Wales: Changing Climate, Challenging Choices

- a Scoping study of climate change impacts in Wales

May 2000

Prepared for the National Assembly for Wales

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SUMMARY

This report describes a scoping study of the possible impacts on Wales of climate change over the next 100 years. It combines consideration of the probable change in climate, expert opinion on the consequences of the changes in climate, and the results of interviews with nearly 70 stakeholders from many Welsh institutions and economic sectors. The report does not consider mitigation, the means by which we can limit the process of climate change itself. A summary report (Wales, Changing Climate, Challenging Choices) was published in February 2000 and copies can be obtained from the National Assembly for Wales.

The natural and managed environment - biodiversity, agriculture, and forestry - will be substantially affected. Wales contains many sites of national and international importance; its uplands are particularly sensitive. Both increased temperature, and drier summers, are expected to alter many terrestrail and freshwater habitats.

Agriculture and forestry are closely dependent on climate, and will be subject to significant changes. Livestock may be more liable to heat stress. The season for grass growth will be extended. Other sectors of the economy will also be affected, and the insurance industry in particular will respond to extremes of weather. Impacts on the economy will be greatly influenced by how climate change affects other countries.

Both the provision of water for human use, and the control of flooding from rivers and the sea, will become much more difficult. Although rainfall will be greater, summers will be drier and so supply of water to consumers may require more capacity for storage or a reappraisal of the current situation where much water falling in Wales is exported to England. The frequencies of both coastal and inland flooding are set to increase greatly, due to sea level rise and more episodes of heavy rainfall. Coastal defences will need to adapt.

Many, if not all, of the deleterious impacts of climate change can be avoided by timely planning and action. Similarly some of the opportunities presented by climate change – for example to the tourism industry – need forethought if they are to be realised. We therefore have made a series of recommendations which are embedded in the relevant sections of the report, but for convenience are gathered together below.

A feature of the recommendations is that they involve a range of Welsh and UK institutions, and indeed it is clear that the challenge presented by climate change will best be met by the integrated activity of bodies which do not necessarily work closely together now. The experience of managing agri-environmental schemes such as Tir Cymen and Tir Gofal could be extended to such integrated planning. We do not have all the information we need to take well-informed decisions, and so we identify areas where research is required. It is equally clear that both the public and decision-makers need to be provided with the best information available to help them adjust to the impacts of climate change.

Recommendations

Climate Change Scenarios

Regional models for the future climate of Wales (such as Had RM2) need to be developed and evaluated as (a) its climate is so variable and (b) the possible east-west gradient in climatic change needs to be tested.

More research is needed on (a) the daily climate variables especially precipitation and windspeed and (b) prediction of extreme events, necessitating the refinement of current, or development of new, models.

Further work to assess storminess changes on the Welsh coastline is required to assess the levels of risk to which different parts of the coastline are exposed.

The inevitable uncertainty in model predictions needs to be better communicated to users and public.

Flood defence and coastal protection

Better information, *e.g.* accurate Digital Elevation Model (DEM) data, is needed to identify more precisely the extent of coastal areas most at risk from flooding.

Further work to monitor and assess the effects of increased storminess on the Welsh coastline is required.

Government needs to clarify responsibility for flood and coastal defence which is at present distributed between a range of bodies

The Assembly needs to take account of the likely impacts of climate change in revising planning guidance (Technical Advice Notes) in areas potentially susceptible to flooding and coastal erosion.
Sectors which might be affected by flood defence measures, such as archaeology and biodiversity, need to be involved at all stages in the planning of defences

Ecological Impacts
There is a need for closer involvement of the relevant professionals with all aspects of planning and strategic development which impinge on their work and will be impacted by climate change.
Collection of data sets for freshwater and terrestrial organisms which may act as indicators of climate change in Wales are needed. This should occur by a combination of (a) instigating more collection of new data along the lines of the ECN and (b) collating existing data for species and sites within Wales which exist scattered across a range of bodies.
Incorporate climate change impacts in biodiversity action plans and the criteria for site designations of SSSIs, SACs etc.
Need for close monitoring of ecosystems and sites deemed to be at most risk.
Need for research on how climate change will interact with other environmental challenges (N deposition, acid rain, ozone pollution, overgrazing) in its effects on communities, especially in the uplands.
There is a need for the consequences of climate change for this sector to be incorporated into agri-environmental schemes such as Tir Gofal.
Better analysis of effects on freshwaters and freshwater organisms in analogue years (eg drought; mild wet winters; positive NAO phases) and assessment of freshwater ecosystems and management problems in analogue locations of future climate pattern (eg Gallacia, NW Pyrenees)
Better development of freshwater models to link with climate models.

Historic landscapes, built heritage and archaeology
Integrate preservation of built heritage with the planning of other sectors affected by climate change, especially rural land use and construction of hard defences against flooding, and new build developments.
Incorporate the consequences of climate change for the built heritage into agri-environment schemes such as Tir Gofal.
Increase understanding of climate change issues in the archaeological community and prioritise sites at risk from climate change against the resource available to investigate them.

Health Impacts
The Assembly should consider how its policies and strategies for human health will be affected by climate change.
Research is required on the effects of climate change on insect vectors.
The public need to be informed of the relevant risks, such as increased probability of skin cancer.
The Food Standards Agency to consider whether modified advice on food hygeine will be required.

Economy
Socio-economic scenarios need to be developed for Wales, taking account of the regional economic statistics to provide a more detailed picture of how the interaction of climate change and socio-economic scenarios might impact on Wales.
Organisations need to consider how corporate strategic plans should be informed by a wider range of issues than currently, due to the high degree of interaction between sectors which climate change will highlight.
The Assembly needs to develop economically viable strategies which recognise the interactions between climate change, agriculture, conservation and water resources.

Agriculture and forestry
The Assembly should give strong support and adequate funding to agri-environmental schemes such as Tir Gofal, and such schemes should take full account of the impacts of climate change

The most important research needed by Welsh agriculture and forestry include the following:

i. Impacts of climate change (including elevated CO_2) on grass growth and quality in improved grasslands, alone and in interaction with other environmental challenges such as nitrogen deposition, ozone pollution, overgrazing and acid rain.
ii. Impacts of climate change (including elevated CO_2) and grazing pressure on the semi and unimproved grasslands of the uplands.
iii. Impacts on systems of grass conservation and on the ensiling process.
iv. Impacts of climate change including effects of elevated CO_2 on the pests and diseases of farm animals,
v. Impacts of climate change on the welfare of farm animals, eg effect of elevated CO_2 on animal performance
vi. Impact of climate change on the productivity of Welsh forests and woodlands

There is a need to increase understanding of how climate change will affect the major international competitors for products of importance to Wales, eg lamb.
The current debate on the future of Welsh woodlands should include consideration of climate change impacts.
Information on climate change impacts with greater predictability needs to be made available to the agriculture and forestry sectors.

Manufacturing industry and market services
More clarity on actual meteorological effects of climate change, including forecasted changes to: wind speeds, frequency of events, and likely areas to be affected.
Industry sector studies to determine specific impacts. These should include an appraisal of how industry in Wales may develop and the evolution of industry sectors. For example, foreseeable impacts on current industry base may become outdated if looking 20 years into the future - plant closures may reduce the significance of a particular sector in Wales.
Business needs to consider the opportunities as well as the threats offered by climate change.
The Assembly needs to ensure that DETR considers Building Regulations to ensure that they address climate change impacts during the lifetime of the structures being planned

Transport
Three specific recommendations were made by those in the transport sector in relation to climate change. These were to obtain:

More specific projections of the changing severity and frequency of unusual weather events.
More specific studies scoping the impacts of climate change on the roads network and further development of Railtrack's work on the rail system.
Review of the design standards required for transport infrastructure to accommodate changes in climate.

Energy
There is a need for a co-ordinated approach, with both central and local government supporting a coherent climate change strategy. For example planning applications for wind power generation need to reconcile the direct merits for the economy and for mitigation with possible negative effects on the tourist industry and local concerns.
Predictions of extreme events such as peak wind speeds need to be incorporated into such decisions as whether power cables are over- or under-ground, and the design of wind turbines.
There needs to be careful reconciliation of adaptation and mitigation strategies. Stakeholders identified the following possible actions relating to mitigation: promotion of "Green Energy", including hydro-electric and the utilisation of Renewable Energy sources to reduce CO_2 emissions; increase "Dispersed Generation", thus having smaller scale generators but more of them, thus lowering transmission wastage; commercial options for sustainable energy supplies from a range of renewables.
Provision of information about, and contribution to the wider discussion of, climate change is needed by this sector. The sector would like more detailed weather/climate forecasts, especially of particular combinations of weather. Accurate forecasts of temperature can be used to adjust loads.

The industry regulators need to ensure that the power utilities place sufficient emphasis on measures to assist adaptation to climate change. They need to recognise that the regulatory regime may be hindering a response to climate change impacts.

Water resources

There is a need for different public and private sector bodies to be involved in planning for the impacts of climate change on water resources.

The water industry, either as individual companies or through Water UK, are able to directly liaise with climatological modellers to obtain the best and most up to date advice on climate. They urge DETR to continue supporting the core products produced by Met Office and the Climate Research Unit at UEA. The industry hopes the scenarios become more robust and weighted for thus relative likelihood

The Environment Agency and water industry should provide strategic advice on the drivers for water demand, particularly issues such as promotion of tourism (which causes a rise in water demand in summer) and new industrial demand, and to encourage water conservation and promote demand side management. EA is well placed to give objective advice on demand forecasting, optimal management of water resources and water efficiency.

Local Government has a role to play in providing local area expertise in how demand for water is likely to change bearing in mind their development and housing plans. NAW has a role to play in co-ordinating these plans and ensuring they are consistent.

The regulators need to ensure that the water utilities place sufficient emphasis on long-term measures to assist adaptation to climate change. They need to ensure that the conditions under which the utilities operate do not mitigate against adaptation. Some water companies feel that the continuing drive to reduce water bills is likely to jeopardise their in-house research.

Tourism and recreation

The tourism industry needs to examine its policy of expanding into the shoulder periods in the light of the seasonality of climate change.
The industry needs to consider the likely impacts of sea level rise and storms on beaches important to tourism.
The industry needs to consider improvements to its processes of gathering data to facilitate adaptation.
The Assembly should consider adequate support for the three Welsh National Parks to plan for climate change in their roles of environmental care and being foci for tourism.

Communicating Climate Change

The Assembly and other organisations need to consider how to increase public awareness of climate change issues whilst taking account of the attitudes of Welsh people to environmental issues.

The Assembly needs to consider setting up a forum of local stakeholders and experts to exchange information , concerns and ideas, to act as a focus and facilitator for the climate change debate, and to start building networks within Wales

Funding

The Assembly should consider creating an independent Environmental Body to work with ENTRUST.
The Assembly should assist those seeking to initiate research relevant to climate change impacts in Wales to acquire co-funding from EU and UK bodies.
The Assembly should consider prioritising its research needs for climate change impacts to facilitate its support of the research community.
The Assembly and other Welsh organisations need to ensure that Welsh issues are fully incorporated into UK-wide research on climate change impacts.

1. INTRODUCTION

How will climate change affect Wales? How much do people know about climate change? How should Wales prepare for it? The National Assembly for Wales (NAW) commissioned researchers[1] to answer these questions and to suggest what extra work needs to be done. Policies favouring sustainability, a key cross-cutting theme of the Assembly, will clearly need to account for the long-term impacts of climate change.

This scoping study follows on from a successful Workshop on Climate Change Impacts in Wales organised by the National Assembly for Wales (then the Welsh Office) held on January 20th 1999. Over forty people attended the workshop representing academia, business, NGOs and the National Assembly. One of the workshop's clear findings was that people did not know enough about climate change and wanted to know more.

This scoping study uses a mixture of literature review and stakeholder consultation to answer these questions. **Section 2** presents information on **four climate change scenarios** for the 2020s, the 2050s and the 2080s giving results for changes in temperature, rainfall and sea-level rise. A range of scenarios is used because we still do not fully understand climate science, nor do we know the degree to which countries will succeed in reducing emissions of greenhouse gases. Climate change will alter rainfall, temperature, sea-levels and winds, and so will affect the **Welsh natural and built environment**, its **coastlines** and the **health** of its people, and may increase the frequency of flooding. **Section 3** describes these impacts drawing on literature reviews and interviews with key stakeholders within and outside Wales. Agricultural and forestry, and outdoor tourism, are important to the economy of Wales. Wales is a major exporter of water to England. **Section 4** reports on the issues of key stake holders in these and other economic sectors. A mixture of literature, economic and stakeholder consultation is used. **Section 5** addresses the issue of **how climate change should be communicated** to the general population and business so that the information is authoritative, and interesting enough to maintain people's attention. As a result of this study, we make recommendations of how the work on climate change should be taken forward: these appear at the end of each section. This technical report should be read in conjunction with the summary report., Wales; Changing Climate, Challenging Choices, February 2000.

This work draws heavily upon the climate impacts programme being funded by the Department of Environment, Transport and the Regions. The central piece of this programme is climate change modelling by the UK Meteorological Office's Hadley Centre. The results of the modelling are used by the UK Climate Impacts Programme (UKCIP). The UKCIP provides public and private sector organisations with a framework for research into how climate change will affect them. This report is one of several scoping studies on climate change that have been initiated within the UK. Others have been completed in England's North West and South East regions and in Scotland. A new study has just commenced in the English East Midlands. South West England organised a large regional conference in October 1999. There are a range of studies in various stages of completion covering health, insurance, risk assessment, biodiversity and integrated modelling of climate, water, agriculture and biodiversity.

2. EXPLORATORY REGIONAL CLIMATE CHANGE SCENARIOS FOR WALES

2.1 Summary of the UKCIP98 scenarios

The following ten predictions for Wales are drawn from the UKCIP98 climate change scenarios. The predictions depend on the rate at which greenhouse gases accumulate in the atmosphere, and so 4 scenarios based on variation in the current rate of greenhouse gas addition are used and give a range of values.
Annual average temperature will rise between 1 and 2.9 ^{o}C per century.Warming is more rapid in autumn and winter than in spring and summer (seasons: DJF, MAM, JJA, SON)

1. In winter, minimum temperatures rise more rapidly than maximum temperatures, reducing the diurnal temperature range; in summer the opposite occurs.
2. Variability of winter temperature between years will decrease (very cold winters become rare)
3. Variability of summer temperatures will increase (very hot summers will occur more frequently)
4. Annual precipitation increases by 3-5% by 2050, by a combination of increased precipitation in winter (7-15% increase) and autumn, and no change or decrease (0-10%) in summer.

[1] University of Wales - Bangor, ECOTEC Research and Consulting, Institute of Terrestrial Ecology, Bangor, University of East Anglia

5. Year-to-year variability of seasonal precipitation changes, so that the frequency of ‘dry’ summers will double and of ‘wet’ winters will treble by 2080.
6. Daily precipitation intensity will increase, especially in winter. Thus more of the increased precipitation will fall in intense storm events than at present.
7. Potential evapotranspiration increases in all seasons, by up to 10% in summer and 15% in autumn.
8. Sea level will rise due to climate change by 25 cm by 2050 under one scenario (Medium-High) which, coupled with natural coastal subsidence, would mean a net sea level rise of 26-36 cm by 2050.

This section develops the understanding of these climate predictions for Wales and considers whether the changes will occur uniformly throughout Wales.

2.2 Observed trends in Welsh Climate

2.2.1 Historic Trends in Welsh Climate

Although the interannual variations of the Central England Temperature series are strongly correlated with those over Wales (Jones and Hulme, 1997), we have used here a dedicated temperature series for Wales extracted from the global data set of New *et al*. (1999; 2000). Figure 1 shows the record of annual, winter and summer mean temperature for Wales from 1901 to 1998. Annual mean temperature shows a slight warming trend over this period, with five of the nine warmest years occurring in the last decade - 1989, 1990, 1995, 1997 and 1998 (all these years were between 0.9 º and 1.1 ºC warmer than the 1961-90 average). The warming has been greatest in autumn and winter; summer temperatures have shown little trend over the century. There has been a small decrease in the diurnal temperature range due to night-time minima increasing more rapidly than day-time maxima.

To quantify recent precipitation trends, we have used a regional precipitation series for Wales, again extracted from the data set of New *et al*. (1999; 2000). This series extends from 1901 to 1998. Annual precipitation in Wales has increased only very slightly (+3 per cent) over this period. Summer precipitation has fallen by up to 15 per cent since the early 1900s (Figure 2), with the summer of 1976 being the driest (about 60 per cent below normal). The summer of 1995 was about 50 per cent below normal. There has been a slight compensating increase (nearly 10 per cent) in winter precipitation over the course of the century, with the two wettest winters on record occurring in 1989/90 and 1994/95. The lowest panel in Figure 2 shows the difference between winter and summer precipitation in the region and emphasises the contrasting behaviour of winter and summer precipitation. In recent decades Welsh winters have been on average about 150 mm wetter than Welsh summers, whereas during the early decades of this century the difference was less than 100 mm. These seasonal trends in observed precipitation for Wales, and especially the contrast between winter and summer, are consistent with the UKCIP98 climate change scenarios (Hulme and Jenkins, 1998) discussed in Section 2.3.

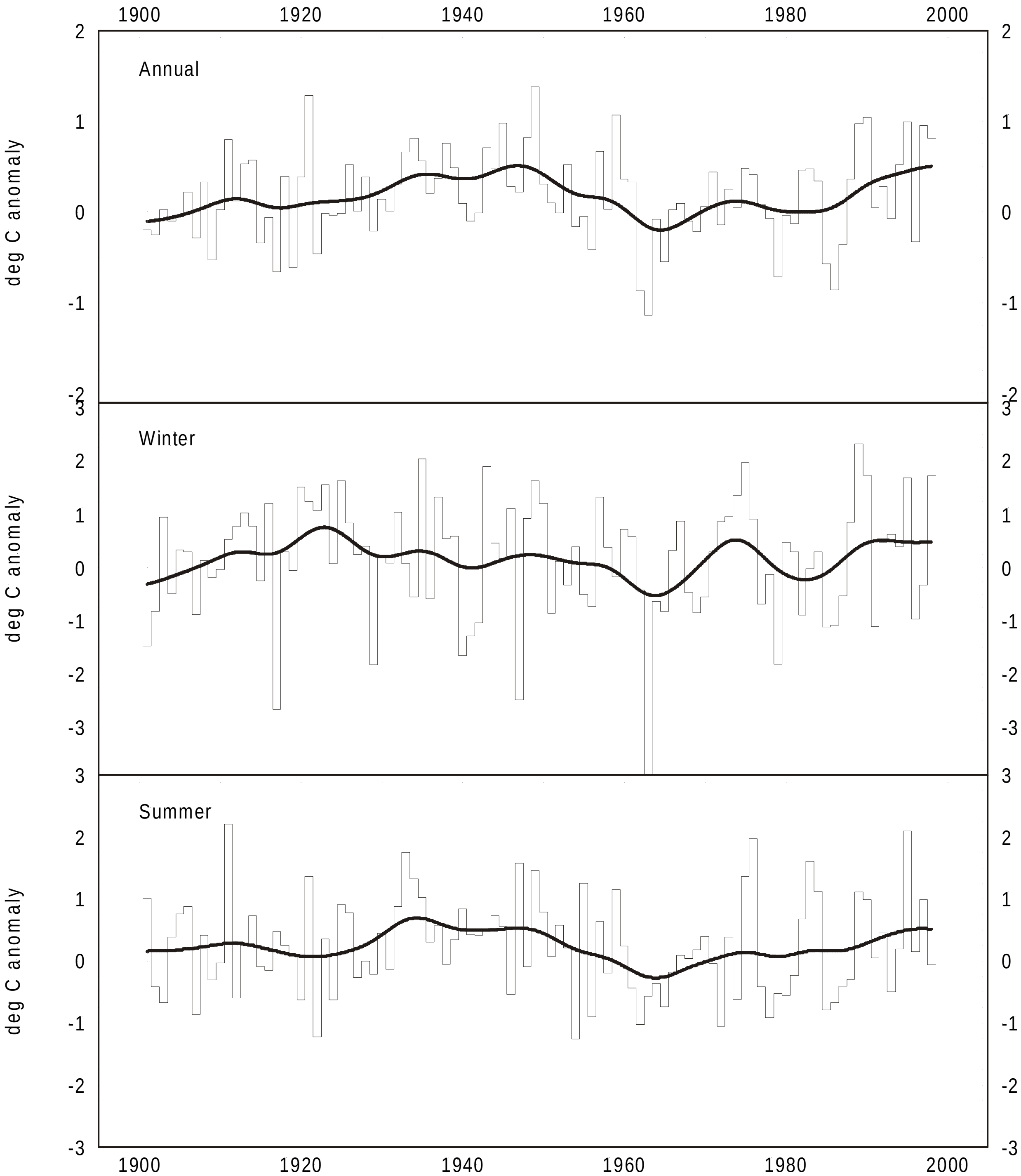


Figure 1: *Annual (top), winter (middle) and summer (bottom) mean temperature for Wales from 1901-1998. Smooth curves show 20-year smoothed data and horizontal lines show the 1961-90 average.*

