summer demands				B	E	S
Environmental Services	Water supply and purification	fewer frosts leading to less burst water pipes in winter	S						B	E	S
Environmental Services	Water supply and purification	increased cracking pipes due to ground desiccation	S		Use of alternative pipe materials, improved ground investigations prior to pipe laying	B	E	S			
Environmental Services	Water supply and purification	Increases in heavy rainfall following dry periods leading to more runoff resulting in poorer raw water quality	S		SUDS, improved water treatment, improved urban design, increased use of water quality modelling	B	E	S			
Environmental Services	Water supply and purification	increase in power cuts due to storm damage	S		back up generation capabilities, opportunities for local energy plants	B	E	S			
Environmental Services	Water supply and purification	warmer summer temperatures could mean more eutrophication of water courses leading to treatment problems	S	Other contributory factors e.g.nutrient enrichement from diffuse pollution	Nutrient removal from effluents, destratification and sediment removal from e.g. reservoirs	B	E	S			
Environmental Services	Water supply and purification	spread of pests e.g. zebra mussels - increased treatment costs and	S		Chemical dosing at water treatment works, filtration at works	B	E	S			

	purification	maintenance			at works						
Environmental Services	Pollution control and clean technology	need for more energy efficient plant due to increasing energy costs resulting from policies to mitigate climate change	S	carbon tax will require companies to "clean up their acts"	Development of energy efficient processes, increased use of renewable energy	B		S	B	E	S
Environmental Services	Pollution control and clean technology	warmer summers - more hours of sunshine	S		production of photo voltaic cells and other alternative energy sources				B	E	S
Environmental Services	Pollution control and clean technology	increase in wind speeds	S	wind energy plants may have a visual or noise impact	opportunities for wind energy production		E	S	B	E	S
Banking and Finance	Insurance	Insurance industry exposed to greater risk, so more reinsurance and increase in premiums necessary	S	Links to UK economy and risk assessment techniques. Will effect insurance premiums	More research into risk assessment models and appreciation of risk	B		S	B		
Banking and Finance	Insurance	Some population groups and businesses may find insurance harder to obtain	S	Links to UK economy and risk assessment techniques. Will effect insurance premiums	More research into risk assessment models and appreciation of risk	B		S			
Banking and Finance	Insurance	Market differentiation could occur, with certain insurance companies only wanting to insure certain items	S	This will decrease choice for the customer and will effect insurance premiums	More research into risk assessment models and appreciation of risk	B		S			
Banking and Finance	Insurance	Ownership of property may not be beneficial if no economic insurance can be found	S	Links to UK economy and risk assessment techniques. Will effect insurance premiums	More research into risk assessment models and appreciation of risk	B					
Banking and Finance	Insurance	Impact on UK insurance market due to spreading the risks of climate change impacts overseas	S	insurance is a global market therefore losses in other countries would affect UK market	More research into risk assessment models and appreciation of risk	B		S	B		

Banking and Finance	Insurance	Effects of increased frequency of extreme climatic events occurring together (e.g. high winds and inland flooding as one event) leading to larger immediate payouts then if happened separately in same year	S		More research into risk assessment models and appreciation of risk, promotion of design standards, introducing clauses in policies to limit claims	B		S			
Banking and Finance	Insurance	More payouts will be necessary, due to e.g. increase in frequency and severity of inland flooding	S		Work with the UK Government and planning authorities to control where houses are built + with environment agency, Better landuse mapping and freedom of information, increase insurance premiums to compensate	B		S			
Banking and Finance	Insurance	Mortgage lenders will increasingly enforce buildings insurance on borrowers due to greater risk to property from climate change	S		More research into risk assessment models and appreciation of risk, building standards on new properties	B		S			
Banking and Finance	Insurance	Insurance premiums for older properties will increase due to risk of damage during extreme weather conditions. West Midlands has considerable amounts of older properties	S	More payouts will be necessary, driving insurance premiums higher	More research into risk assessment models and appreciation of risk	B		S	B		
Natural Resources	Mineral Extraction	Open-cast mining is affected by higher levels of rainfall, increased flooding and the associated potential pollution problems.	S		Increased pumping and pollution prevention measures	B	E	S			
Natural Resources	Mineral Extraction	Dry periods will result in increased formation/ suspension of dust and particulate matter.	S		Vehicles will need to be washed on exit of sites. Dust on access roads etc. will need to be 'wetted' down as to prevent dust and particulate matter.	B	E	S			