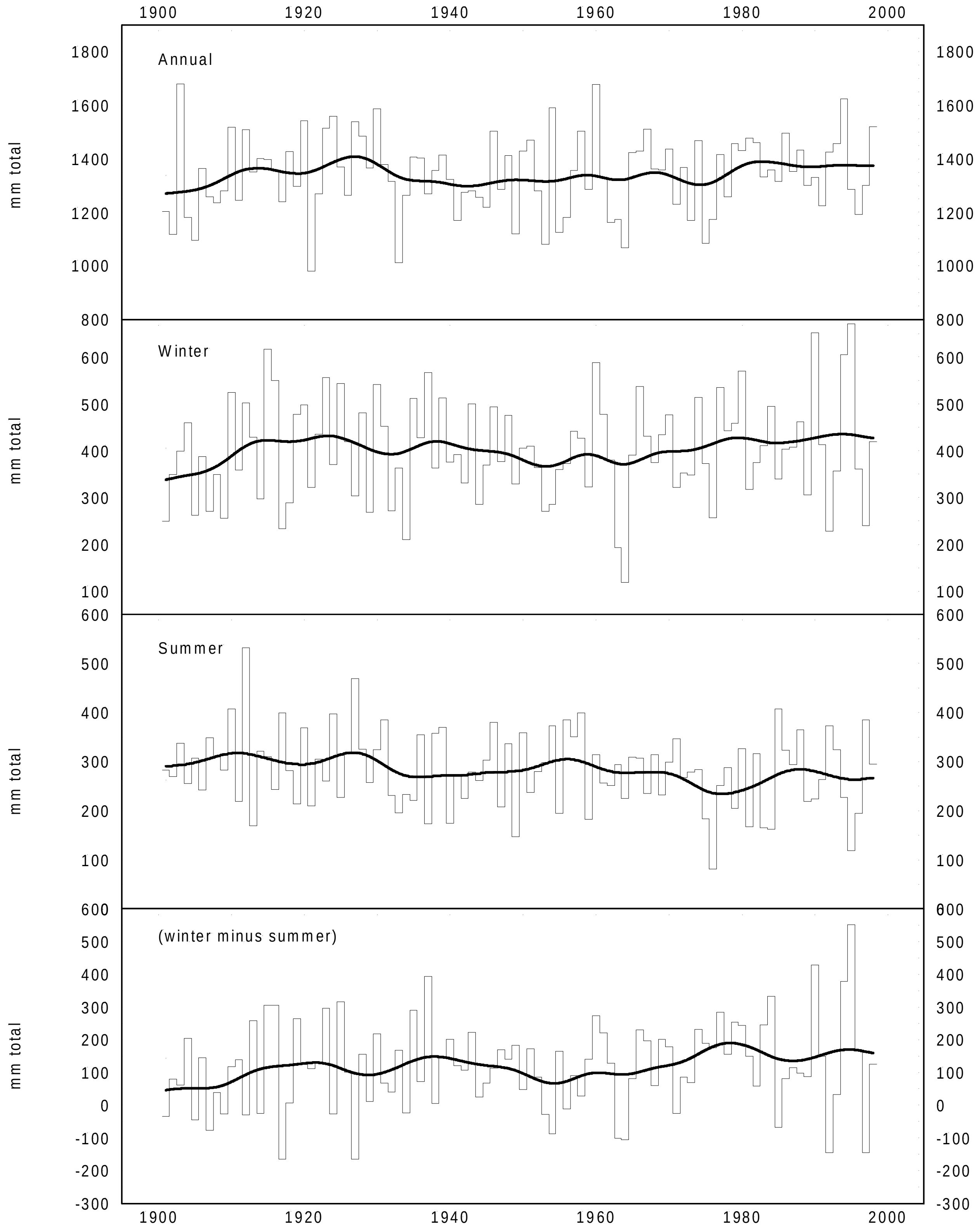


Figure 2: *Annual, winter and summer precipitation for Wales for 1901-1998. The bottom panel shows the difference between winter and summer precipitation. Smooth curves show 20-year smoothed data and horizontal lines show 1961-90 average.*

Changes in daily precipitation intensities are also important for many applications. We do not present an analysis of the observed precipitation intensity record here, but we note the recent analysis performed by Osborn *et al*. (2000) for the UK as a whole. They included ten stations from Wales in their nationwide analysis which showed that for the UK the heaviest daily precipitation intensities were increasing in winter and that daily precipitation in summer was becoming slightly less intense. These national trends were replicated in Wales, where it was also shown that autumn intensities were increasing slightly and spring intensities decreasing slightly. Trends in the climate of upland Wales are now being monitored at the Environmental Change Network site on Snowdon.

2.2.2 Climate Change Analogues

Analogue scenarios are constructed by identifying recorded climate regimes which may resemble the future climate in a given region. These records can be obtained either from the past (temporal analogues) or from another region at the present (spatial analogues).

2.2.3 Temporal analogues

Temporal analogues make use of climatic information from the past as an analogue of possible future climate. They are of two types: palaeoclimatic analogues based on information from the geological record, and instrumentally-based analogues selected from the historical records, usually within the past century. Both have been used to identify periods when the global (or regional) temperatures have been warmer or cooler than they are today. Other features of the climate during these periods (e.g. precipitation, windspeed), if available, are then combined with the temperature pattern to define the scenario climate. The major disadvantage of using temporal analogues for climate change scenarios is that past changes in climate were unlikely to have been caused by increasing greenhouse gas concentrations. Palaeoclimatic changes were probably caused by variations in the Earth's orbit around the Sun. Changes in the instrumental period, such as the 1930s drought in North America, were probably related to naturally occurring changes in atmospheric circulation.

2.2.4 Spatial analogues

Spatial analogues are regions that today have a climate analogous to that of the study region in the future. For example, northern Britain has been used as a spatial analogue for the potential future climate of Iceland. The approach is severely restricted, however, by the frequent lack of correspondence between other important features (both climatic and non-climatic) of the two regions (for instance, the daylength in the summer is shorter in northern Britain than in Iceland). Hence, it is unlikely that the present-day combination of climatic and non-climatic conditions prevailing in an analogue region today would be a physically plausible scenario for conditions in the study region in the future. Spatial analogue climates should be used very cautiously in scenario studies.

2.2.5 Analogue Years for Wales

Although there are clear limitations to the value of analogue scenarios, we can illustrate what the UKCIP98 climate changes might mean for Wales by examining two recent extreme seasonal climate anomalies - the hot summer of 1995 and the mild winter of 1988/89 - and using these as analogue years for future climate change. The summer of 1995 was the second warmest recorded in Wales (after 1911) with a mean temperature anomaly of 2.1 ºC above the 1961-90 average. We show the annual cycle of these 1995 temperatures for Valley and Rhoose and compare them to the 1961-90 average (Figure 3). The summer warmth of 1995 equates to the *average* summer to be expected by the mid-2050s under the UKCIP98 **Medium-high** scenario (see Section 2.3), i.e., five summers in ten by the mid-2050s will be warmer than the 1995 summer in Wales. By 2050s an extreme summer will be considerably warmer than this, perhaps reaching 3.7 ºC above the 1961-90 average, 1.6 ºC warmer than the mid-2050s average summer. The summer of 1995 also experienced an exceptionally large number of very hot days - defined as maximum temperature above 25 ºC, with frequencies of such hot days in Wales between four and eight times higher than average (Table 1).

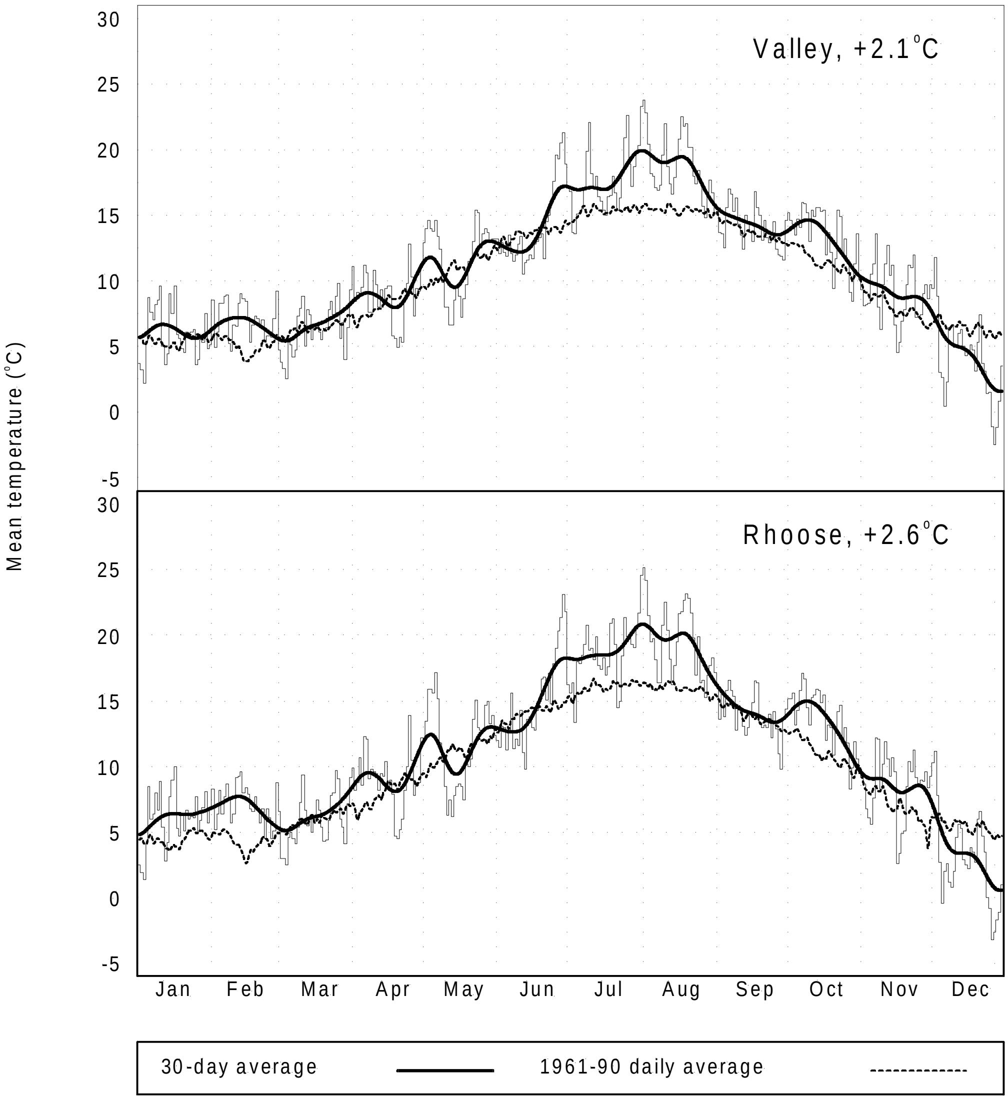


Figure 3: *Daily mean temperature for Valley (top; summer mean anomaly +2.1°C) and Rhoose (bottom; summer mean anomaly +2.6 °C) for the hot summer of 1995. The average 1961-90 daily mean temperature is shown as the dotted curve, while the daily temperature for 1995 is shown as histograms and smoothed as a 30-day average. The year 1995 may be seen as an analogue year for the average climate of the 2050s according to the UKCIP98* ***Medium-high*** *scenario.*

	'Hot' days		**'Cold' nights**	
	1995	**1961-90**	**1988/89**	**1961-90**
Cwmystwyth	19	2	15	65
Rhoose/Cardiff	26	6	7	37
Swansea	26	4	1	19
Valley	17	3	1	20

Table 1*: Frequencies of 'hot' days (Tmax >25 ºC) and 'cold' nights (Tmin <0 ºC) for four locations in Wales, for the anomalous summer of 1995 and winter of 1988/89, compared to the long-term 1961-90 average frequency.*

We can repeat the above analogue exercise for the mild winter of 1988/89, the mildest recorded in Wales this century with mean temperature 2.4 ºC above the 1961-90 average. By the 2050s, about half of all winters for the UKCIP98 **Medium-high** scenario will be at least as mild as 1988/89, but some individual winters will be much milder still. Thus, for example, an individual winter in the 2050s may be 4.2 ºC milder than the 1961-90 average, 1.8 ºC milder than the prevailing 2050s average. Such mild winters will see diminishing numbers of air frosts, nights when the air temperature falls below 0 ºC. During the 1988/89 winter, Swansea and Valley recorded only one such occurrence, compared to an average of 19 and 20 respectively (Table 1).

2.3 Highlights of the UKCIP98 Scenarios for Wales

The UKCIP98 climate change scenarios were examined for their implications for Wales. These scenarios are derived from a global climate model with a spatial resolution of 250 x 250 km, and Wales is represented by just one grid box. There is therefore no discrimination in these scenarios between climate change over upland and lowland Wales, nor between coastal and inland areas. Some key climate indicators are extracted from the UKCIP98 scenarios and these are related to the analogue year(s).

2.3.1 The Four Scenarios

The UKCIP98 scenarios were derived from the HadCM2 model, and contain four alternative climate futures termed '**Low**', **'Medium-low'**, **'Medium-high'** and '**High**'. The **Low** and **Medium-low** scenarios assume a relatively slow growth in future greenhouse gas concentrations (~0.5% per annum growth), whereas the **Medium-high** and **High** scenarios assume a relatively rapid growth in future concentrations (~1% per annum growth). The growth in global greenhouse gas concentrations during the 1990s has averaged about 0.8% per annum. It is not possible to objectively quantify the relative probabilities of each of these four scenarios occurring and all four possibilities should be evaluated in a full risk-assessment exercise. The impact and significance of climate change for Wales would be quite different if Welsh climate in one hundred years time looked, for example, like the **Low** scenario rather than the **High** scenario.

2.3.2 Seasonal Temperatures

The rate of future climate warming in Wales ranges from 1.0 ºC per century for the **Low** scenario to 2.9 ºC per century for the **High** scenario. For comparison, mean temperature over Wales during the period 1900 to 1998 has warmed at a rate of about 0.3 ºC per century (see Section 1). The UKCIP98 scenarios for Wales predict slightly more rapid warming in autumn and winter than in spring and summer. In winter, minimum temperatures rise more rapidly than maximum temperatures which reduces the diurnal temperature range. In summer the opposite occurs.

The year-to-year variability in seasonal temperatures also changes in the future. Winter variability decreases (very cold winters become rare) whereas summer temperature variability increases (very hot summers occur more frequently). A typical example is shown in Table 2 for the UKCIP98 **Medium-high** scenario. 'Hot' summers that presently occur once-a-decade (e.g. 1975) occur 64 per cent of the time by the 2050s and 80 per cent of the time by the 2080s. The one-in-ten 'cold' winter (e.g. 1995/96) virtually disappears, whereas 'mild' winters (e.g. 1994/95) occur in 85 per cent of years by the 2080s.

	Typical Years	**Present**	**2020s**	**2050s**	**2080s**
'Warm' year	1998	10	72	93	100
'Hot' summer	1975	10	39	64	80
'Cold' winter	1995/96	10	3	0	0
'Mild' winter	1994/95	10	45	58	85

***Table 2**: Percentage of years experiencing hot or cold annual or seasonal mean temperature anomalies for Wales. Results from the HadCM2 model for the UKCIP98 **Medium-high** scenario. Seasonal extremes are based on the 1-in-10 year return period for current climate as defined by HadCM2. The 'typical years' are selected from the data in Figure 1.*

2.3.3 Daily Temperature Extremes

The UKCIP98 scenario report (Hulme and Jenkins, 1998) said relatively little about the changing frequency of daily temperature extremes. The only relevant maps show changing numbers of days above and below certain temperature thresholds. Thus, by the 2050s under the **Medium-high** scenario, days with maximum temperature above 25 ºC nearly doubled over Wales, whereas days with minimum temperature below freezing reduced by about 60 per cent.

We can use the SPECTRE model (Barrow and Hulme, 1996) to extract some more specific estimates of changing daily temperature frequencies for Plymouth - the nearest location to Wales for which this analysis has been conducted. The average number of 'hot' days (days with Tmax above 25 ºC) increases from about 3 to between 4 and 10 by the 2050s, while the number of freezing winter nights decreases from about 21 to 3-10 (Table 3). Individual years will greatly exceed these average figures. Thus, during the warm year of 1995 there were no less than 18 days at Plymouth with Tmax above 25 ºC and during the mild winter of 1942/43 only three freezing winter nights were recorded. Individual warm summers and mild winters in the future will comprise even more hot days than the average shown in Table 3 and fewer freezing nights. Indeed, it is likely that before much longer Plymouth may experience its first ever winter without a night air frost. One might expect rather similar sensitivities for coastal Welsh cities such as Swansea and Cardiff.

	Tmax>25ºC	Tmin<0ºC
Average 1961-90 climate	3	21
Extreme historic year	18 (1995)	3 (1942/43)
Average 2050s climate		
Low	4	10
Medium-low	6	7
Medium-high	8	5
High	10	3

***Table 3**: Average annual number of days at Plymouth with daily temperatures exceeding the stated thresholds for current climate and for the 2050s under the four scenarios.*

2.3.4 Precipitation

Before commenting on the UKCIP98 precipitation change scenarios it is important to emphasise the substantial variation in precipitation totals averaged over 10 or 30 year periods that can occur quite naturally. For Wales, 30-year annual precipitation totals can vary naturally by up to ±5 per cent or more, whilst winter and summer totals may vary naturally by as much as ±10 and ±15 per cent respectively. Individual years vary, of course, by much more than this, typically by up to ±60 per cent. These levels of natural variability may pose as great a challenge to water management in the country as is presented by the human-induced changes in climate summarised below.

Annual precipitation over Wales increases in all four UKCIP98 scenarios, by between 3 and 5 per cent by the 2050s. Winter precipitation increases over Wales by between 7 and 15 per cent by the 2050s. Summer precipitation decreases by up to about 10 per cent by the same period. Spring precipitation changes little. All of these changes are for 30-year averages calculated with respect to the 1961-90 average.

	Typical years	Present	2020s	2050s	2080s
'Dry ' summer	1996	10	13	23	17
'Wet' winter	1993/94	10	24	20	34

Table 4*: Percentage of years experiencing dry or wet seasonal mean precipitation anomalies for Wales. Results from HadCM2 for the UKCIP98* ***Medium-high*** *scenario. Seasonal extremes are based on the 1-in-10 year return period for current climate as defined by HadCM2. The 'typical years' are selected from the data in Figure 2.*

The year-to-year variability in seasonal precipitation also changes. Precipitation variability increases in all seasons meaning that seasonal precipitation totals become less reliable. A typical example is shown in Table 4 for the UKCIP98 **Medium-high** scenario. 'Dry' summers that presently occur just once-a-decade (e.g. 1996) almost double in frequency by the 2080s, whereas 'wet' winters (e.g. 1993/94) become at least three times more frequent than at present. These changes - more frequent drier summers and wetter winters - are consistent with the changes in mean seasonal precipitation. The UKCIP98 scenarios also suggest that daily precipitation intensities will increase in the future, most notably in winter. Thus as well as experiencing wetter winters, Wales may expect to see more of this increased winter precipitation falling in more intense storm events than at present. There is little change in summer precipitation intensities in the UKCIP98 scenarios. We comment further on changes in daily precipitation intensities derived from a higher resolution climate model in Section 2.4.

2.3.5 Evaporation

Evaporation over Wales increases in all scenarios and seasons. Potential evapo-transpiration (PE) defined as evaporation from a plant surface, increases by up to 10 per cent in summer by the 2050s and up to 15 per cent in autumn. Annual PE increases amount to about 10 per cent by the 2050s under the **Medium-high** scenario. Such changes are important to factor in to any calculations of water balance.

2.3.6 Sea-level

One of the most likely consequences of global warming is a rise in mean sea-level. This occurs primarily because warmer ocean water expands and also because of the melting of polar ice sheets and land glaciers. The UKCIP98 scenarios include estimates of future global-mean sea-level rise. These estimates range between 12 cm and 67 cm of further climate-induced sea-level rise by the 2050s compared with the average 1961-1990 levels, with the **Medium-high** scenario prediction of 28 cm. In addition, it is necessary to take account of the isostatic rebound from the last glacial period. Parts of the UK are still rising and parts subsiding; the isostatic fulcrum is along the north Wales coast to the Lleyn with areas to the south subsiding. Thus effects of sea level rise are increased, by between 2 and 14 cm/century around the Welsh coastlinewith considerable local variation (Woodworth *et al*., 1999). The Severn Estuary is subsiding at 2.1 cm/century, whereas Cardigan Bay is almost stable, and Milford Haven may be anomalous in rising. The subsidence is variable around the Welsh coast, due to local geology, with the range 0.2-1.4 mm/year or 2-14 cm/century (Hulme, 1999; Shennan 1989). Combining the general subsidence rate of 2-14 cm/century and the climate-induced sea level rise leads to the estimated net sea level rise to be in the range 26.5-35.5 cm by 2050 from average 1961-1990 levels (based on the **Medium-high** scenario).

2.3.7 Coastal flooding risk

A further factor to consider in relation to sea-level rise and coastal flooding risk is the changing nature of storm surges. A rise in mean sea-level may result in a lower surge height being necessary to cause a given flood event, leading to a potential increase in the frequency of coastal flooding. The risk of flooding rises when a surge coincides with a high tide. If surge statistics remain the same in the future the changed flooding risk may be calculated quite simply. However, surge statistics may change for a number of reasons. The tracks and intensity of mid-latitude cyclones may change in the future and the formation and evolution of storm surges may also change, particularly in shallow waters. One of cyclical trends in the tracking of weather across the North Atlantic is termed the North Atlantic Oscillation which is a major disturbance of the atmospheric circulation and climate of the North Atlantic-European region linked to a waxing and waning of the dominant middle-latitude westerly wind flow. The NAO index is based on sea-level pressure difference between the south (eg Gibraltar) and the north (eg Iceland). When the index is positive, the westerly flow across the North Atlantic and Western Europe is enhanced, but when the index is negative, temperatures fall. The effects of the NAO on climate change are not fully understood and are currently being investigated.

The UKCIP98 report (Hulme and Jenkins, 1998) does not take into account storminess changes, but they did provide one extreme example for Harwich in eastern England - of how return periods of high tide-levels may change. In this case the rise in mean sea-level mentioned above (25 cm by the 2050s) could convert a high tide-level with a current return period of 100 years into one that recurs on average every 10 years. The tides at Harwich cover a small range - Lowest Astronomical Tide to Highest Astronomical Tide is 4.6 m, with a difference of only 1 m between Mean High Water Neap Tide and Highest Astronomical Tide. As a result, a surge could be a flood threat even at a neap tide. In contrast the tidal range around the Welsh coast ranges from 15.1 m at Avonmouth to 6.4 m at Holyhead and 10.6 m at Liverpool. Differences between Mean High Water Neap Tide and Highest Astronomical Level are 5.1 m at Avonmouth, 1.9 m at Holyhead and 3 m at Liverpool. As a result, surges are a threat when they coincide with high spring tides, but not high tides generally. The possibilities of such coincidence reduces from over 700 times/year on parts of the Welsh coast to about 50 times/year for most of the Welsh coastline. A 25 cm increase in mean sea level rise will have much less effect where there is already a large tidal range. Further work to assess storminess changes on the Welsh coastline would be helpful to assess the levels of risk to which different parts of the coastline are exposed.

2.4 The Regional Climate Models for Welsh Scenarios

We present a preliminary exploration of the results from one of the Hadley Centre's climate change experiments completed using their regional climate model (RCM). This experiment simulated future climate for the period 2080-2100 period under the Medium-High UKCIP98 scenario. This RCM has a spatial resolution of 50 km and Wales is therefore represented by about 11 land grid cells with average elevation varying from 61 m to 340 m. This allows for some geographic and altitude differentiation in the climate change results from this experiment. We compared, for mean seasonal climate only, these more spatially-discerning climate changes with those derived for Wales from the equivalent Global Change Modem (GCM) experiment using HadCM2 to produce the UKCIP scenarios. This scoping study does not allow for the analysis of daily output from the RCM. We evaluated how important the differences between the UKCIP98 and RCM scenarios may be for Wales.

2.4.1 The Question of Downscaling

The resolution of the GCMs - such as HadCM2 - is too coarse for regional analysis, because the HadCM2 gridbox at the latitude of Wales represents an area of about 70,000 km^2. Wales has an area of only 20,800 km^2 and, is contained within just one HadCM2 gridbox with the elevation of the country being represented by a single value of 107 m. Climate changes in the UKCIP98 scenarios are therefore quoted as single values for the 'Welsh' gridbox, e.g., annual warming of 1.9 ºC and a precipitation increase of 3 per cent by the 2050s for the **Medium-high** scenario. To generate climate change scenarios at finer space scales requires some form of climate 'downscaling'.

In the UKCIP98 scenarios, additional spatial detail was obtained by a simple interpolation of the GCM scale changes to a finer spatial resolution and then by combining these interpolated changes with observed climate information at that finer resolution. For example, the various UKCIP98 scenario changes for different periods were interpolated to a 10 km resolution using a standard spatial filter and then added to an observed 10 km mean monthly climatology for 1961-90 to yield 10 km climatologies for the 2020s, 2050s and 2080s. This approach is termed 'unintelligent' because no new meteorological insight is added that goes beyond the GCM-based changes and because the basic spatial patterns of present climate are assumed to remain largely unchanged in the future. This very simple approach to downscaling is easy to apply and allows impact assessment models to use climate scenarios at a resolution that would otherwise be difficult or costly to obtain.

A more intelligent forms of downscaling is based on a dynamical downscaling approach, namely the use of the Hadley Centre's RCM (HadRM2). This model possesses a spatial resolution of 50km, thus each cell represents a surface area of 2,500 km^2. Wales is represented by approximately 18 such RCM grid cells (Figure 4). The mean elevation of these cells ranges from 61 m to 340 m, still less than the absolute elevation range in Wales which is from sea-level to 1085 m (Snowdon), but considerably better than the single GCM elevation of 107 m. Analysis of this RCM experiment allowed us to consider the following questions relevant to climate change scenarios for Wales.

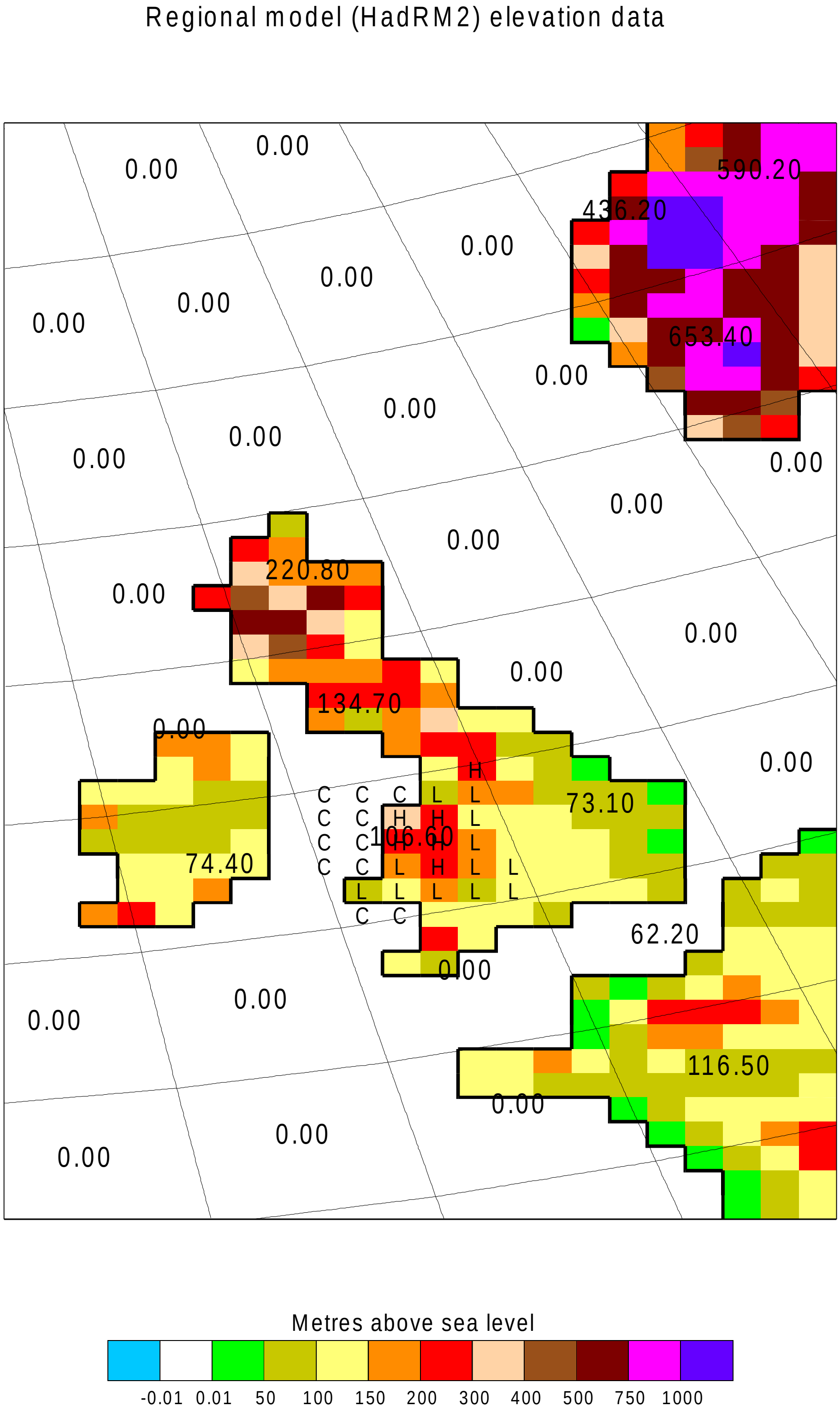


__Figure 4:__ Configuration of the regional climate model (HadRM2) 50km grid, plotted with the elevation field imposed. The thin black gridlines mark the HadCM2 grid, while the dotted black lines are longitude/latitude. The 'C' (coastal ocean), 'H' (highland) and 'L' (lowland) indicate the category to which each RCM 'Welsh' grid cell was allocated.

Does the GCM and RCM Yield Similar National-scale Climate Changes for Wales?
The RCM (HadRM2 model) was run for 20 years of simulated climate for the period 2080-2100 with boundary conditions extracted from the equivalent period in the GCM (HadCM2 GGa2) experiment. This is one of the GCM experiments that contributes to the UKCIP98 **Medium-high** scenario. We therefore compared the GCM climate change for this 20-year period for the GCM 'Welsh' gridbox with the average of the climate changes from the 29 RCM cells that approximate this GCM domain[2]. We ensured that these changes were calculated with respect to the average model-simulated climate of the period 1961-90. We made this comparison from mean temperature and precipitation and for annual, winter and summer climates (Table 5).

Temperature	**GCM**	**RCM full domain**	**RCM land-only**
Annual	2.9	2.7	2.9
Winter	3.6	3.2	3.4
Summer	2.4	2.3	2.5
Precipitation			
Annual	8.7	12.9	10.5
Winter	32.4	27.4	28.0
Summer	-24.9	-16.0	-21.4

***Table 5**: Mean seasonal change in temperature (degC) and precipitation (per cent) by 2080-2100 with respect to 1961-90 for the UKCIP98 **Medium-high** scenario for the 'Welsh-domain' in the GCM (HadCM2) and RCM (HadRM2). For HadRM2, a land-only domain is also shown.*

The GCM response is much closer to the land-only response of the RCM than it is to the full domain RCM response. Temperature changes are within ±0.1ºC and precipitation changes within ±4 per cent. These levels of agreement are well within the 'noise' levels of natural climate variability (see Section 2.2). The full domain response of the RCM is slightly different from the GCM - less warming, smaller seasonal precipitation changes - because of the 11 ocean cells included in the RCM domain. Ocean cells warm less rapidly than land cells, and the precipitation responses are somewhat different. However, for the land area of Wales, and for mean climate, the climate responses of the GCM and RCM to the same greenhouse gas forcing are consistent.

How Much Regional Variation in Future Climate Change is there within Wales?
The 'Welsh-average' change in annual temperature by 2080-2100 for the GCM-derived **Medium-high** UKCIP98 scenario is 2.9 ºC, identical to the change for 'Welsh' land areas given by the RCM. But how much does this climate change vary across Wales in the RCM?

Table 6 summarises the sub-regional variability in the RCM responses for our standard seasons and variables. Thus for annual temperature the change may be between 2.7 and 3.2ºC over land areas depending where in Wales one looks. Similarly for annual precipitation, the change may be between a 4.2 and 13.9 per cent increase, compared to a land-only domain average response of 10.5 per cent. Other seasons are shown in Table 6. The sub-regional variability over land areas for temperature is greater in summer (standard deviation 0.27ºC) than in winter (0.14ºC), and for precipitation the sub-regional variability is greater in the winter and summer seasons (standard deviation nearly 6 per cent) than it is for annual precipitation (2.7 per cent). We analyse the reasons for these differences in the next sub-section.

Whilst these sub-regional variations in Welsh climate change revealed by the RCM may appear in some cases to be large (e.g. a decrease in summer precipitation ranging over land from -14 to -32 per cent), it is important not to over-interpret the significance of the differences. They may not be genuine regional differences in the climate

[2] We include both land and ocean RCM cells in this averaging, 11 ocean cells and 18 land cells.

response to greenhouse gas forcing (and therefore not worthy of informing an impacts assessment over and above the results from a GCM) for at least two reasons.

	Range		Standard Deviation	
Temperature	**Full domain**	**Land-only**	**Full domain**	**Land-only**
Annual	2.3 to 3.2	2.7 to 3.2	0.28	0.15
Winter	2.7 to 3.6	3.1 to 3.6	0.31	0.14
Summer	1.8 to 3.0	2.2 to 3.0	0.36	0.27
Precipitation				
Annual	4.2 to 20.9	4.2 to 13.9	4.54	2.67
Winter	12.8 to 36.6	17.4 to 36.6	6.25	5.99
Summer	-31.9 to 1.5	-31.9 to -13.8	11.08	5.70

***Table 6**: Sub-regional variability (range and standard deviation) of the mean seasonal changes in temperature (degC) and precipitation (per cent) by 2080-2100 with respect to 1961-90 for the 29 cells in the 'Welsh-domain' of the RCM (HadRM2) experiment. The land-only variability is derived from the 18 land cells. See Table 5 for the domain-average responses.*

First, natural climate variability exists on these sub-regional scales and this variability will be unrelated to greenhouse gas forcing. For example, when averaged over 20-years (as done here) the mean climate anomaly in one part of Wales may be several tenths of a degree warmer or colder than another part of the country for reasons totally unrelated to greenhouse gas forcing. This has been demonstrated for Scotland and eastern England by New (1999), who showed that such sub-grid-scale variability in 30-year mean seasonal anomalies can amount to ±0.4ºC for temperature and ±7 per cent for precipitation. Second, we have only the results from one RCM experiment to analyse. Different simulations with the same greenhouse gas forcing, but using the same regional model with different initial conditions or using different regional models, will yield different patterns of sub-grid-scale variability. Some of these sub-regional pattern structures may be systematically caused by greenhouse gas forcing but some will be random effects. Until we have more results from regional model experiments to analyse it will be hard to distinguish between these two sources of spatial variability in the regional climate change. One way to tackle this problem is to see whether any of the sub-regional variations are related to known and plausible physical mechanisms. We do this is the next section by looking at coastal and elevational influences on the sub-regional variations in the RCM response to greenhouse forcing.

Are these Regional Variations Systematically Related to Geography?

For the purposes of this comparison we divided the 29 RCM cells in the 'Welsh' gridbox into three categories - ocean (i.e., sea-level, n=11), lowland (<200 m above sea-level, n=12) and highland (>200m above sea-level, n=6). We examined the changes in mean seasonal climate for each RCM cell according to these three categories (Figure 5).

Temperature change over the offshore ocean grid cells is consistently smaller than for the RCM land cells, generally by between 0.5º and 1ºC, but in some extreme cases by more than 1ºC. There is little systematic difference in the temperature response between the lowland and highland regions of Wales, with the possible exception of summer, where the mean lowland warming is perhaps about 0.2ºC greater than the highland warming. The correlation between temperature change and elevation, however, is close to zero and this does not support the hypothesis that one can differentiate climate change over Wales on the basis of elevation.

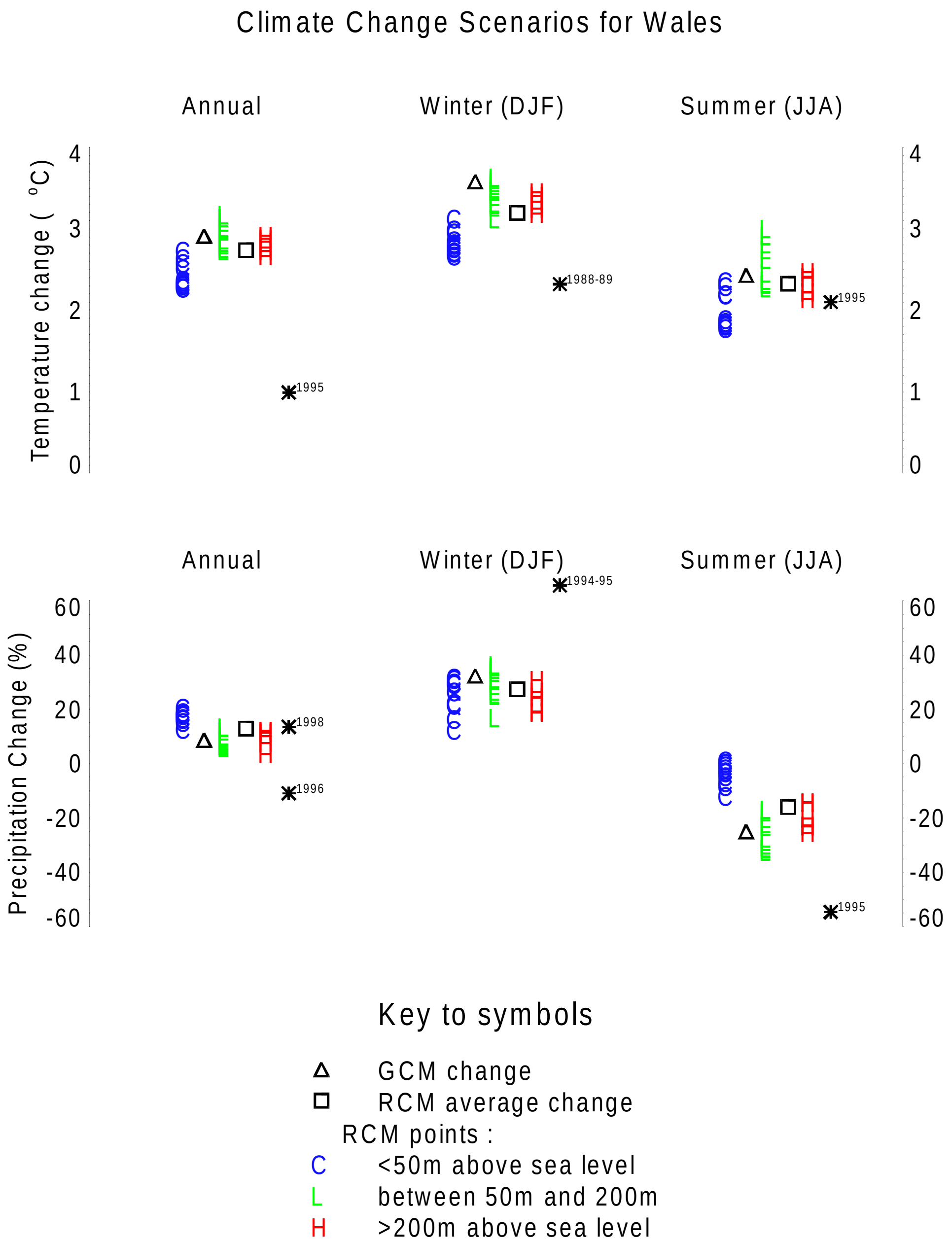


Figure 5: *Change in mean annual and seasonal climate over Wales by 2080-2100 relative to 1961-90 for the **Medium-high** UKCIP98 scenario; (top) temperature and (bottom) precipitation. The open black symbols show the domain-average response for the GCM and the RCM, while the coloured letters (C, L and H) show the responses as the individual RCM cell locations in the 'Welsh' domain. See text for further explanation.*

For annual precipitation, the offshore ocean cells become a few per cent wetter than the land cells in the RCM. This is due largely to the summer season when the land dries by between 14 and 32 per cent (depending on location) and the precipitation over the ocean sees a reduction of only a few per cent. This land/ocean contrast in summer precipitation change may be partly related to a drier land surface in summer reducing precipitation over land areas. There is again no evidence of systematic differences between precipitation change and elevation.