Natural Resources	Mineral Extraction	Increased frequency of droughts could curtail production and increase costs as extracted mineral preparation, especially coal, requires a lot of water	S		Development of improved processes, development of new water resources	B	E	S			
Natural Resources	Mineral Extraction	Waterlogging resulting from rising water tablecould lead to increased costs e.g. of pumping			Improve site drainage, develop new processes	B	E	S			
Natural Resources	Mineral Extraction	The restoration of the sites could be complicated due to the 'changing' habitat; altering hydrology; storage and quality of top soils etc.	M	Very hard to predict the effect of climate change on small scale habitats	Model anticipated changes to the habitat	B	E				
Natural Resources	Mineral Extraction	The increased activity in improving sea and river flood defences could lead to an increase in the demand for aggregate resources.	S				E		B		
Natural Resources	Mineral Extraction	Changes in the energy market in connection with 'space heating' and air conditioning requirements due to changing weather conditions would affect the demand for fossil fuels.	M	Increased energy demand for air conditioning in warmer summers may be offset by decreased need for heating in milder winters	Investment in energy efficient technology, adoption of green energy technology	B	E	S	B	E	S
Natural Resources	Mineral Extraction	Overcast skies can affect the strength of blast noise due to reflection from the cloud base.	S		New blast technology operating procedures	B	E	S			
Natural Resources	Mineral Extraction	Methane venting can be affected by alterations in the atmospheric pressure, i.e. lower atmospheric pressure can increase the rate at which the methane moves leading to knock-on effects in the production process	S	Many UK underground mines have seams/ strata which contain methane under pressure. Under normal operating conditions, the gas is gradually released from the strata into a ventilation system which is designed to be sufficient to dilute them	Develop effective capture and venting systems, use as potential energy source	B	E				
Natural Resources	Mineral Extraction	Increase in severe storms leading to imcreased drilling breaks of offshore oil and	M		Increase cost of product to compensate for increased extraction costs, increase	B		S			

		gas extraction.			use of imported fuels						
Natural Resources	Primary Use	As a result of growing concern regarding climate change, development of renewable energy and the expansion of nuclear power has been advocated.	M	Climate change will have an impact on the energy sector long term	Education, Improve and develop technology		E	S		E	S
Environmental Services	Solid Waste Management Landfill site operation.	Increased rainfall will result in further generation of mud and spray.	S	Onsite and approaching highways	Potentially approaching roads will need to be cleaned especially if the sites are in close proximity to other developments/ or if part of planning requirements. Vehicles will need to be washed more frequently as will the use of street clea	B	E	S			
Environmental Services	Solid Waste Management Landfill site operation.	Increased and intense rainfall will increase the erosion of internal temporary access roads (constructed of waste materials and aggregates).	S	Onsite and approaching highways	Additional aggregate may be required to help increase the longevity of the access roads, develop alternative materials	B	E	S			
Environmental Services	Solid Waste Management Landfill site operation.	Dry periods will result in increased formation of dust and suspended particulate matter.	S	Onsite and approaching highways	Vehicles will need to be washed on exit of sites. Dust on access roads etc. will need to be wetted down as to prevent dust and particulate matter.	B	E	S			
Environmental Services	Solid Waste Management Landfill site operation.	Climatic conditions may affect waste degredation in landfill sites	M	Engineering practices need to account for the moisture content of the sites. Drier sites tend to have a slower degradation process and produce a more concentrate leachate over a longer period. Which potentially could impact on the leachate	Changes in site engineering and operational practices	B	E		B	E	
Environmental Services	Solid Waste Management Landfill site operation.	Extreme weather conditions leading to slippage of engineered cells	S	Site Engineering	Slippage potential of the engineered cells and storage heaps will need to be addressed	B	E				

Environmental Services	Solid Waste Management Landfill site operation.	Potential for sites to be at risk of flooding	L	Site Engineering	Increased pumping, changes in design of sites	B	E	S			
Environmental Services	Solid Waste Management Landfill site operation.	Increasing temperatures will ultimately affect the rate of landfill gas and leachate production, and thus the long term liabilities associated with landfill sites	L	Landfill gas & leachate production. If the temperatures increased and moisture input remained the same, then the production rate of landfill gas should increase. Therefore, potentially the long-term liability (with regards landfill gas) o	Changes in design/operation of site to optimise gas and leachate production				B	E	S
Environmental Services	Solid Waste Management Landfill site operation.	Patterns and type of waste production (resource consumption) are likely to alter as people adapt to climate change.	S	Changes in waste composition will affect degredation processes, volumes of waste my change, or alternative disposal/recycling methods may become more prevalent	Changes in design and operating practices	B	E		B	E	
Environmental Services	Solid Waste Management	Increasing temperatures and changing rainfall patterns may result in faster rates of bio-gradation. This may facilitate alternative disposal methods such as composting.	S	Increased waste separation requirements, changes in council collection schemes			S		B	E	S
Environmental Services	Solid Waste Management Landfill site operation.	Increased frequency of strong winds could lead to rubbish and debris being blown around the site.	S	General house-keeping, particularly an issue if sites are located near housing and developed areas.	Suitably positioned fences to catch rogue material., changes in cell coverage practices to reduce potential for escaping litter	B	E	S			
Environmental Services		Odour, hotter summers could lead to more smell complaints, especially if housing or developed areas are nearby.	S	Impact on built environment	Modification to operational practices, eg damping down, immediate coverage of waste, reduction in organic content of waste.	B	E	S			
Built Environment		Increased rainfall will result in increased surface waters requiring management and increased costs.	S		increased capacity to collect and pump surface waters, treatment of top liquors	B	E				
Environmental Services	Solid Waste Management Landfill site operation.	Potential increase of pests and disease, especially due to standing water and increased temperatures.	S	Health & Safety Implications	Pest control, changes to operational management and design	B	E	S			