This analysis suggests that any systematic sub-regional differences in climate response in the RCM are more likely to be related to coastal influence that to elevation. This is borne out by a comparison of the two 50 km RCM cells within which the Gower Peninsula and Snowdon are located. These two cells maximise the elevation differences in the RCM - 61m and 340m respectively - and yet they display almost identical mean climate change responses. Gower warms less and wets more than Snowdon in winter, but warms more and dries more than Snowdon in summer, but these differences amount to less than 0.2ºC and less than 5 per cent respectively and are not part of any systematic climate change/elevation relationship over Wales.

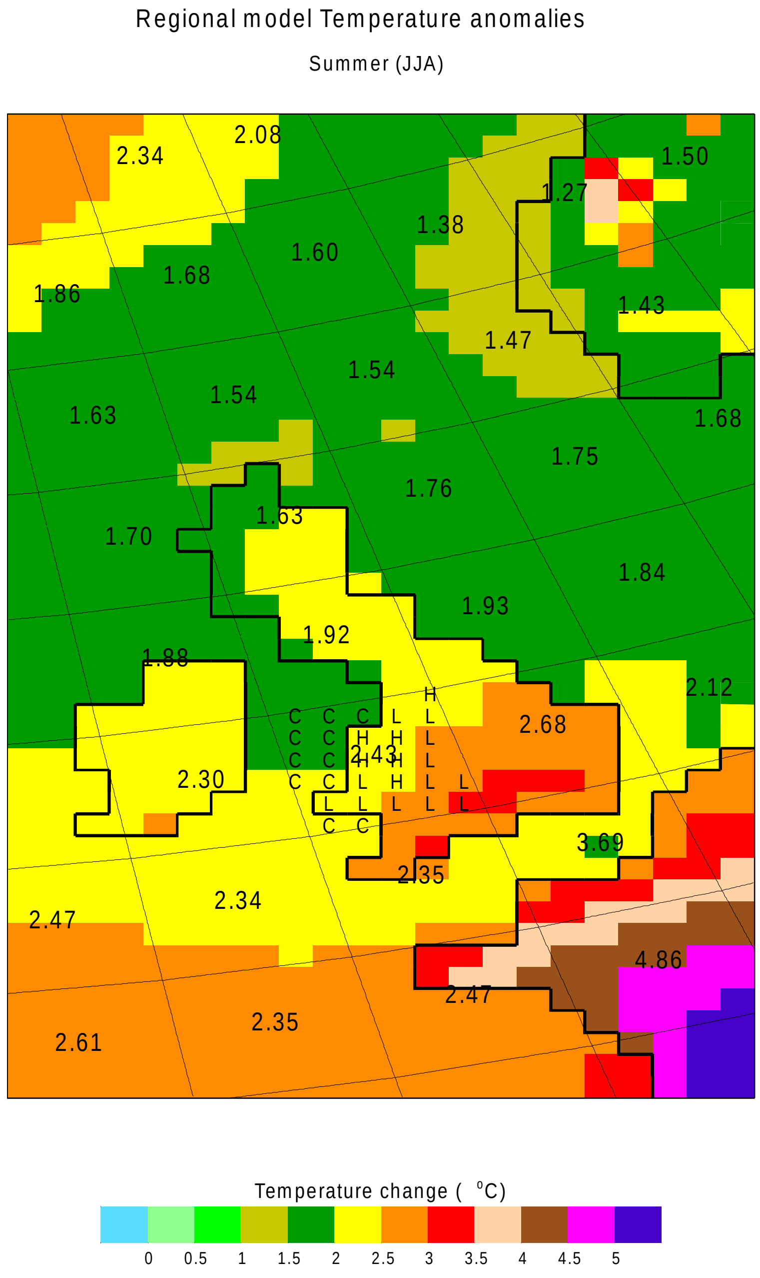


Figure 6: *Change in mean summer temperature over the British Isles by 2080-2100 relative to 1961-90 for the* ***Medium-high*** *UKCIP98 scenario. The bold black numbers are derived from the GCM, while the coloured changes are extracted from the RCM. The superimposed letters over Wales (C, L and H) show the categorisation of the RCM land cells into 'coastal', 'lowland' and 'highland'. See text for further explanation.*

The importance of the coastal influence is greater, however, as shown in Figure 6. This shows the change in mean summer temperature across the British Isles in the RCM experiment, with the changes from the GCM superimposed. The gradient of summer temperature change across Wales is clearly one from west (2-2.5 ºC) to east (3-3.5 ºC), a gradient that would appear strongly related to the continental character of the local climate. It is interesting to note, however, that this gradient is crudely captured by the GCM - warming over Ireland in the GCM is 2.3 ºC and over eastern England is 2.7ºC.

Figure 5 also marks the location of the seasonal anomalies of the analogue years we identified in Section 1. This therefore compares the magnitude of these recent observed seasonal anomalies (e.g. summer of 1995) with the 20-year mean climate changes anticipated for the period 2080-2100 under the **Medium-high** UKCIP98 scenario. Comparison is not strictly valid between individual year anomalies and 20-year mean climate anomalies, but it serves to highlight the much larger annual variability of current precipitation than of temperature relative to our climate change scenarios. The wet winter of 1994/95 (+65 per cent) was very much wetter than the mean changes in winter precipitation simulated by the models, whereas the hot summer of 1995 (+2.1ºC) is roughly comparable to the mean 2080-2100 change in summer temperature.

Does the RCM Yield Further Insights that the GCM cannot Satisfactorily Resolve?

2.4.2 Changes in annual climate variability

Here, we compare the response of the GCM and RCM to greenhouse gas forcing on the annual time-scale rather than the seasonal-mean responses examined in the previous section. Figures 7 and 8 present these results, in each case for annual climate, followed by winter and summer climates. In all cases, the yearly/seasonal climate anomalies are shown with respect to average 1961-90 climate.

The year-to-year variations in annual temperature anomalies for the 20 years at the end of the century as simulated by the GCM (solid black line) and RCM (coloured lines) are shown in Figure 7. As with Figure 5, the RCM response curves are colour-coded to separate ocean, lowland and highland responses. With just one or two exceptions, the RCM anomalies follow the GCM domain-average anomalies very closely. Particularly warm years in the future (e.g. 2090) are warm in both GCM (+3.4ºC) and RCM (+3.2ºC), while less warm years in the future (e.g. 2087) are also less warm in both models. This high degree of consistency between the two models is due to the large-scale boundary conditions extracted from the GCM that constrain the RCM response at the regional scale. The exceptions tend to occur in winter. For example, the 2084 winter is predicted to be particularly warm by the GCM (+5ºC), but very much less so in the RCM (+2.5ºC). Such inconsistencies in response between the GCM and RCM warrant further investigation. In any given year the maximum sub-regional variability over land in annual temperature anomaly is about ±0.5ºC (e.g. 2098). In many years, however, the sub-regional variability in the annual temperature anomaly over land is much less (e.g. 2092 it is only ±0.1ºC). As noted above, the temperature response over the ocean surface surrounding Wales is rather less (a few tenths of a degree C) than over land. Figure 8 shows the equivalent information for precipitation. Future precipitation changes - whether annual or seasonal - are not as large as the temperature changes in relation to natural climate variability. Although there is a clear tendency in both GCM and RCM for wetter winters and drier summers (and again on a year-to-year basis the GCM and RCM anomalies agree very well over land areas) over Wales, occasional dry winters (e.g. 2093) and wet summers (e.g. 2086) still occur at the end of next century. Also marked on Figures 7 and 8 are the analogue years and seasons that were mentioned in Section 1. For annual temperature, all years between 2080-2099 are warmer than the 1995 analogue year (at least for this UKCIP98 **Medium-high** scenario), although this is not always the case for winter and summer temperature. For precipitation, the much greater natural climate variability of annual or seasonal totals becomes apparent, since the analogue years generally fall at the outer extremes of the regional climate change responses (Figure 8).

2.4.3 Changes in daily precipitation intensities

How different between the GCM and RCM is the response of regional and sub-regional climate in terms of *daily* climate variables such as precipitation intensity and wind speed? Such analysis of daily variables is beyond the scope of this preliminary exploration, but comments are made which draw upon other recent work. When the RCM is used to simulate present-day climate it generates characteristics of daily precipitation that are more similar to those observed than does a GCM (Durman *et al*., in prep.). When *changes* in daily precipitation characteristics are examined, however, the relative increase in the frequencies of the most intense events are quite similar between the GCM and the RCM. This conclusion only applies when thresholds used to define intense events (e.g. events that occur on average once-in-a-hundred wet days) are calculated with respect to the particular model characteristics - hence the use of the term *relative* increase. This suggests that the extremes of the daily precipitation distributions in the two models are changing in a qualitatively similar way despite their different spatial resolutions. This opens up the possibility that changes in such extreme events *can* be extracted from GCM experiments and applied, with care, to sub-regional domains. The analysis also suggested that the most intense daily precipitation events increase over the UK by about 50 per cent in summer and by 150 per cent in winter, by the 2080-2099 period under the UKCIP98 **Medium-High** scenario. Similar analysis has not yet been performed for daily mean or daily extreme wind speeds but would be informative.

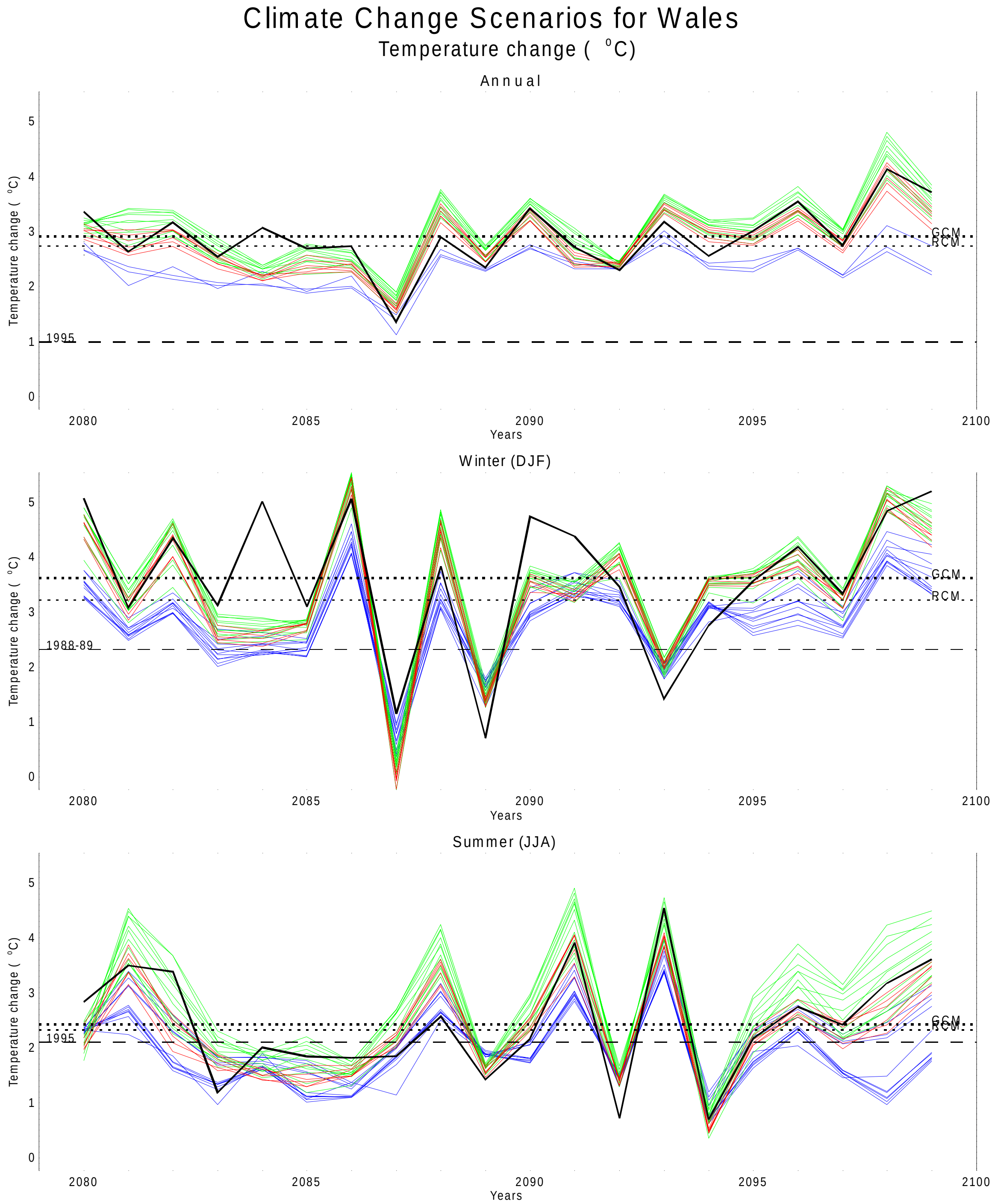


Figure 7: *Comparison of the GCM and RCM for annual temperature anomalies. Solid black line: GCM, coloured lines: RCM coded as for figure 5 to separate ocean, lowland and highland responses for individual RCM cells.*

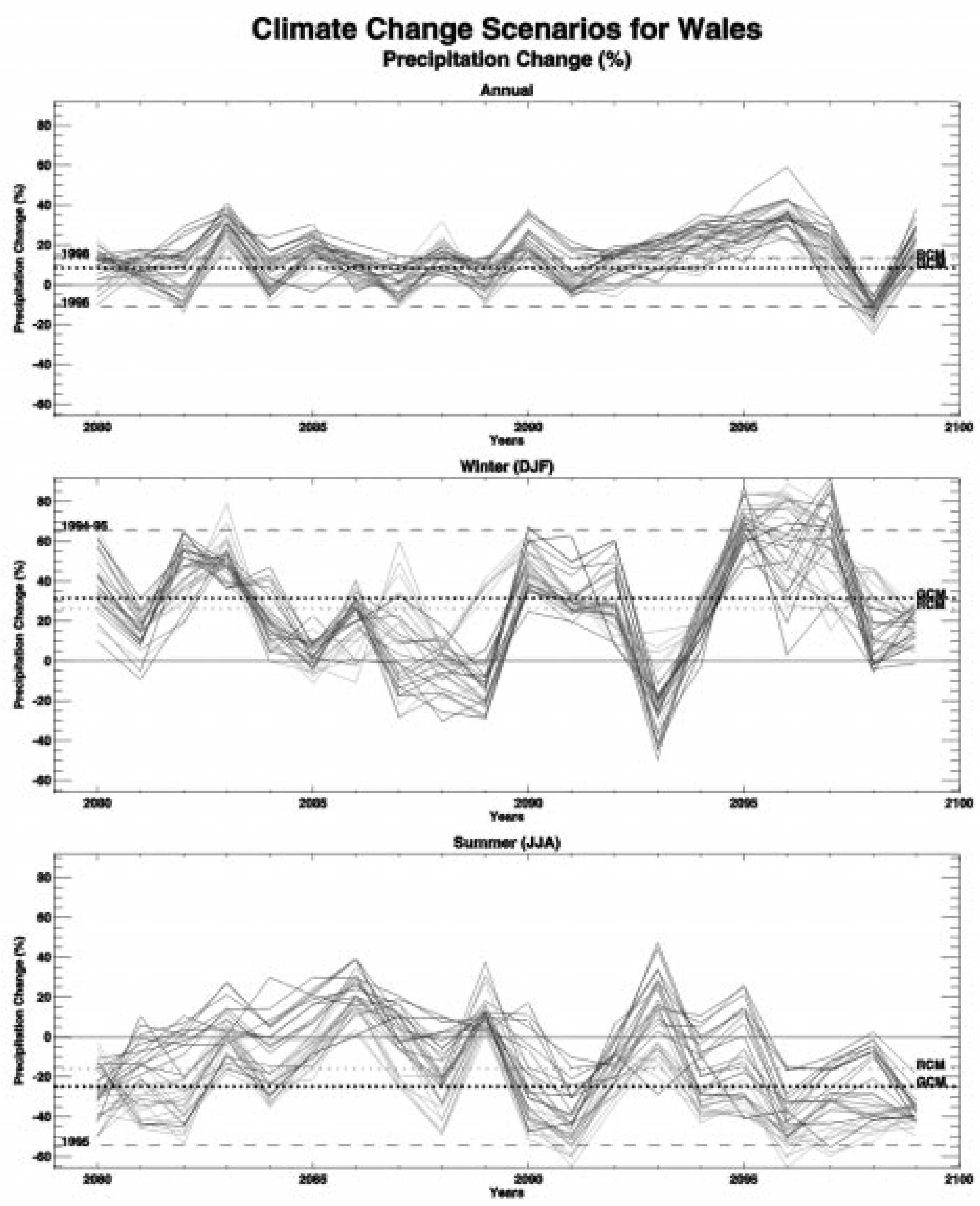


Figure 8: *Comparison of the GCM and RCM for annual precipitation anomalies. Solid black line: GCM, coloured lines: RCM coded as for figure 5 to separate ocean, lowland and highland responses for individual RCM cells.*

2.4.4 Summary

We have examined whether climate change scenarios for Wales derived from the GCM-based UKCIP98 scenarios are substantially modified when higher resolution information from a Regional Climate Model is examined. In particular we have investigated whether the regional-average climate response in the GCM and the RCM is different and whether there are large sub-regional differences in climate response to greenhouse gas forcing across Wales. We conclude that the use of a RCM to simulate future climate change over an area like Wales does not introduce a *fundamentally* different response of these variables to greenhouse gas forcing compared to that simulated by a GCM. The comparison does suggest, however, some rather small systematic differences in the climate response to greenhouse gas forcing between the ocean areas surrounding Wales and the land domain, and also some modest sub-regional differences over land in the mean seasonal response.

For temperature, a GCM simulation for Wales represents the mean climate change of any 50 km RCM cell to within ±0.3 ºC, and for precipitation to within ±8 per cent. These orders of magnitude are not large in relation to other uncertainties in future climate change scenarios that stem from uncertain forcings, from differences between different GCMs, and from differences induced by natural internal climate variability (Hulme and Carter, 1999). On a year-to-year basis the difference between the domain-average response for Wales and the sub-regional response may reach ±0.8 ºC for summer temperature and ±15 per cent for summer precipitation

2.5 Recommendations

Regional models for the future climate of Wales (such as Had RM2) need to be developed and evaluated as (a) its climate is so variable and (b) the possible east-west gradient in climatic change needs to be tested.

More research is needed on (a) the daily climate variables especially precipitation and windspeed and (b) prediction of extreme events, necessitating the refinement of current, or development of new, models.

Further work to assess storminess changes on the Welsh coastline is required to assess the levels of risk to which different parts of the coastline are exposed.

The inevitable uncertainty in model predictions needs to be better communicated to users and public.

3. IMPACTS OF CLIMATE CHANGE UPON THE NATURAL AND CULTURAL HABITAT AND HEALTH

3.1 Flood Defence and Coastal Protection

3.1.1 Need for flood defence and coastal protection

As a result of the geology of Wales and the relative inaccessibility of central Wales, most of the population and industrial development is in the coastal zone. Most of the major towns are coastal, *e.g.* Cardiff, Swansea, Aberystwyth, and Bangor. There is also a sizeable seasonal population due to the number of tourists who visit the coastal areas. Most industry in Wales is located on the coastal zone, *e.g.* the oil refineries of Milford Haven, steel and chemical works at Port Talbot, aluminium works at Holyhead. Some such as the nuclear power station Wylfa, on the coast of Anglesey, are located on cliffs, and are not at risk from flooding; others, such as the port facilities at Holyhead and Milford Haven, are lower-lying. Large parts of the coast of Wales are designated conservation areas, for example:

Sites of Special Scientific Interest (SSSI), *e.g.* the Mawddach estuary; some SSSIs are also:
Special Protection Areas (SPA), *e.g.* the Dee and Severn estuaries, the Burry Inlet - for birds, waders, *etc.*
Marine Nature Reserves (MNR), *e.g.* Skomer.
Ramsar sites, *e.g.* Dovey estuary - for wetlands conservation.
Geological Conservation Review Site, *e.g.* Newborough Warren - for its coastal geomorphology

Coasts are highly dynamic areas of erosion and accretion with ever changing boundaries and they are still not fully understood. Wales has about 1300 km of coastline. Most is ancient coastline with some 45% comprising hard rock cliffs and has withstood the tests of time. Many parts of the lower lying Welsh coast have natural sea defences, such as salt marshes and sand dunes. These natural defences move and adapt to gradual changes and will continue to do so, unless 'unnatural' barriers impede them. Cliff falls in 1999 include those on the Lleyn (Pared yr Henborth) and at St Govan's Head, Pembroke. Rises in sea level threaten low-lying land and accelerate coastal erosion.