Environmental Services	Solid Waste Management Landfill site operation.	Employees operating in extreme weather and associated hazards.	S	Health & Safety Implications	changes to site management and operating procedures, additional protective equipment and clothing, employee relations	B		S			
Environmental Services	Solid Waste ManagementMunicipal Waste Collection	As waste is currently disposed and charged by weight, wetter weather will inevitably increase the tonnage and thus disposal cost.	S	Run-off/ leakage from the waste collection vehicles contravenes the Road Traffic Regulations, EPA 1990, in that the leachate is not contained/ managed in a proper manner.	Operation of contracts, changes to the design of the containers e.g. covers	B	E	S			
Environmental Services	Solid Waste ManagementMunicipal Waste Collection	Wetter weather will ultimately affect the quality of paper product for recycling..	S		Operation of contracts, covered collection points	B	E	S			
Environmental Services	Solid Waste ManagementMunicipal Waste Collection	Increasing difficulty in collection of waste from flooded areas.	S	This needs to be considered when tendering for contracts. Should specific clauses be included into the tenders/ contracts	Changes to collection and storage systems, waste reduction, observe or predict weather patterns, planning contingency for extreme events, contract clauses	B	E	S			
Environmental Services	Solid Waste ManagementMunicipal Waste Collection	Increased temperatures increasing the rate of waste decomposition leading to odour and health problems.	S	? Additional income	During hotter months the waste collection rate needs to be increased, changes to design of waste recepticles, forecasting weather trends	B	E	S			
Environmental Services	Solid Waste ManagementMunicipal Waste Collection	A population shift, possibly due to relocation from flood prone areas, tourism etc. can lead to an increase in the regional production volumes of waste.	M	Geographical shift	Change business logistics, operation, regularity schedules	B	E		B	E	
Environmental Services	Environmental Consultancy	Changes in workload and topic areas due to changing business needs resulting from climate change	S		Develop business, increase marketability, diversify, link to research establishments, create innovative ethos				B		S

Engineering	Manufacturing	Manufacturing techniques changing due to higher temepratures	S	Higher temperatures will mean less energy will be needed in manufacturing techniques	If too hot, increased refrigeration or cooling systems will be needed	B			B		
Engineering	Manufacturing	Manufacturing locations changing due to increased risk of flooding	S	Engineering industry may have to move away from flood hot spots	Flood alleviation schemes	B	S	E		E	S
Engineering	Engineering sector	Loss of 20,000 jobs in engineering in the West Midlands sector due to the climate change levy proposals		Links to the local West Midlands economy	Working with local and national Government to find althernative work opportunities and to retrain people	B	S				
Biodiversity	Vulnerable habitats	Changes to Aqualate Mere - the largest of the meres & mosses in Staffordshire & N.Shropshire - v.vulnerable to extended droughts/storms.	S		Proactive conservation measures eg. through the EA BAP	B	E	S			
Biodiversity	Vulnerable habitats	Changes in plant & animal species distribution &abundance.	S	V.difficult to separate from those duwe to other causes (esp. acid deoosition for other plant species) Small impact could signif.affect man's economic activities (esp. agriculture) but is likely to only cause interesting, minor variations	Changes in legisaltion eg. IPPC to mitigate pollutioning effects of industrial activity.		E	S		E	S
Biodiversity	Vulnerable habitats	Loss of species. The most vulnerable species are likely to be those that are rare and local, being on the edge of their ranges*, or specialised in different ways and therefore inflexible**	S	On a regional scale there is a very complex network of processes must be taken into consideration and there is insufficient info. about the effects of CO2 on these processes to permit reasonable predictions	International wildlife conservation treaties will be required. Improved education and public awareness.		E	S			
Biodiversity	Vulnerable habitats	basic ecosystem processes are likely to be affected due to the loss of some species	S	Lack of knowledge as to how this may impact.	Proactive conservation measures		E	S			
Biodiversity	Vulnerable habitats	Direct & indirect impacts on climatic change will lead to changes in species composition, dominance and ecosystem structure, and the distribution and abundance of species.	S		Proactive conservation measures		E	S			

Biodiversity	Vulnerable habitats	Threat to ecosystems which are vulnerable to increased fire risk during summer droughts. Drought itself is likely to be the most significant early feature of climatic change in these habitats.	S	This would lead to changes in species - with common grasses and bracken becoming dominent at the expense of heather.	Proactive conservation measures	B	E	S			
Biodiversity	Vulnerable habitats	An increase in the severity of summer drought is likely to have signif. effects on the spring ground flora of woodlands - eg. primrose, bluebell & wood anemone are likely to be the most affected.	S		Proactive conservation measures		E	S			
Biodiversity	Vulnerable habitats	A possible increase in incidence of storms could result in further forest destruction on a similar scale to 1987. It is unlikely that tree-species composition will change signif. over the next 60 years unless as a result of severe frequent	M	Potentially not ecologically serious but aesthetic implications for amenity	Increased mangement		E	S			
Biodiversity	Vulnerable habitats	Loss of biodiversity associated with reduction in suitable agricultural land	S		Proactive conservation measures		E	S			
Biodiversity	Vulnerable habitats	Loss/change to sensitive habitats - notably montane & raised bogs (loss of climatic conditions), soft coastal habitats (due to changes in coastal defences) & chalk rivers (due to water use and agricultural practice). Others sensitive to sp	S	Links to agriculture & tourism.	Proactive conservation measures	B	E	S			
Biodiversity	Species	Changes to the distribution of the Freshwater Pearl Mussel - Shropshire has one of the largest remaining populations in England	S	See reference - English Nature & MAFF associated studies	EA BAP / EN (MONARCH) research project	B	E	S			

Biodiversity	Species	Changes to the distribution of the predominantly Midlands found Grass-wrack pondweed - inc. Montgomery Canal	S	Uncommon aquatic plant - primarily found in the Midlands (esp. Montgomery Canal).	EA BAP		E	S			
Biodiversity	Species	Increased dominance of fast growing herbs, (eg. Rosebay willowherb, Nettle) in nutrient-rich well-watered habitats. It is believed that these will benefit most from CO2 enhancement.	S	Ecosystem change/uniformity. Plants most likely to show the most rapid response to env. changes assoc. with global warming are small, often inconspicuous ones, and those least likely to attract serious concern from the general publi	Habitat management		E	S			
Biodiversity	Species	The ability to migrate rapidly will allow some species within every plant & animal group to respond positively to climate change (inc. beetles, water plants, snails and mayflies).	S		Proactive conservation measures						
Biodiversity	Species	Species currently at their northern range extremity (e.g. Dartford Warbler) are likely to benefit. Conversely, those at the southern limits of their distribution in Britain are vulnerable.	S		Proactive conservation measures		E	S		E	S
Biodiversity	Species	A changed climate may allow introduced species to be highly invasive, carry parasites and disease which will further disrupt existing ecosystems.	S		Increased pest control measures, barriers to entry						
Biodiversity	Species	Long term changes in the distribution & abundance of long-lived species (esp. trees) due to climatic changes. Impoverishment is almost certain; a net enrichment of species is very unlikely without management intervention. Losses will incl	S	These changes will be much slower to become apparent than in those of short-lived shrubs, herbs, grasses, ferns, bryophytes, lichens and invertebrates.	Proactive conservation measures		E	S			

Biodiversity	Species	Unknown, but potentially adverse impact on Great Crested Newt populations	S	Upper reaches of R.Severn, Cannock,& Shropshire are known habitats areas	EA & local BAPs, Haps & SAPs		E	S				
Biodiversity	Species	Unknown, but potentially adverse impact on Twaite Shad (Salmonid fish) populations	S	The Rivers Severn & teme provide some of the few remaining known spawning areas for this species.	EA & local BAPs, Haps & SAPs		E	S				
Biodiversity	Species	Unknown loss of species which could be advantageous for medicine (drugs) - eg. asprin originally derived from willow & meadowsweet.	S		Proactive conservation measures	B	E	S				
Biodiversity	Species	Highly mobile species (typically from southern climes) may proliferate due to climate change and some may become serious pests.	S		Pest control measures	B	E	S				