3.1.2 Direct Effects of Climate Change on the Coast

The major effects of climate change for coastal areas of Wales are from:

- increased storm frequency and storm surge events
- elevated sea temperatures (Havard – why delete this? it fits in a broad definition of coastal protection and is not dealt with elsewhere. Protection isn't only blocks of concrete!)
- sea level rise
- the North Atlantic Oscillation (NAO)

The overall impacts of these factors are still largely unknown. The difficulty is the unpredictable nature of some of the events, especially changes in rainfall patterns and severe storm events. Individual effects, such as increases in storm events, sea level rise, and elevated sea temperatures, have been studied, but there is much uncertainty in the estimations of these changes. It is, however, the combination effect that will cause the most change. Sea level rise will move the dramatic effects of storms *etc*. further up the shore. It is possible to identify vulnerable areas, those most at risk from different impacts, but without more precise data the full risk cannot be assessed. A better understanding of the dynamics of coastal regions is needed.

Better information, *e.g.* accurate Digital Elevation Model (DEM) data, is needed to identify the extent of areas most at risk more precisely. The Environment Agency has completed accurate digital elevation models using LIDAR for some susceptible parts of the Welsh coast: Wye to Cardiff Bay, and Kenfig to Margam, with further work planned for Swansea and South Pembrokeshire. Mid- and north Wales are not covered. However, many parts of the Welsh coast are low-lying; figure 9 shows a map of Wales with the regions estimated to lie 0-1, and 1-5, m above sea-level. The development of Shoreline Management Plans is a critical part of the assessment of the impacts of climate change on the coast of Wales. Wales is producing Shoreline Management Plans (SMP) with maps showing the different regions of interests (see below), although these do not address all impacts of climate change. With the inventories of the UK estuaries and the survey data from the Marine Nature Conservation review, assessment of the conservation areas at risk from the impacts of climate change on the coast of Wales will be possible. Assessment of risk is crucial - where is at risk and who or what is going to be affected. Management strategies to reduce risks to the coast of Wales are needed *e.g.* by avoiding new developments (housing, industry) in low-lying coastal areas, and where appropriate by encouraging the use of natural defences not hard sea defences. The option of using natural defences alone may result in a coast which has altered greatly, but which is less liable to sudden changes.

Increased storm frequency and storm surge events

Severe wind events (storms) are increasing in both frequency and severity. Most of the Welsh coastline experiences winds of greater than 3.5 m s^{-1} for 75 % of the time. South westerly winds dominate and most gales occur in winter, when the wave height of 1.5 m can be exceeded for more than 10 % of the time. The period from 1988-1997 had the highest frequency of severe gales since records began (UKCIP, 1998). It is predicted that by 2050 Wales and southern England will suffer a 30 % increase in gales (CCIRG, 1996).

With a tidal range from 6 m to more than 10 m (see 2.3), increased heights of storm surge may significantly increase the risk of flooding. The current 50-year storm surge can cause over 1.5 m rise in tidal height, the highest surges being in the east (Pugh 1987). Tidal flow in many regions is sufficient to move sediment, causing changes in bedforms and transporting sand along the coast, so the nature of the coastline is continually changing, as is the natural protection afforded by beaches. A series of storms the first of which reduce beach levelsand leave defences vulnerable to later storms can be particularly damaging.

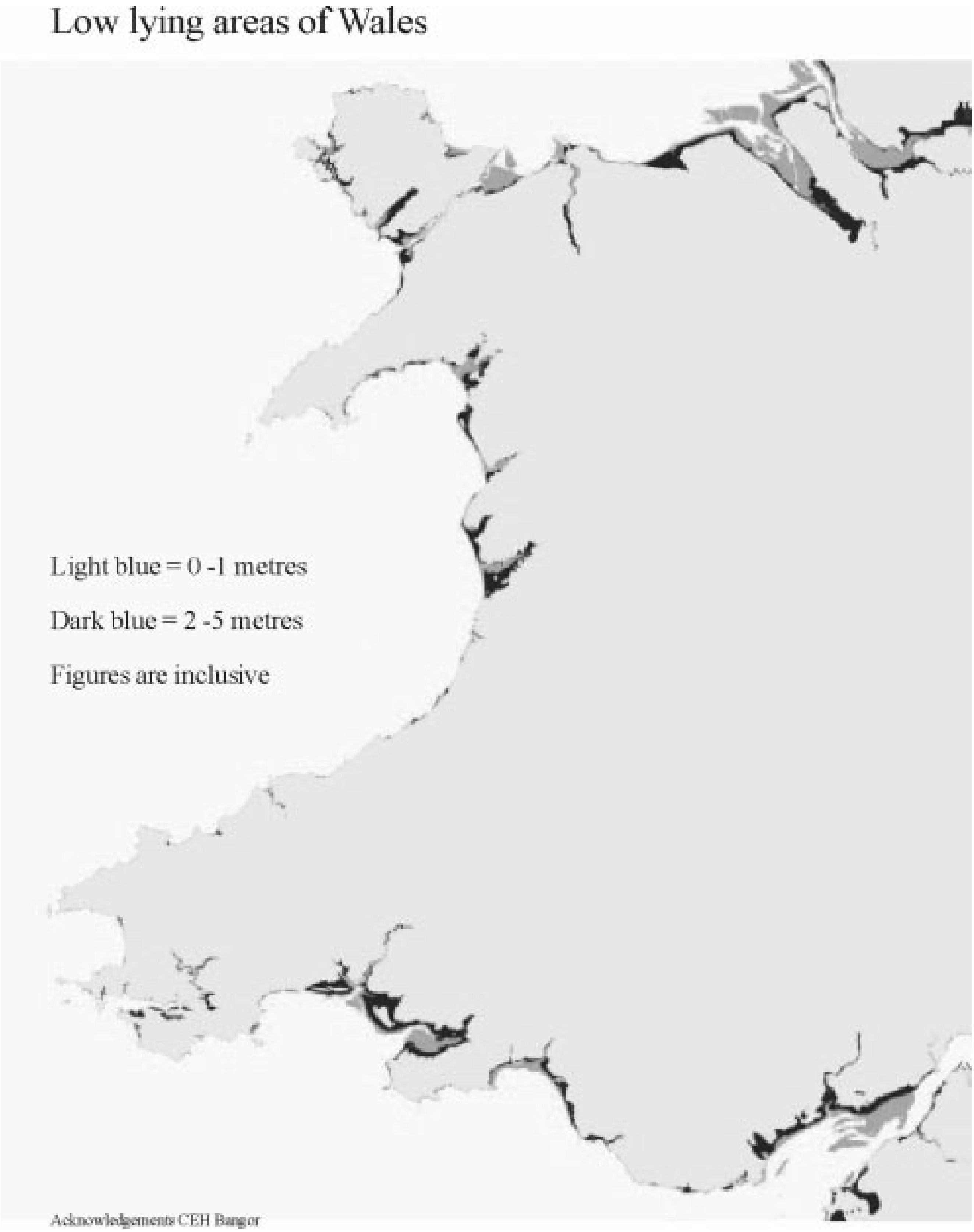


Figure 9: *Map of Wales with the regions estimated to lie 0-1, and 1-5, m above sea-level*

Sea level rise

Global sea level rises are attributed to climatic factors which result in thermal expansion of the oceans, and themelting of glaciers, small ice caps and ice sheets

As described in Section 2.3, the UKCIP scenarios (UKCIP, 1998) estimate climate-induced sea level rise to be 12-67 cm by 2050 compared with the average 1961-1990 levels. Combining the climate-induced sea level rise with isostatic rebound leads to the estimated net sea level rise from average 1961-1990 levels by 2050 to be in the range 26.5-35.5 cm, based on the **Medium-high** scenario; the **High** scenario predicts up to 79 cm. Since 1991, the National Rivers Authority (formerly) and now the Environment Agency has adopted the guideline of allowing for 5 mm/year sea level rise in the design of coastal defences in Wales, which is within the predictions of the Medium-high, but not the High, scenario.

Increased rainfall

Historic climate data for the UK confirm that winters are becoming wetter. Precipitation is increasing for both the north and south of the UK in winter and in summer for the north. Increases of 3-5 % on an annual basis have been estimated for Wales by the 2050s (Hulme, 1999), but with winter precipitation increasing by 7-15% (see Section 2.3). Increased rainfall will in turn increase the flow of rivers, and can lead to inland flooding. When a flood and a high tide coincide there is a rise in water levels due to a backwater effect in the area of tidal limit, with implications for river defence. At low tide, this backwater effect can extend downstream when a river is in flood, but since the water levels are lower, there is no flood risk.

The North Atlantic Oscillation (NAO)

The North Atlantic Oscillation is the result of changes in the westerly wind flow causing a disturbance of the atmospheric circulation and of the climate of the North Atlantic European area (see Section 2.3). In terms of risk of coastal flooding, the main factor is that the NAO will change the tracking of storms across Wales, leading to an increase in the number of storm surges. The extent of the effects of the NAO on climate change is not fully understood and is currently being investigated.

3.1.3 Coastal Protection and Flood Defence

Much of the Welsh coast is hard rock which reduces the need for coastal protection, though sea defences have often been built to protect settlements, industry, historical sites, rail and road networks. Coastal protection is important even though much of the Welsh coastline is rocky. For example, cliff falls in Pembrokeshire in 1999 were associated with high waters and storm. Sea and flood defences are common around low-lying estuaries and inlets, and in areas where intertidal land has been reclaimed from the sea for building or agriculture.

About 30% of the Welsh coastline is protected by some 380 km of artificial coastal defences. 240 km protect primarily against erosion (coastal protection) and 140 km protect primarily against flooding (sea defence) based on flood walls and embankments. Most estuary defences are included in the coastal defence category eg Dee up to Flint, Dyfi up to Dyfi Bridge. The Environment Agency maintains 95 km of these flood walls and embankments (sea defence). Some 83 km of coastal defences which protect against erosion have a secondary flood defence function against wave over-topping. As a result, the total length of sea defences against flooding is 223 km. In many cases defences on private land are maintained by the Environment Agency and local authorities.

The National Assembly for Wales has responsibility for policy on flood defence and coast protection, and for coordinating the response to river, sea and tidal flooding emergencies in Wales. The Assembly also provides grants to operating authorities for new and improved flood warning systems and flood and coastal defence measures. The Environment Agency is responsible for all flood defence matters through the Water Resources Act 1991. The Agency exercises general supervision over all matters relating to flood defence and undertakes measures to reduce the risks of flooding from the sea and designated main rivers. On coast protection and flood defence on non-main rivers, powers rest with local authorities except in specified districts with special drainage needs, where Internal Drainage Boards have powers for flood defence and sea defence. MAFF has responsibilities in England and works closely with the EA. The division of responsibilities presents some confusion to the public in knowing who is responsible for flood and coastal defence in their areas. Better coordination of information would help to clarify the position.

Coastal management has a number of components: Shoreline Management Plans (SMPs), Coastal Defence Strategy plans, Harbour or Estuary Management Plans, and Local Environment Agency Plans (LEAPs). SMPs explicitly explore the 4 main options for shoreline management (Shoreline Management Plans - A Guide for Coastal Defence Authorities MAFF, WO, Association of District Councils, English Nature, National River Authority, 1995)

- hold the existing line
- advance the existing line
- retreat the line
- do nothing

SMPs set out the strategy for coastal defence taking account of coastal processes, coastal defences, land use and the human and built environment, and the natural environment. The Plans assess a range of strategic coastal defence options in coming to a preferred approach, and outline the future needs for monitoring, data management and research. The Plans also inform coastal planning and identify opportunities for maintaining and enhancing the natural coastal environment. The Plans are working documents which look forward at least 50 years and are reviewed every 5 years. The coastline of Wales and England has been divided into 11 sediment cells, defined as lengths of coastline which are relatively self contained as far as the movement of sand and shingle is concerned. The major cells for Wales are (i) Severn Estuary to St David's Head, (ii) St David's Head to Bardsey Sound, (iii) Bardsey Sound to Great Orme and (iv) Great Orme to Solway Firth.

All defences will be vulnerable to climate change. Since 1991, the guidelines for global warming and land level adjustment have been to allow for 5 mm/year rise in relative sea level rise in the design of coastal defences in Wales (Strategy for Flood and Coastal Defence in England and Wales MAFF/WO 1993). The major risk of flooding will not be the result of sea level rise or storm surges alone, but a combination of events, such as seen at Towyn, Clwyd, in February 1990, when a 467 m length of the sea defences were breached by a combination of a storm surge of 1.3 m, high tide and 4.5 m high waves. Floods covered 10 square kilometres with a maximum depth of 1.8 m; power to sewage pumping stations was lost so the flood waters were contaminated. 2800 properties were affected and over 5000 people evacuated. 6% of households had no property, and 38% no contents, insurance; the total cost was estimated at £35 million(Roe 1990). The conditions producing this flooding would return every 500-1000years – with our current climate. (JNCC, 1996; Roe, 1990).

There is a conflict of interests between the natural sea defences, which benefit the landscape and the wildlife allowing them to find their own manner of adjustment to change, and man. For people, especially those already living on the coast, natural protection is not always an option and man-made sea defences are needed to protect housing, industry *etc*. Natural defences can only work if they are able to migrate inland, and so may not provide the degree of security required. Where they reach areas where man-made structures will stop them, then the natural defences, *e.g.* beaches, sand dune, salt marsh, will be lost. Artificial defences also need careful assessment to ensure that they do not move the problem along the coast and cause more damage, *e.g.* sea walls can protect the area behind them, but may also accelerate beach erosion, which in turn can result in an increase in wave action.

River Basins

The Environment Agency has powers to undertake flood defence works along 3,932 km of larger watercourses (main rivers). On smaller rivers, responsibility rests with local authorities, except where there are internal drainage districts where Internal Drainage Boards are responsible. Flood risk follows heavy rain and is dependent on the capacity of drains and sewer systems as well as river defences.

The low-lying estuaries of the Neath, Loughor, Taf and Towy are all subject to flood risk (JNCC, 1995), as are the three large catchment basins from the rivers Dee, Severn and Wye. As sea levels rise the distance of tidal reach into estuaries increases and salt water can threaten freshwater environments and aquifers. (No this does not result in flood risks) On 8 and 9 April 1998 heavy rain caused rivers to overflow in England and Wales. Talgarth, on the Afon Ennig, was badly flooded for the first time. Damage, mainly in England, was estimated to be £350 million. This event would recur every 20 – 170 years with our current climate. Heavy rain and the consequent water flows may also cause increased soil erosion. Flooding can cause sewers to overflow, with a consequent rfeduction in river water quality and health hazard, such as at Aberfraw in 1998.

Flood risks can be managed by a combination of hard defences, planning restrictions, and flood warning systems. The former may themselves be destructive of environments valued for other reasons, such as archaeological or biodiversity, whether they concern walls and embankments or maintain river channels.

3.1.4 Findings from stakeholder consultation

Overview

The stakeholders were generally well informed about climate change and many of its impacts. Those of particular importance related to rising sea levels, changes in the storm characteristics and the need to plan for future flooding events. The major impediments to dealing with such impacts were perceived to be more political than technical, and most stakeholders were optimistic that feasible solutions were available. A need for better and more certain predictions was identified, and it was unclear from where finance would be derived in order to fund any necessary engineering works.

Quotes:

‘We are trying to define future floodplains in order to plan development on the flood plain.’

‘It is not top of the list, sustainability, biodiversity and general land use matters probably take precedence. This is because of the perceived lack of major impact of climate change.’

‘There is a conflict with conservationists. For example they call for water levels to be raised to restore habitat but this can interfere with drainage functions for flood defence.’

‘Attitudes, especially among local politicians, are a problem. Our politicians are more interested in parochial matters, there is a lack of understanding and a lack of appreciation of what these issues can ultimately lead to.’

‘We would build better defences and deter building on the flood plain. Last programme of work we started in the 1950s and finished in 1975, we have gone 9 years now since the Towyn disaster and we have done a certain amount but it will take us another 10-15 years to bring it up to the standard we have set ourselves, unless there is more urgency and awareness among people who have greater influence on decisions than we have.’

Understanding of climate change and reaction to existing impacts

There was a generally good understanding of climate change, its causes and consequencesInformation was gained from the general press, newspapers, magazines, radio/ TV and technical reports, The Environment Agency, planning authorities and investors were useful sources of information. All stakeholders discussed rising sea levels and they were concerned that rising sea levels would lead to an increase in flooding of coastal areas and flood plains; most knew that it was not the rise in sea level which would pose the biggest single threat, but the storm effects.. There was some confusion as to the actual values, *e.g.* of predicted increases in sea level, but the information sources available to the stakeholders (mainly the media) and the scientific literature give a variety of values. The need to review flood defences and to assess risk, and examine the possibility of managed retreat was considered important. The evidence linking recent weather events to climate change was considered to be anecdotal and lacking in rigorous analysis. The stakeholders knew that these changes will have significant impacts on themselves personally and on their business activities.

The activities of some stakeholders had been affected by the Easter floods of 1998. Most stakeholders felt that their activities could be affected by changing weather. The areas of activity that could be affected included:

- Changes in sea level need to be taken into account for flood defences, current practice may need to be reviewed.
- Extra work in dealing with flood events and helping people in areas affected.
- Groynes need to be aligned in the optimum position for storms and surges, and the prevailing direction of future storms needed to be determined.

Reaction to potential impacts
Examples of impacts that would arise from the climate change predictions included:

- a need to review flood plain delimitation and land drainage functions.
- problems with sewerage systems and increased operation of storm overflows
- increased surges on top of sea level rise will put great pressure on sea defences.
- a clarification of predictions and subsequent review of flood defences
- the need to install new defences in areas, where they have not been required.

On measures to avoid or reduce impacts, apart from emissions reductions, stakeholders considered it important to review policies with respect to flood plain development, and attempt to locate new developments, roads and railways away from areas of flood risk. There was surprise at the concentration of rainfall in the winter and concern about flash floods. It was considered that the Environment Agency needed to reduce runoff from new developments, for example, through adoption of source control techniques, and more could be done.

All stakeholders felt finance would be a big barrier to any adaptation, because of the large amounts of money needed to deal with impacts. Measures would require a fair amount of political persuasion to provide the financial resources. Uncertainty was seen as a particular barrier preventing proactive measures. Despite these problems some of the stakeholders felt they could react quite quickly, i.e. in 4-10 years. Corporate planning horizons, and the planning system, dictated the time to respond. Although the physical building of defences could be done quickly the planning processes were very slow, with decisions no longer being made locally by those fully aware of the risks and potential impacts. The option of adaptation through changing site was not usually applicable to land use planning. Even so, many housing allocations are quite long standing and would be difficult to move without very strong evidence of a flood threat. More money spent on sea defence was thought to be better than putting the money into warning and prediction services as flooding is so fast. .

On direct opportunities or benefits arising from these changes, it was felt that there might be an increase in tourism. This could have effects on beach safety with higher numbers of summer visitors. Extension of the tourist season into winter might put a higher population at threat from flooding.

Long term planning
Stakeholders were governed by different factors in their planning as follows:

- Business and environmental issues, but not specifically climate change.
- Land use planning
- Flood risk with respect to planning applications, including planning for road and rail network.
- Currently plan for a 5 mm rise in sea level per year when designing flood defences.
- Currently developing a shoreline management plan.
- Plans also take into account financial, sustainability, biodiversity, and land use issues.
- Corporate planning process covers flood defence, abstraction, water quality, release of greenhouse gases from industrial and landfill sites
- A potential conflict with conservation issues was identified

Their planning horizons, particularly for corporate planning, tended to be 4-5 years. Other plans varied as follows:

- For land use planning currently look to 2011
- In terms of revenue planning the horizon is 5-10 years ahead.
- For coastal protection the shoreline management plans have a 50 year perspective and are reviewed every 5 years. Any coastal works or flood protection works normally have a design life of 50 years.
- For flood defence, plans are based on 5-10 year work programmes, with defences planned for a 50 year life but plans are often thrown into disarray by particular events, so tend to be reactive. Generally work to 1 in 100 year flood event and a 1 in 200 year event on the coast where it is economically justified.

All stakeholders thought future weather conditions featured in their planning to some extent although this tended not to be a high priority. Because predictions of the degree of change are uncertain and imprecise, planning is difficult. Measures taken were as follows:

- Discussions with the various agencies about flood defence measures and delimitation of the flood plain on all of the main rivers.
- Flood defences are now constructed to allow a 5 mm increase in sea level year on year and are also constructed in a manner which allows them to be raised if need be.

All stakeholders said they had strategic/emergency/contingency plans in place for climate-related emergencies Those mentioned were included Emergency Flood Plans, Flood Prevention Plan, Flood warning dissemination plan, and individual site emergency plans.

Needs in relation to climate change

The main point was the need for greater certainty in relation to the climate change impacts to influence stakeholders to take action, particularly in complex coastal areas such as Carmarthenshire. Stakeholders felt financial help would be required in order to help them adapt to any future changes. These could be in the form of incentives to private industry and increased funding of flood defence works. . Some felt that the technical knowledge on dealing with impacts and climatology was good. It was generally agreed that the Environment Agency should hold the information on climate change but that initially it must come from central government. The major problem identified was that Government information needs to be more accessible to influence current practices, especially where development is involved. Government documents were felt to be outdated and better estimates of climate change should be widely available.

Stakeholders thought financial support should come from central government, particularly for capital works. Funding for flood defence is complex and it was felt that the Flood Defence Committees in Wales didn't always receive all the funding due to them. In addition it was felt that central guidance on the need for planning for climate change was essential. Whereas the guidance with regard to flooding was in place, the problem now is more to do with confidence in the prediction scenarios and the political nature of the planning process.

The stakeholders thought they could contribute to the overall adaptation process in Wales through the provision of professional expertise and data. Resources to inform and influence were essential to aid these processes.

3.1.5 Recommendations

1. Better information, *e.g.* accurate Digital Elevation Model (DEM) data, is needed to identify more precisely the extent of coastal areas most at risk from flooding.
2. Further work to monitor and assess the effects of increased storminess on the Welsh coastline is required.
3. Government needs to clarify responsibility for flood and coastal defence which is at present distributed between a range of bodies
4. The Assembly needs to take account of the likely impacts of climate change in revising planning guidance (Technical Advice Notes) in areas potentially susceptible to flooding and coastal erosion.
5. Sectors which might be affected by flood defence measures, such as archaeology and biodiversity, need to be involved at all stages in the planning of defences.

3.2 Ecological impacts

3.2.1 Terrestrial habitats

Climate change is probably already having a substantial effect on biodiversity in Wales, due to both direct and indirect impacts. Changes are indeed occurring in the UK as a whole as indicated by changes in the timing of appearance, spatial distribution and breeding success of well recorded biota such as birds, butterflies and moths, for which there are good long-term data (Cannell *et al.,* 1999). The number of Welsh data contributing to these UK figures is small and specifically Welsh data sets are scarce and mostly local. However, records such as those for insects collected over more than 40 years by the late Mrs Joan Morgan of Bangor (now archived in the National Museum of Wales, Cardiff), and the long-term bird migration records from Bardsey Island and other

Welsh observatories could be used to confirm or otherwise the UK data for earlier arrival of summer migrant birds such as Swallow, and emergence of spring-flying butterflies such as the Orange Tip. Depending on the nature and rate of climate change, some habitats and species are likely to be favoured or unaffected, others are likely to be affected adversely. The interactions between species competing in changing climates which favour some species more than others are likely to have profound effects on the outcomes. A major study, MONARCH, is currently addressing biodiversity underway in the UK and Ireland, and will report in December 2000; a study by ADAS has recently appeared (ADAS 2000; DETR/MAFF Review of Biodiversity).

The climate changes predicted by the University of East Anglia as part of this review suggest a move towards a more Mediterranean climate with wetter, milder winters and drier, hotter summers. Even their best case prediction of 1 ^{o}C warming over the coming century for Wales is three times greater than the rise recorded this century, whilst the worst case envisages a 3 ^{o}C rise. In the best case situation there would probably be an acceleration of the current changes in biodiversity favouring the spread northwards of species whose current centre of distribution is further south in Europe. If the worst case scenario applies it is extremely difficult to predict what changes might take place as a range of interacting factors are likely to be amplified. It is certain, however, that if increasing temperature leads to substantial sea level rise this will have a major impact on coastal and estuarine habitats and species in Wales which are of national (UK) and in some cases international importance. However, the extent of this impact will vary in different parts of Wales due to isostatic adjustment (see sections 2, 3).

Wales is a land of contrasts with an upland core, which divides the wet and windy west from the drier and more sheltered east. In some places in the west (North- and Mid-Wales, Lleyn Peninsula) the uplands, which are predominantly covered by semi-natural vegetation, reach almost to the coast, there being only a narrow coastal belt of more fertile, agriculturally improved land. In other parts (SW and SE Wales) there is a much wider band of richer agricultural lowland. The land to the east of the upland core on the English border has a different feel to that in the west, the fertile soils and drier climate allowing the cultivation of arable crops as well as grass. The effects of climate change on biodiversity are likely to vary between the uplands and lowlands and perhaps between the western and eastern parts of Wales.

Lowland ecosystems

The ecosystems of much of the Welsh lowlands have been modified by agriculture. In South and Northeast Wales urbanisation has affected significant areas. Semi-natural ecosystems survive, especially around the coast (sand dunes, salt marshes, sea cliffs) and on inland sites of low agricultural value (lowland bogs, lakes, steep valley-side woodlands) or which have not been swallowed up in urban development. The coastal habitats, especially those associated with offshore sand banks and salt marshes (e.g. Lavan Sands, Llanrhidian Marsh), sand dunes (Kenfig dunes, Morfa Harlech), and estuaries (Dee, Severn) are in many cases very vulnerable to sea level rise, especially if it is rapid and associated with increased storminess. In some places there may be opportunities for managed retreat leading to replacement of lost habitats, but in others this will not be an option. It is important to determine the potential for and cost of such managed retreat on a regional basis. It is also necessary to identify the terrestrial habitats that would be lost should managed retreat take place. In some instances they may be as or more important for conservation of biodiversity as the coastal ecosystems which replace them.

Inland semi-natural lowland ecosystems are generally likely to be less vulnerable to climate change than coastal ecosystems. However, wetlands such as the internationally important raised bogs at Cors Erdrreiniog on Anglesey and Cors Tregaron in mid-Wales are exceptions. Their ecological characteristics and contribution to biodiversity depend primarily on retaining year-round water saturation. This may be compromised by hotter, drier summers, and especially by droughts, which are predicted to become more frequent. The predicted wetter winters are unlikely to offset the damaging effects of drought significantly and existing management to counteract the effects of past drainage may need to be enhanced to cope with the extra drought stress. Similarly, more resources may need to be devoted to supplementing low river flows in drought years from stored sources. This could give rise to conflict when deciding where to site the new reservoirs or which existing reservoirs to enlarge. It should also be noted that very little is known about the effects of increasing temperature on nutrient dynamics in soils and waters. If these effects are large there could be substantial ecological changes due to nutrient enrichment of a wide range of habitats.

It might be expected that climate change will influence breeding patterns and success and distribution of both native and exotic flora and fauna. Native species which are currently at the northern or western limits of their ranges in South Wales (e.g. Dormouse, Nightingale, Mistletoe) may spread north and west. Exotic species from warmer climes, such as the invasive wild rhododendron which is already having a major adverse impact on native broadleaved woodlands in Wales, and Himalayan balsam which excludes native vegetation along lowland watercourses, may spread more widely requiring even more resources for their control. Native species with a northern distribution in the British Isles and which currently reach their southern limits in Wales (e.g. Arctic Char, Northern footman moth, Bird cherry), may be sensitive to climate warming and become less fitted and could become extinct in Wales

However, the extent to which factors associated with climate change, notably increasing temperature, affect the current distribution of species, as compared with the effects of other environmental factors (e.g. habitat loss, acidification, eutrophication) and intrinsic effects (e.g. geology and soils, limited gene pool, disease) is poorly understood. The pattern and rate of species migration may, for example, be strongly influenced by landscape-scale patterns of habitat distribution. Habitat fragmentation and isolation are likely to be of key importance, but we know little or nothing about their effects on most species. Thus, while we may be reasonably confident that artificial barriers such as cultivated arable land or urbanised land will form effective barriers to the migration of many species associated with semi-natural habitats, we have little knowledge of which species will be affected most seriously and why.

Upland ecosystems

A much greater proportion of the Welsh uplands than lowlands is occupied by semi-natural ecosystems, some of which (heather moorland, blanket bog, upland oakwoods) are of international as well as national importance for the conservation of biodiversity. These and other ecosystems of more local interest, notably arctic-alpine plant and invertebrate communities, are likely to be particularly vulnerable to the effects of climate change as climate and associated soil characteristics are primary factors influencing their development and stability. Conversely, some vegetation types, notably bracken-dominated grassland in Wales, are likely to benefit from warmer, drier summers. The already rapid spread of bracken (Taylor 1980; Senior Technical Officer's Group, Wales 1988) may be further accelerated, with invasion at higher elevations becoming possible if late frosts which damage the emerging fronds (Pakeman & Marrs 1996) become less frequent and severe. Because the impacts of climate change on biodiversity are likely to be greater in the uplands than in the lowlands, it is important that our current inadequate knowledge of these impacts be improved.

Remnant arctic-alpine communities, although of very limited occurrence in Wales, are of special concern to conservationists who consider that they are particularly vulnerable to climate change (CCW 1999). It is argued that having survived since the last ice age in the few sites where they are able to compete with other vegetation, notably on cool, wet, north-facing cliffs and boulder screes, they have "nowhere to go" if climate change occurs, since the mountains are not high enough to offer refuges at higher elevations. However, this concern is based on supposition, there being no experimental evidence from studies in Wales or elsewhere to support it. Indeed, evidence from genetic studies on the Snowdon lily (Jones & Gliddon 1009) suggests that the few small Welsh populations of this species, although isolated by considerable distances from the nearest populations in the Alps, are surprisingly varied genetically. This suggests that the Snowdon lily in Wales may be able to respond to climate change more successfully than was previously supposed. Similar information is required for other key arctic-alpine species, plus knowledge of their likely responses to climate change based on experimental testing in carefully controlled experiments. This will enable more effective conservation management responses to climate change to be planned and if necessary implemented.

A major unknown which currently bedevils all attempts to devise effective management of climate change impacts is our lack of understanding of the effects of interactions between climate change and other key factors affecting biodiversity. Upland land use (especially intensity and pattern of sheep grazing), and soil and water acidification and eutrophication arising from atmospheric nitrogen deposition, are two of these factors. Field experiments are in hand to investigate these interactions in heather moor/grassland ecosystems, but more research is needed. Elevated concentrations of atmospheric carbon dioxide may lead to wide-ranging enhancement of plant biomass production, which might enable lower stocking densities without reduction of livestock production. Both factors are likely to have large impacts upon diversity, but we have little understanding of which communities and species will be affected or how. Summer drought interacting with higher temperatures might set in train the irreversible drying out and subsequent oxidation and breakdown of peat. This could lead to wide-ranging ecological impacts, including dramatic changes in the vegetation cover of moorland areas and the loss of many plant and animal species. Such changes would make nonsense of existing national (SSSI, NNR) and/or international (SAC, SPA, RAMSAR) biodiversity-related site designations (see Table 7).

Table 7: Numbers of designated areas of different types in Wales

Designation	**Number of sites**
National Nature Reserves (NNRs)	62
Sites of Special Scientific Interest (SSSIs)	963
Special Areas for Conservation (SACs)	38
RAMSAR and/or Special Protection Areas (SPA's), (designated or proposed)	13

The Potential effect of Climate Change on individual habitats and species

An assessment of the potential impacts of climate change on individual habitats in Wales follows. Species can not be included for reasons of space but it can be assumed that they will be affected along with their habitats. The 1997 CCW publication *Action for Wildlife* lists the species of special concern in Wales and their habitat needs. A high proportion are associated with coastal or wetland habitats which are particularly susceptible in many cases to climate change. However, it should not be assumed that species within a community will behave uniformly in response to climate change, indeed the experimental evidence available suggests that species will respond individually and in largely unpredictable ways (Buckland *et al.* 1997; Stirling *et al.* 1998). Habitats are prioritised in this list according to the author's subjective assessment of their likely susceptibility to damage by climate change. This is based on a mixture of personal knowledge, conversations and correspondence with experts on particular habitats, and consideration of the very limited scientific information available in the literature.

1. BAP Habitats likely to be affected by Climate Change

High risk

a. <u>Coastal and flood plain grazing marsh</u> (HAP published 1995, area in Wales >5000 ha)
Predicted increase in sea level could lead to a major loss of this habitat, which supports many rare plants and animals including BAP species. However, the extent of the problem will vary depending not only on the amount and rate of sea level rise due to climate change, but also on the part of the coast involved, since geological uplift in the north and west of Wales will reduce the impact there. Losses which do occur may be offset by managed retreat in some areas, but in others this may not be an option.

b. <u>Seagrass beds</u> (HAP published 1995, area in Wales probably <1000 ha)
Threatened by sea-level rise unless managed retreat provides new areas for this habitat. Increased storm frequency leading to enhanced turbidity could also be damaging.

c. <u>Coastal vegetated shingle</u> (HAP published 1999) and coastal sand dunes (HAP published 1999,)
Impacted by sea level rise and may be eliminated in some areas unless new defences are provided. More innovative approaches involving enhancement of natural shingle and dune building processes might be more appropriate.

d. <u>Saline lagoons</u> (HAP published 1995, area in Wales <100 ha)
Threatened by sea level rise, which could result in breakdown of barriers separating them from the sea. However, new lagoons may be created as part of managed (or unmanaged) retreat.

e. <u>Montane</u> (alpine & subalpine, area in Wales <100 ha)
Habitat likely to become less suitable for specialist arctic-alpine species as summer temperatures rise, droughts increase in frequency and severity, and the incidence of cold winters decreases.

f. <u>Lowland raised bog</u> (HAP published 1999, area in Wales <1000 ha)

Some of the best raised mires in Britain and Europe in Wales. They are likely to be damaged by warmer summers and more frequent droughts. Existing hydrological management may need to be revised or where there currently is none it may need to be designed and implemented.

g. Blanket bog (HAP published 1999, area in Wales >10,000 ha)
Depending on the severity of climate change there could be a minor or considerable impact on this habitat, which is dependent upon high year-round rainfall and air humidity. These changes could be irreversible on shallower peats once the peat dries out and oxidises. This is probably the biggest potential impact in terms of area affected by knock-on effects to other (especially wetland and aquatic) habitats, and positive feedback to climate change through release of greenhouse gases.

h. Fens (HAP published 1995, area in Wales >1000 ha)
Threatened by decrease in summer rainfall, which is unlikely to be compensated for by increased winter precipitation. Water quality is likely to be affected by impacts of drying and warming on soils and nutrient cycling in surrounding habitats.

i. Purple moor-grass and rush pastures (HAP published 1995, area in Wales >5000 ha)
This habitat, which is particularly characteristic of parts of lowland Wales, will be adversely affected by decrease in summer rainfall. Drying could rapidly lead to expansion of Purple moor-grass swamping out small associated species. There could also be loss of characteristic species requiring high summer water tables.

Medium risk

j. Lowland heathland (HAP published 1995, area in Wales >5000 ha)
Dry coastal heathland may be favoured by warmer, drier summers although there is a possibility of a shift towards more xeric communities typical of those found in SW England and NW France. Wet heathland is likely to be adversely affected and smaller areas may require positive hydrological management to ensure survival.

k. Upland heathland (HAP published 1999, area in Wales >5000 ha)
Wetter types likely to be adversely affected but may lead to increase in area of drier upland heathland types.

l. Upland oakwood (HAP published 1995, area in Wales >500 ha)
Tree growth likely to improve with warmer, drier summers, except on shallow or skeletal soils where drought may cause problems. However, biodiversity value as habitat for bryophyte communities, including internationally scarce species and invertebrates particularly associated with damp woods, is likely to decline.

Low risk (impacts uncertain)

m. Limestone pavement (HAP published 1995, area in Wales >500 ha)
A habitat restricted by available geology, which is unlikely to be significantly affected.

n. Ancient and/or species-rich hedgerows (HAP published 1995, length in Wales >20,000 km)
Climate change is unlikely to be of significant importance compared with agricultural management.

o. Cereal field margins (HAP published 1995, area in Wales >1000 ha)
The impact is likely to be an increase in the amount of this habitat if cereal acreage increases as a result of warmer, drier summers.

p. Reedbeds (HAP published 1995, area in Wales >500 ha)
May be adversely affected by summer drought unless special attention is given to hydrological management. Successional processes towards carr, with loss of open water habitat, likely to be accelerated.

q. Mesotrophic lakes (HAP published 1995, area in Wales <100 ha)
Warming and drying of the surrounding habitat may lead to increasing eutrophication of these lakes as a result of increased rates of nutrient cycling and release from soils.

r. Unimproved grassland (including lowland meadow, lowland dry acid grassland and lowland calcareous grassland [HAPs published 1998, area in Wales >1000 ha)
Difficult to predict effects because much depends upon climate change impacts on nutrient turnover. Available evidence needs to be reviewed. Drying and warming may favour more xeric communities, which could be regarded as beneficial since they are presently more restricted in extent than their more mesic counterparts.

s. Maritime cliff and slope (HAP published 1999, area difficult to estimate, probably >100 ha)

May be impacted by sea level rise and perhaps by increased summer drought and warming. May also be affected by increased erosion rates on soft cliffs due to increased storminess. May be increase in landward extent of seaspray deposition also due to more frequent storms.

t. Urban
Increased temperature and summer drought likely to lead to increase in proportion of exotic species.

Comments
Few of the responses mentioned above are likely to be affected by climate change alone. There will be more or less complex interactions between climate change and other factors, notably atmospheric nitrogen deposition and land management. We are currently powerless to predict the outcomes with any acceptable level of confidence. We can be sure, however, that the rate at which climate change takes place will be important, especially for species responses. Some species, especially those with short generation times (e.g. microbes, many invertebrates, annual plants), are likely to be better able to evolve in time to survive rapid climate change than other, longer-lived species (e.g. raptors, large mammals, trees). Thus, as has happened under changing climates in the past, the balance of different types of organisms may change in particular ecosystems and perhaps at large, as well as the suite of species.

3.2.2 Freshwaters

Due to its temperate location in a wet maritime region, freshwaters, wetlands and brackish estuaries represent a major characteristics of Wales' natural environment. Geological structure and relief have produced a substantial radial drainage system in which major river are fed by a stream network of over 25,000 km length. Among the major rivers, several qualify in their own right as Special Areas of Conservation under the EU habitats directive (eg Usk, Wye), and were among the first UK rivers to be notified as Sites of Special Scientific Interest (Wye). Equally, several Welsh rivers drain into maritime zones which include a range of Special Protection Areas (eg Severn, Burry Inlet, Dee; SPAs under the EU Birds Directive) of international importance with respect to breeding and migratory birds.

Although there are no large standing waters comparable to those in mainland Europe, there are many examples of lowland or relict upland lakes in post-glacial settings. Among them are Sites of Special Scientific Interest (e.g. Llyn Idwal, Llangorse Lake) and lakes that in combination form important networks (eg Duigan et al. 1996). A range of other important wetland habitats form integral parts of some drainage systems. Some are designated in their own right for their nature conservation importance (eg Cors Llyn National Nature Reserve) while others form part of a declining UK resource. For example, 573 ha area of *Phragmites* reed bed occur in Wales (S. J. Tyler 1994) representing locally important stocks of a habitat emphasised nationally in biodiversity action planning (Bibby and Lunn 1982, G. Tyler 1994, 1998). Some unusual drainage systems of importance to nature conservation in Wales have their origins in agricultural activity (eg Gwent Levels), whilst artificial habitats such as farm ponds are receiving increasing emphasis by virtue of their value in replacing semi-natural wetlands that have been lost.

Freshwater and wetland biota
Biological resources in Wales' physiographically varied network of rivers, lakes and wetlands are diverse. Algae, bryophytes, higher plants, invertebrates, amphibians, birds and mammals all figure prominently among the aquatic biota, and a range of other groups depend on production freshwaters in some form. Several aquatic species in Wales have explicit mention in European or UK conservation legislation (see 'Impacts on Biodiversity'). Some such as the salmon *(Salmo salar)* are recognised by virtue of their economic importance so that their biology and distribution is well known. By contrast, current knowledge of some species previously acknowledged for restricted UK or European distributions is now poor (eg *Ephemeralla notata*; *Potamanthus luteus, Baetis digitatuts* Ephemeroptera; *Stenelmis caniculata,* Coleoptera).

Wales' geographical position means that representative aquatic biota include groups of both northern and southern evolutionary origin. Resident wetland organisms whose richness or abundance increases to the warmer SE include the Odonata (dragonflies) and among birds, the Kingfisher *Alcedo atthis* and Cettis Warbler *(Cettia cettia)*. Elements with evolutionary origins in the cooler north include the Plecoptera, some ephemeropterans and some trichopterans among aquatic invertebrates, and the Dipper (*Cinclus cinclus)* and Goosander among birds. Yet other groups of organisms have distinctly western or maritime distributions including a range of important bryophyes. Understanding these general patterns of distribution have some bearing on understanding future responses to climate change. Intriguingly, recent colonists in Wales include organisms of both northern (eg Goosander) and southern (eg Cettis Warbler, Little/Cattle Egrets) origins.

International migrants to Wales reflect distinct groups of wetland species that arrive in winter after breeding in the arctic north and east (eg many waders, waterfowl, water rail *Rallus aquaticus*). Others arrive in summer after wintering to the south, for example in the African or Mediterranean regions (eg wetland migrant warblers in the genus *Acrocephalus*; Common Sandpiper *Actitis hypoleucos*). Thus, understanding the future conservation impacts of climate change on aquatic systems in Wales will require us to look beyond our borders.

In all these cases, distribution and abundance in Welsh freshwaters and estuaries reflects a wide range of abiotic factors as well as interactions with other species including prey, predators, parasites and diseases. Important influences on distribution can arise at several important periods of the life cycle including breeding, dispersal, wintering and migration. General and straightforward predictions about the effects of climate change will thus be elusive without increased understanding. We note in passing that coastal seas will be warmer too; they may impact coastal biodiversity by differentially favouring particular species.

Effects on freshwater ecosystems

Previous predictions of the effects of climate change on aquatic ecosystems (UKCCIRG 1991) have been nearly entirely qualitative and speculative and in large part remain so. This reflects the scarcity of quantitative studies or reviews of the ecological effects of climate change on UK freshwaters (Table 1). Thus, despite increased publishing activity about climate-change during the current decade, the vast majority of available peer-reviewed literature has arisen from North America (60%) and mainland Europe (16%). No papers explicitly assessing the effects of climate change on freshwaters have involved Wales.

At the UK level, a small amount of available literature has addressed aspects of hydrology (Arnell & Reynard, 1996), water quality (eg Ferrier *et al*. 1995) and temperature (eg Mackey & Berrie, 1991), and modelling of this type continues at the UK Institute of Hydrology and Exeter University (B. R. Webb). By contrast, understanding of the biological effects of climate change on rivers is limited. Work at the Llyn Brianne experimental catchments shows that drought could have negative effects on salmonid growth. Observations and modelling studies also suggest that enhanced North Atlantic Oscillation (NAO) might affect maritime locations such as Wales with consequences for freshwaters (Kiely, 1999). Data from Llyn Brianne over 14 years has indicated that positive NAO values, associated with milder winter conditions over north-west Europe, strong westerly winds and up to 30 percent more winter rainfall than the long-term average, have been linked with markedly reduced stability and abundance of aquatic invertebrates, although the exact mechanisms are unclear (D. Bradley & S. J. Ormerod, unpubl. data). In the absence of other quantitative assessment or process studies, assessments of climate change on Welsh rivers can only be speculative, and some possible scenarios are outlined below.

Effects on rivers

In general, river temperatures are closely affected by air temperature. Altered river temperature would affect metabolism and growth among poikilothermic (cold-blooded) organisms in some cases positively, but above certain thresholds there will be negative effects on cold-water species such as salmonids. In response to temperature change, northern aquatic species will move to higher altitudes where habitat exists, otherwise their southern range will contract northwards. Invasions of southern continental species are possible, but might be limited by opportunities for dispersal. There will be direct disturbance of species using temperature as a clue to breeding, migration or dispersal.

Changes in rainfall patterns and amounts resulting in increased discharges and storms will alter hydrological pattern, hydraulics and sheer-stress with consequences for benthic organisms, including those such as salmon whose eggs and larval stages occupy bed habitats. Feeding activity by riparian vertebrates will be affected and long-term shifts in habitat structure might arise from erosion. Drought, which is likely to be accompanied by increased temperature, will lead to short-term gains for organisms dependent on riparian habitats such as gravel bars, but negative effects will arise in many other cases through decreased wetted perimeter with consequences for the accessibility and mix of habitats represented. Marginal habitats – often important for some species and for some life stages of fish – might be affected disproportionately.

Climate change effects will interact closely with issues of river water quality (Arnell, 1998). This will reflect changes in river processes, and effects from the surrounding catchment. Increased temperature will directly reduce oxygen concentrations, while interactions with the decomposition of organic matter might lead to severe local problems. Chronic organic pollution and pollution incidents from agriculture will be exacerbated, but interactions with organic decomposition from natural sources such as plant material are possible. They will be worse under drought conditions, as in the River Wye in 1976 when the decomposition of *Ranunculus* led to substantial salmon mortality. Increased temperature will affect metabolism in ways that interact with stresses from pollution, particularly because drought conditions will reduce the dilution of pollutants. Whilst increased rainfall will sometimes benefit pollutant disposal, there will be increased risk of storm-related incidents and large negative effects on acid episodes. The latter will risk offsetting or obscuring recovery from acidification, still a major problem.

Impacts on quality of Welsh water

Altered nutrient dynamics involving catchment releases of N and P are also possible, but our weak understanding of the processes leading to catchment release make predictions very uncertain. Altered catchment outputs of dissolved organic carbon from areas with peat soils will form an issue in its own right, but local increased loading of organic acidity will be one consequence. Amelioration of effects from toxic metals through complexation might also occur in acidified locations.

Effects on lakes

As in rivers, temperature change will have direct effects on poikilothermic organisms with consequences for their range and status. The changes could be profound for relict arctic-alpine forms. Where thermal stratification is disrupted, altered temperature patterns in lakes could have disproportionately large effects if nutrients or other material is mobilised orimmobilised in sediments. In lakes where there are important littoral habitats, or where the euphotic zone is disrupted, increased fluctuations in level might also have disproportionate effects. There are examples elsewhere in Britain (George and Taylor, 1995) of lakes affected by altered wind patterns during different phases of the NAO.

As in rivers, there are possibilities of indirect influences on surface chemistry in lakes. Some will be similar, but others will be unique to lakes, including the increased risk of blue-green algal blooms under new climatic conditions which will favour this group.

Effects on wetlands

One of the major direct effects on coastal wetlands will be from sea level rise which will lead to direct reduction in inter-tidal habitat, and possible saline intrusion into freshwater coastal marsh. The former will have direct consequences for organisms dependent on the intertidal zone, while the latter will reduce local species richness (Arnold & Ormerod, 1997).

Changes in water levels in wetlands of all types will have potentially major effects on their persistence as habitats, and on their ecological function at potentially sensitive periods for organisms (eg breeding in birds). Both flooding and drying have potential consequences to affect dispersal and connectivity between wetland systems.
In estuaries, increased runoff under storm conditions is likely to transiently reduce salinity, and this should be seen alongside the risk of saline intrusions. Some wetlands, even in the UK, are among the worlds most productive habitats. A range of production and decomposition processes will be altered by temperature with consequences for linked aquatic habitats.

Non-linearities and unexpected effects.

It should be noted for all habitats that rapidly changing circumstances are difficult to predict. There are risks of non-expected effects, for example from the invasion of non-native plant species, or altered use of pesticides following pest outbreaks, which could have large, unpredictable and non-linear consequences for all surface waters. Future interactions between mean conditions, ranges and extreme events may have particular significance to by exposing freshwater systems to severe flooding or prolonged droughts.

Gaps in knowledge and quality of available information

In view of the speculative nature of most of the suggested impacts, and the dearth of published information from Wales and the UK, gaps in knowledge in the freshwater ecosystem sector must be regarded as large. This is reflected also in the speculative and non-quantitative nature of the responses from stakeholders. Suggested freshwater indicators of climate change in the UK (Cannel *et al.* 1999) also under-represent Welsh environments. Potential approaches to filling some of the existing gaps include: i) better analysis of effects on freshwaters and freshwater organisms in analogue years (eg drought; mild wet winters; positive NAO phases), ii) assessment of freshwater ecosystems and management problems in analogue locations of future climate pattern (eg Gallacia, NW Pyrenees), iii) analysis of long-term data from well recorded freshwater environments (eg Plynlimon, Llyn Brianne) and iv) better development of freshwater models to link with climate models.

Table 8: *Regional coverage in scientific publications featuring the words "climate change" in the title, abstract or list of key words and "lakes" or "rivers". The values are total numbers per year from a search covering 1981-1999. Source: BIDS.*

Region	"Lakes"	"Rivers"	Total
North America	115	37	152
Africa	9	4	13
Meso/South America	8	3	11
Arctic/Antarctic	9	1	10
Asia	3	5	8
Oceania/Australasia	4	2	6
Europe	34	6	40
United Kingdom	2	5	7
Ireland	0	1	1
Wales	0	0	0

Note: The Bath Information Data System lists scientific publications according to key words used in searching. Although not listing all scientific journals, it contains data on most with recognised quality and wide circulation.

3.2.3 Findings from stakeholder consultations

Interviews were conducted with persons working for, or with an active interest in, organisations with a major involvement in conservation, freshwaters, or planning organisations. Interviewees were experts in conservation, fisheries, water resources, freshwater science, upland management birds and habitat management, water supply and planning. All are professionals and can offer advice on biodiversity and habitat management, and the organisations they work for can offer this advice at both the local and all-Wales level.

Understanding of climate change

There was generally a good understanding of what the likely changes in climate would be and of associated impacts, especially sea level rise. There was some questioning of whether recent weather has been unusual, and the need for longer-term trends to confirm that climate change is occurring.

Reactions to impacts

Generally little action has been taken so far, partly due to lack of certainty by organisations/individuals about the nature and scale of the impacts upon aspects of biodiversity of concern to them. Most respondents understood what actions would be required to protect vulnerable habitats and species, especially in the lowlands, should the effects of climate change accelerate. Their primary concern was to protect habitats/species having high profiles in

Wales (Arctic-alpine communities, Marsh fritillary butterfly) rather than concern for the larger-scale habitats (blanket bogs, wet acid grasslands) and their associated species, which may be equally or more adversely affected by climate change. The important point was made that the unpredictable effects that climate change may have, especially if it is extreme, on farming practices and rural life in general in Wales make it difficult to predict outcomes for biodiversity.

Recent unusual weather had indeed influenced their activities. In one case new sea defences had been built to accommodate sea level rise and protect low-lying marshland, in another very low summer river flows had allowed fish passes to be built without having to divert the flow. Some interviewees were increasing their species and habitat monitoring activities, and were thinking more about the potential impacts of climate change. Some quoted problems arising from increased storminess, which had resulted in coastal erosion and increased windthrow in woodland nature reserves, and wet winters that had caused delays to hedgerow renovation work.

Interviewees were asked whether future changes to the weather were likely to affect their activities. All were of the opinion that the entire range of their activities is likely to be substantially affected, because:

- losses, gains or changes in distribution of species and habitats will occur, although it was felt there are considerable uncertainties about the nature and magnitude of the potential effects. Specific examples include:
- decline of western Atlantic bryophytes because of dry summers
- wetlands and associated wildlife (e.g. marsh fritillary) lost or damaged by dry summers, but *Sphagnum* moss may benefit from wetter winters
- tree growth restricted in dry summers; broadleaf woodland expansion uncertain
- changes in littoral communities because of increased temperature and storminess
- cold water marine species retreat north because of warmer water, and warm water species expand northwards
- invasion of new terrestrial species which may outcompete native species
- *Rhododendron* may thrive in damper winters
- bluebells may decline in drier springs
- heather moors may be damaged by heather beetle, which favours warmer conditions
- drier summers could have substantial effects on wet grassland breeding birds
- change in vegetation community structure because of the loss of the dormancy period for certain plant species
- coastal habitat ‘squeeze’ because of sea level rise and increased storminess, potential damage to sand dunes, saline lagoons etc.
- wetter winters causing difficulties with land management
- opportunities for re-creating habitats, e.g. estuaries on land currently in agriculture
- the need to restore the natural water-holding capacity of catchments, e.g. floodplains, wetlands, blanket bogs etc., to ensure an adequate water supply through dry summers
- Many species are at the northern end of their range in southern Britain and if temperatures rise these might expand northwards. Examples given were sand lizard, smooth snake, many insects, and the nightingale.
- a positive impact could be a more diverse farmed landscape with more tillage crops, which would be beneficial to birds if managed appropriately
- higher winter temperatures will allow grass to grow for longer and result in even greater intensity of dairy and sheep, systems which are the least desirable for wildlife
- human settlement moves from the coast, putting pressure on other land and habitats
- conservation bodies will need to do more research and monitoring in order to give reliable advice to other organisations and individuals.
- climate change will potentially affect a wide range of freshwater habitats.
- changes in climate will affect policy issues, e.g. whether to purchase a particular nature reserve, or how planning policy might be influenced.
- changes in climate will affect operational management of water resources, since it will be necessary to incorporate predictions into long-term planning.
- dry summers will increase demands for abstraction of water from rivers.

- additional flood defences will be required.
- potential loss of arctic alpine plants
- the threat to the natterjack toad, currently being re-introduced to Wales, from increased spring rainfall
- retreat northward of the eider duck, a cold water species, currently found as far south as South Wales
- increased diversity and abundance of insects, including insect pathogens because of improved climate increased levels of over-wintering
- coastal zone management needing to be altered, in response to sea level rise
- freshwater productivity could increase, but there might be increased incidence of algal blooms. Improved summer climate may increase recreational activities on rivers, with increased disturbance to wildlife.
- changes in agricultural and forestry practices which affect biodiversity, and agri-environment scheme prescriptions needing to change
- nature reserve management needing to be adapted
- the detrimental effects of low summer flows and warmer waters on salmon and trout were expected to be especially severe.
- increased winter runoff could be important for riverine birds because of impacts on food supply, turbidity, and enhanced runoff of pollution.
- cold water rivers tend to have specialist birds such as the dipper; warmer waters will create even more stress for these species.
- low summer water flows will have a major impact on freshwater invertebrates.
- there is a need for greater storage of water on floodplains, and this will have an impact on planning policy.
- allowance will be needed for greater evaporation rates in summer from water bodies.
- heavier winter rain will affect sewer systems and rivers, and increase flooding.
- demand might increase in lowland England for Welsh water.
- better summers will increase the demand for amenity use of rivers and lakes.
- land management will need to change, which will have largely unknown knock-on effects in freshwaters.
- there will be significant losses of revenue to the local economy if salmon fisheries decline. Each salmon caught is valued at around £3000.

Existing actions in terms of individual professional roles and responsibilities

So far very little action had been taken to deal with likely impacts of climate change. Whilst most interviewees understood what the impacts of the climate change scenarios would be on the habitats and species they manage, few felt that they personally could do much about it. Rather they saw the need for political solutions (reducing pollution, enhancing agri-environment schemes). Some respondents were more imaginative, picking up the opportunities to apply technological solutions to such problems as loss of coastal habitats and drying out of wetlands. There was a strong feeling that institutional inertia and lack of adequate resources were widespread and would hinder effective response. Respondents generally understood the possibilities for managing habitat response to climate change and the need to revise traditional approaches which often assume that NNRs, SSSIs etc. will remain unaltered if protected from damaging management activities or neglect. There was also general awareness and acceptance of the inevitability of species losses and gains under the worst case climate change scenario. It was accepted that exotic species will become established in Wales, perhaps to the detriment of some native species. There was considerable concern, however, that some established exotics, notably *Rhododendron ponticum,* might be favoured by climate change and become even more damaging to native biodiversity than at present.

An interesting positive observation was that increasing public concern over climate change might lead to greater interest among policy makers and a greater allocation of resources to environmental issues, improved planning policies, and more radical decisions. Perhaps the over-arching impacts of climate change might strengthen the hands of those seeking to promote more integrated approaches to environmental planning. A similar view was that it was important to view climate change as preventable, since then politicians would be more likely to act. All of the interviewees thought that negative effects heavily outweighed benefits.

Examples of actions included:

1. Examination of catchment management options to ameliorate the hydrological effects of climate change.
2. Microtagging salmon in order to monitor fish stocks and assess any impacts of climate change.

3. Preparation of outline views on which important wildlife areas should or could be defended, especially in coastalregions.
4. Taking action to influence planning policy to ensure, for instance, estuarine and floodplain development are more critically examined in future.
5. Examination of possible effects of climate change in order to update 25-year planning horizon.
6. Defining options for restricting water abstraction in times of drought.
7. Applying integrated catchment management plans whose aim is to plan all aspects of land use and industry.
8. Including potential effects of climate change in a draft National Park Management Plan.
9. Contributing seeds of scarce, potentially threatened plants to the Kew Millennium seed and DNA bank.

Regarding barriers to taking action, a common response was that institutional inertia and limited finances would be a problem. The uncertainty in the nature and extent of change is a barrier, and it would be necessary to see changes occur before committing effort. Competing or more immediate priorities are also a barrier. The lack of appreciation of the possible scale of change and the practical difficulties of taking action were also regarded as barriers. A major problem was the lack of knowledge about individual habitats and their management.

Stakeholders were asked how quickly they could adapt to changing climate, and whether they could adapt by changing site. Clearly, it is impossible to change the sites of critical and sensitive habitats such as arctic alpines. They responded with the following points:

1. Speed of response depends on resources available and a need to define priorities for freshwater habitat and species conservation.
2. Water supply companies cannot respond quickly because new infrastructure may take up to 20 years to complete.
3. In some ecosystems, response can be fairly quick, for instance to develop greater bird potential on new flood storages.
4. In the case of organisations with Corporate Plans, speed of response is up to 4 years, which is the time span for such plans.
5. Nature reserve and agri-environment scheme management plans are regularly updated, and so climate change impacts would be accommodated as they occurred
6. It should be possible to adapt quickly once the impacts are known or observed
7. If habitat re-creation or restoration is required, it may take many years and much resource.
8. Certain habitats may drift, or slowly re-establish themselves elsewhere, if conditions are made right for them
9. Water supply companies are already under pressure to abstract less water from rivers, for example in South Wales, and there are no alternative sources locally. There could also be increased demands for water from outside Wales, which would further reduce available options

Strategic planning

Of the organisations consulted, the water supply industry stands out as having the only comparatively long term plans. These operate on a 25-year timescale to ensure adequacy of water supply, and potential impacts of climate change are incorporated as a priority in these plans. Otherwise, planning in this sector is short to medium term and whilst climate change is a high priority in the Corporate Plans for a 3-year timespan for one Agency, climate change impacts do not yet feature significantly in most of the activities underpinning strategic planning. Some BAPs mention climate change, but it is given a low priority. There was some indication that climate change impacts will have a higher priority in future plans. The statutory and voluntary conservation bodies prepare species and habitat action plans that operate over a 10-year period, but most do not include effects of climate change. The RSPB develops 5-year strategies for influencing Government policy, for instance on planning control, floodplain development, water resources etc. Climate change impacts are built into these plans but are of lower priority than immediate impacts, such as threats from road schemes, agricultural activities etc. Two angling associations do not prepare long-term plans but look to the future (3-10 years) by carrying out salmon re-stocking and attempting to manage catchments to benefit fish. Examples of medium term plans include agri-environment scheme and other land management agreements that tend to be for ten years, and Biodiversity Action Plans (BAPS) which have a 10-20 year timescale. CCW have a ‘ten year vision’ and realise they should ideally be looking ahead 50 years. The National Parks' development plans, although primarily focused on housing and industrial development, may impinge on biodiversity interests and operate to a 25-year timescale. Otherwise, corporate plans, financial and business plans, National Park Management Plans and nature reserve management plans extend for three to five years only.

Stakeholders were asked if their organisations have in place contingency plans to deal with the kinds of events predicted to happen with climate change. Some did; some did not. There are site-specific contingency plans to deal with floods, storms etc., the Environment Agency has comprehensive flood warning plans, and Hyder has contingency plans to supply water if infrastructure failure occurs; plans to deal with flooding and fires on nature reserves, to implement wild-fowling bans in harsh winters, and to deal with pollution incidents.

Some possible actions for the future were mentioned Wetlands might be artificially (and expensively) protected from drying out by engineering. Careful and more inspired land use planning policy integrated with agri-environment and other land management schemes, and habitat re-creation, could be a core component of adaptation. Most stakeholders in this sector thought there were potential opportunities or benefits from the predicted changes in climate, some of which have already been referred to. Species new to Wales would arrive, and these would be welcome so long as they did not out-compete native species that remain and adapt to climate change. There would also be opportunities for habitat expansion or recreation, such as wetlands, and through 'managed retreat'. It was also hoped that the opportunity would be taken to adopt a more integrated approach to planning, using climate change as the spur. Finally, it was felt climate change would raise awareness in the public of environmental matters, which can only be a good thing.

Needs in relation to climate change

Some interviewees thought that increased certainty that climate change is happening would stimulate more positive action to counteract or adjust to its effects. Others considered that their organisations would simply adjust to the new situation as it arose. There was a general, valid feeling that effective response to the threats posed by climate change depended upon better research information and more resources to plan for and react to the expected impacts. It was also felt, probably rightly, that the planning and carrying through of such research and the allocation of adequate resources was a matter for the UK Government/National Assembly for Wales and was beyond the remit of local authorities and NGOs.

Stakeholders were asked if there was greater certainty in relation to climate change impacts, would this influence them to take action? It would allow them to plan ahead more strategically, but this planning process needs to be integrated amongst Government, the Agencies, local authorities, NGOs and individuals. Good information about impacts would be essential, and they thought more detailed and reliable information and research was needed on the nature of effects on species and habitats. Greater certainty in the predictions would provide justification for the time and expense involved in taking action. Examples of the types of action which might be taken were the planning of new agricultural cropping regimes and land use strategies, passing on advice to members of the public or other organisations, and re-designing the nature and composition of forest plantations. The vehicle of the existing agri-environment schemes will facilitate adaptation.

Support in the form of information is required, as is financial support. Political agreement was required on the need to respond to climate change. Guidance is essential, and should be provided by Central Government (including EU and National Assembly), and where appropriate through the Agencies. The water companies and voluntary sector should also be involved in the suite of organisations responsible for providing guidance.

3.2.4 Recommendations

1. There is a need for closer involvement of the relevant professionals with all aspects of planning and strategic development which impinge on their work and will be impacted by climate change.
2. Collection of data sets for freshwater and terrestrial organisms which may act as indicators of climate change in Wales are needed. This should occur by a combination of (a) instigating more collection of new data along the lines of the ECN and (b) collating existing data for species and sites within Wales which exist scattered across a range of bodies.

3. Incorporate climate change impacts in biodiversity action plans and the criteria for site designations of SSSIs, SACs etc.
4. Need for close monitoring of ecosystems and sites deemed to be at most risk.
5. Need for research on how climate change will interact with other environmental challenges (N deposition, acid rain, ozone pollution, overgrazing) in its effects on communities, especially in the uplands.
6. There is a need for the consequences of climate change for this sector to be incorporated into agri-environmental schemes such as Tir Gofal.
7. Better analysis of effects on freshwaters and freshwater organisms in analogue years (eg drought; mild wet winters; positive NAO phases) and assessment of freshwater ecosystems and management problems in analogue locations of future climate pattern (eg Gallacia, NW Pyrenees)
8. Better development of freshwater models to link with climate models.

3.3 Historic landscapes, built heritage and archaeology

The character and distinctiveness of the present day landscape is fundamental to the way we value the places we live in. It is underpinned by the historic environment, archaeology and the built heritage in all its forms. The historic environment is both fragile and non-renewable Today's landscape is a product of the changing relationship between people and their environment, and change will continue in future. Strategic planning and practical action will be necessary to mitigate the impact of climate change upon the historic environment of Wales.

3.3.1 Heritage Management in Wales

A comprehensive heritage management service is provided in Wales by a number of organisations working in close collaboration:

- The National Assembly is responsible for setting the framework for the planning system and for the protection and preservation of archaeological remains of importance. The Assembly is also responsible for both compiling and maintaining a 'schedule' of nationally important monuments subject to legal protection under the Ancient Monuments and Areas Act 1979 (AMAA 1979). In practice, many of the Assembly's responsibilities are undertaken by Cadw: Welsh Historic Monuments, which maintains the schedule of ancient and historic monuments and has a crucial role in grant-aiding rescue archaeology on threatened sites. It also funds management agreements on certain scheduled ancient monuments and prepares policy advice to the Assembly.
- The Royal Commission on Ancient and Historic Monuments in Wales (RCAHMW) is the national body of survey and record. It compiles a database of ancient monuments and listed buildings in Wales (the National Monuments Record).
- Most of the practical curatorial archaeology is carried out by the four regional Welsh Archaeological Trusts (WATs). They maintain the regional Sites and Monuments Records (SMRs) for their respective areas and provide advice through their curatorial services.

Archaeological perspectives on climate change

Long-term environmental change

Environmental crises are by no means the monopoly of modern times. 'Human-induced ecological problems have occurred…since the last ice sheets started to wane, and have involved societies operating under very different modes of production' (Roberts 1990, 157). There are numerous archaeological examples of human action and behaviour leading to environmental degradation on a large scale. For example, the formation of peat bog over much of western Britain and Ireland in the third millennium BC was triggered by felling of trees and colonisation of new areas of land for stock grazing and crop cultivation (ibid.). Very little of the Welsh landscape is truly natural; it is predominantly a cultural landscape created as the product of a long history of human activity (Castledine 1990). Understanding the changing ways in which societies have organised themselves and have interacted with their environments through time lies at the core of archaeology, so the discipline is well placed to cast light on the relationship between patterns of social behaviour and environmental change. Environmental archaeology is sub-discipline which has contributed to debates on long term patterns of climatic change, accessible publications include Evans 1999; Simmonds and Tooley 1981; Bell and Walker 1992; Taylor ed. 1980; and Castledine 1990.

The impact of past climatic change

Human communities have adapted patterns of settlement and social and economic organisation in response to climatic fluctuations and associated environmental change, for example during a warm, dry, climatic phase in the eleventh to thirteenth centuries AD (Roberts 1990, 160), and a prolonged period of climatic deterioration known as 'the Little Ice Age' between c. AD 1590 and c. AD 1890 (ibid., 159), when the temperature fell by about 1 °C. In upland environments, there was decline of tree growth in marginal areas, and the development of extensive S*phagnum* dominated peat mires. Adverse conditions affected domesticated as well as wild plants with consequent famine crisis in many upland European communities. Hill farmers in northern and western Britain could no longer grow cereals, and much marginal land was abandoned (Roberts 1990). Clearly human action may be influenced by environmental change as well as by socio-economic factors. The relationship between environment and cultural behaviour is complex and mediated by social perceptions.

3.3.2 Possible impacts of the Welsh climate change scenarios on the historic environment

The climate predicted for the twenty-first century has clear implications for the preservation of the historic environment. Most archaeological sites are deteriorating, but the rate of deterioration varies enormously depending on the type of site and the context in which it is located. The preservation of buried deposits is favoured by water-logging. Even small changes to these conditions may reduce the survival of remains. A move towards a more 'Mediterranean' climate with wetter, milder winters and drier, hotter summers would result in significant changes in preservation regimes. The work on the potential impact of climate change on cultural heritage and the historic landscape in Wales, or the British Isles generally, concerns England's Coastal Heritage (Fulford, Champion and Long 1997). No information on specific impacts of the various predicted changes in, for example, storminess, rainfall, and sea level, is available. However, it is possible to make generalised predictions on direct and indirect impacts.

Direct impacts

The scenarios predict increased seasonality, with wetter winters and drier summers. Stable micro-environmental conditions tend to favour preservation of archaeological remains, and buried deposits would be particularly vulnerable to the fluctuating conditions resulting from long episodes of desiccation and re-wetting.

Waterlogged, anaerobic conditions can preserve a wide range of archaeological artefacts, including those made of leather, wood and other organic materials. These artefacts are rare and important. Crucial environmental evidence is also preserved, including ancient pollen, seeds, wood, insects, bone and molluscs. The survival of these remains is linked to the chemical composition of the deposits in which they are contained. Lowering or fluctuating water levels, or pH changes, may have a significant impact on preservation (Castledine 1990). Section 3.2 of this study reports that climate change could have a significant impact on wetland and waterlogged habitats, including raised mires, blanket bog, fens, and reed-beds, all of which are potential areas of good archaeological preservation.

Coastal areas contain a high density of archaeological remains. Wales's rich coastal heritage has recently been emphasised by the results of a survey co-ordinated by Cadw, and executed by the Welsh Archaeological Trusts (Cadw 1999, Davidson forthcoming, Davidson and Yates 1997). Any rise in sea level will lead to damage to, and loss of, sites through inundation and erosion. Statistics are not currently available to assess the extent of damage likely for the three climate change scenarios, which would clearly vary greatly between areas according to local differences in topography and geomorphology. Sites vulnerable to erosion will also be at risk from increased storminess and tidal range. Increased flood frequency and inundation of river corridors resulting from high waters in estuarine areas, and from increased precipitation leading to greater river volume, may also have a significant impact.

Indirect impacts

The impacts of climate change in other sectors, and the strategies taken to mitigate against them, potentially pose a greater threat to the historic environment through knock-on impacts than do the direct (physical) impacts outlined above, but are even more difficult to quantify. The construction of flood and coastal defence systems may result in the destruction of known and hitherto unrecognised archaeological remains. Changes in settlement patterns , new building and transport in future may also damage remains. Farmland accounts for 70 per cent of the land surface of Wales and contains the vast majority of archaeological sites and agriculture is (often inadvertently) one of the greatest causes of their destruction. The long-term sustainability of the historic environment is therefore dependent to a large extent on the changing nature of agricultural practices and rural landuse. Agriculture in Wales is especially reliant upon livestock, and farming regimes have tended to be relatively non-intensive. This is reflected in the extremely high survival rate of above ground archaeological features, particularly in areas of unimproved farmland, in Wales compared with many other parts of the UK.

A shift towards a more 'Mediterranean' climate would result in longer growing and grazing seasons, and possibly, faster growth rates. Cultivation limits and patterns would also shift, with some new areas coming under plough. Deep ploughing is particularly destructive of buried archaeological remains. Any change in landuse away from unimproved or semi-improved grassland is likely to have a deleterious impact on the historic environment. The combination of wetter winters and warmer summers would make soils more vulnerable to poaching (damage to soil structure by grazing animals and from machinery), a major source of damage to vulnerable archaeological sites.. Whilst grazing is a problem in terms of erosion, the removal or substantial reduction of grazing may also cause conservation problems since moderate grazing, prevents scrub and tree growth; woody roots can damage fragile buried deposits. Climate change may lead to lower levels of livestock on farms. Diversification of farm economies might also produce lower grazing levels.

Climate predictions suggest that new areas would be amenable to colonisation by woodland, or to commercial or private plantation. Tree growth can be very damaging to both above-ground and buried sites and features, through root growth and root-pull resulting from tree-blow. The large size of modern planting and harvesting equipment means that extensive areas of archaeological remains can be destroyed in relatively short periods of time. Any impacts upon biodiversity may have effects on archaeological remains.Rabbit burrowing is recognised as a significant source of damage to sites (Dunwell and Trout 1999).

Utilities

The predicted increased seasonal variation in rainfall may require infrastructure changes. The need to move away from non-fossil burning means of electricity production may see a great increase in wind-power, hydroelectricity schemes, and biomass plantations throughout Wales which together may constitute a significant threat to archaeological remains.

Opportunities

Climate change may bring benefits and opportunities for management, understanding and promotion of the historic environment. Drier summers would provide improved conditions for the discovery of buried archaeological remains through aerial reconnaissance. Dry conditions produce marks visible from the air in crops as a result of differential growth over features like buried walls and ditches where moisture content varies considerably from the surrounding soil. The efficiency of both excavation and survey work depends partly on weather, and an ameliorating climate would be a potential benefit. Tourism relies heavily on the beauty of the Welsh landscape. Historic features are an important part of this attractiveness. If conditions for tourism in Wales improve as a result of climate change, there may be increased opportunities for the heritage sector. Archaeological remains are important visitor attractions and their promotion provides significant economic opportunities. The potential of damage to sites and features through visitor pressure should be monitored. On balance the opportunities for heritage management would be significantly outweighed by negative impacts.

The need for scoping studies specific to the historic environment

There is a vital need for a review of long term strategic policy measures and actions. In the short term, the following actions would help refine knowledge of the potential impact of climate change on the historic environment: mapping areas of potentially vulnerable sites by comparing the topographic location and altitude of sites against the climate change predictions; mapping site distributions against likely patterns of landuse change, particularly in terms of agricultural practice; mapping against likely areas of infrastructural change such as settlement, re-housing and flood prevention work. Historic Scotland has funded a series of studies assessing the impact of bracken growth and burrowing animals on the conservation of archaeological remains (Dunwell and Trout 1999; Owen, O'Sullivan and Mills unpublished). Similar studies in Wales would provide a better base of technical knowledge against which the effects of ecological (habitat and species) changes and of natural and visitor erosion on archaeological resources could be assessed. Many current heritage management measures will help to minimise impacts of climate change. However, the scale of such impacts is likely to be beyond current resource levels. New types of threat are also likely to arise, and these will require new conservation mechanisms and strategies.

Land-use and the historic environment

The inclusion of archaeology and the historic landscape as key elements of schemes such as *Tir Gofal* provides one of the best mechanisms for protection of the historic environment. The Forestry Commission, together with Cadw and the Welsh Archaeological Trusts, have developed and committed themselves to a workable accord (Forestry Commission nd). The consultation procedures cover Forest Enterprise land, and areas of private land where new planting is grant aided by the Forestry Commission through the Woodland Grant Scheme.

The key to good management is a strong information base from which to monitor long term trends and prepare strategic plans. Past and continuing research within archaeology is important, but information needs to be accessed and utilised, and integrated with information from other spheres (such as ecology) to ensure success.

Records of Sites and Monuments

The Regional Sites and Monuments Records (SMRs) inform archaeological decisions made within the development control process, and feed into plans such as Unitary Authority Development Plans. Despite their importance, the SMRs do not have statutory provision in Wales. Planning to pressure the historic environment will require integration of archaeological information with that of other disciplines. This could best be achieved through Geographical Information Systems, but the production of a sufficiently complex system will require investment beyond current levels of funding for the SMRs. The WATs are currently discussing this with their relevant Unitary Authorities. The WATs are also planning with Cadw and the RCAHMW to provision for easier public access to a national index of monuments in Wales (based on the Sites and Monuments Records and RCAHMW's National Monument Record).

Threat-related monument studies and historic landscape assessment audits

Cadw grant aids the WATs to undertake threat-related projects assessing the condition and management needs of different classes of archaeological monuments (for example prehistoric and medieval settlement remains). The base-line information from these projects will allow the future impact of predicted changes in land-use, to be evaluated.

Forest Enterprise Wales have recently completed an audit of the archaeological sites and features on their land known as the Welsh Heritage Assets Project. The project has empowered Forest Enterprise Wales to act towards the sustainable management of the archaeological resources on their land. The audit has been followed up by the production of a user friendly Geographical Information System (GIS) database from which information can be drawn when felling and planting operations take place, and for longer term planning at strategic levels. The WHAP provides a model of the value of partnerships in the preparation of management strategies.

Integrated management strategies

Increasing the knowledge base is one part of the problem of long-term protection and preservation. Statutory designations and national planning policy guidance afford protection to some archaeological remains (Welsh Office Circular 60/96, Ancient Monuments and Areas Act (AMAA) 1979). In Wales agriculture and forestry operate outside this planning process. Statutory protection is generally focussed on individual monuments, with insufficient attention to setting, and overall landscape context. The strength of statutory protection for archaeological sites and the framework of heritage management policy and practice may have to be radically reviewed if impacts are not to damage the historic environment. Much current archaeological practice is reactive in nature and operates through development control within the planning process, but the scale of changes due to climate change will be beyond both the financial and logistical resources of this system.

Three main problems will mitigate against long-term and integrated strategic planning:

1. Fragmentation within the profession of archaeology (for example between academics and field archaeologists, heritage managers and researchers, and between different sub-disciplines).
2. Insufficient effort in promoting the understanding, importance and enjoyment of the past to the broader public
3. Resources are a major limiting factor on the effectiveness of current heritage management in Wales.

It is neither desirable or practicable to protect everything that remains from the past, so we need priorities. Efforts to promote the integrated and sustainable management of the historic environment have been developed over the past decade in England (Fairclough 1995 and 1999) and Wales (Avent 1999).

Strategies for dealing with the impacts of climate change will require integration and collaboration. Despite notable exceptions, particularly ecological conservation (Berry and Brown 1994; Cox, Straker and Taylor eds. 1995; Fairclough 1995; Lambrick ed. 1985; Macinnnes and Wickham-Jones eds. 1992 and Swain ed. 1993) archaeology has tended to operate in isolation. The importance of integration is now more widely recognised.

A register of landscapes of outstanding historic interest in Wales has been jointly produced by Cadw, the Countryside Council for Wales, and the International Council on Monuments and Sites UK (Cadw, CCW and ICOMOS UK 1998). This raised awareness of the historic landscape amongst the public and countryside managers. Cadw is grant-aiding the WATs to undertake programmes of historic landscape characterisation throughout Wales. These look at the historical process behind the present day appearance of landscape. They identify the key locally distinctive landscape elements and help inform change and decision making processes by defining acceptable limits of loss. Cadw and the WATs have also been involved in the development of Countryside Council for Wales' LANDMAP (Landscape Decision Making Process) initiative. This is an approach to characterising, describing, evaluating and drawing up management strategies for all of the Welsh landscape (CCW 1997; Davies and Owen 1999).

The public as stakeholders in the historic environment

If successful management strategies are to be developed for the long-term protection of the historic environment, decisions have to be made about the importance of these values to society as a whole. Archaeology needs to be part of broader debates about what society wishes to do with the countryside (Fairclough 1999).

Planning for the future of the landscape requires that the local population is a stakeholder in the environment, (Grenville 1999). A series of tensions run between practical conservation, economics, and ideology in the management of the countryside, and heritage managers need to promote awareness and enjoyment of the historic environment, whilst paying attention to local understandings and wishes. The work of organisations like Common Ground, and *Local Agenda 21* initiatives, have potential for the promotion of local distinctiveness and the involvement of local communities in decision making and action (Clifford and King 1993; Countryside Commission, English Heritage and English Nature).

3.3.3 Findings from stakeholder consultations

Overview

Generally the stakeholders had a good knowledge of the impacts of climate change. However they are used to considering climate and environmental changes over long time spans, and largely for this reason are relatively sanguine about the impacts of climate change on archaeological and built heritage. The stakeholders were unanimous in their view that a central policy was needed before they could plan for climate change, and also in stating that any such actions would need extra resources. Few sites emphasised the important role of environmental archaeology in providing information on past change and in contributing to contemporary environmental debates. Although even basic environmental archaeology text books have sections on contemporary environmental issues.

Quotes:
'If we knew there were going to be major changes on the coast and could predict where archaeological sites and information and material was going to be damaged we could at least point our resources to those issues rather than spread them thinly across Wales'.
'We conserve sites when they become issues or when they are part of visitor experiences, when they are just things in the landscape they are kept a watch on, especially if they are protected'.
'Too many visitors, natural erosion, grazing, too few or too many sheep on site, trees growing are all issues'.
'Climate change doesn't in any way as yet relate to historic landscapes, they are too large and too diverse'.
'There is an opportunity for recording but there is a downside that a lot of archaeological information could be lost by sea erosion'.
'If one had better information and the funding to assess what the impacts would be on archaeology then one would be able to contribute to the sustainability questions as far as archaeology are concerned'.

Understanding of climate change and reaction to existing impacts

Response to the comments of respondents to the stakeholder questionnaire

There was generally a good, but non-technical, awareness of climate change as an issue. The information of the stakeholders had been gained from the media, with little discussion in professional literature. Only one of the stakeholders had consulted other organisations about the current anthropogenic climate change, and this was because they were funding the Archaeological Trusts to pull together their work on coastal archaeology. Some interviewees felt cynical about claims regarding the scale of the current problem, and implied that contemporary trends may just be part of 'natural' long-term climatic cycles, although one interviewee felt that archaeological information about past human impact on the environment cast doubt on the reality of these 'natural' cycles of climate change.

Archaeologists are interested in very long time frames, over which many natural changes in climate have occurred; some stakeholders were unconvinced as to whether the changes in climate were natural or induced/accelerated by man's activities.

Recent long periods of bad weather had disrupted some field work. Following the Towyn floods in 1989/1990 archaeologists are aware of the threat to archaeological sites not only from flooding and erosion, but also from the construction of flood defences. Professional activities could be affected by changing weather, particularly through the threat to coastal archaeology. Accumulations of sand around the coast can seal an obscure archaeological site, as has occurred frequently in South Wales.

Long term planning

Although none of the institutions have plans in place to deal with the impact of climate change, many felt that they held information which would prove valuable as a base-line against which future climate induced threats could be monitored.

Stakeholder said that long term planning in archaeology was difficult because it tends to be reactive and so planning tends to be short and medium term. Organisations' strategic planning horizon was between 3 and 5 years, but although they planned for 3-5 years a lot of their work was reactive to threats from development proposals. Apart from the concern over coastal archaeology, the impacts of the weather did not feature in their long term plans.

As yet there is little sign of action to deal with any likely impacts of climate change. The threat to coast sites, has not been linked to climate change. Whilst it would be quite simple to identify areas at threat from coastal inundation, but taking action to deal with that threat was difficult because historic landscapes are not a high priority with respect to flood defence.

Reaction to potential impacts

Climate change, particularly extreme events, will have an impact on archaeology and the historic environment. Working practices may be affected, but the main impact will be on remains. Coastal impacts, along with rainfall and flooding are the major conclusions. The Gwent Levels were quoted as an area of high historic landscape value that would be particularly vulnerable to inundation by the sea. The interviewees were not clear about the potential nature impacts such as vegetation and land-use changes in the uplands. The impact of construction and engineering works (such as coastal defences, and settlement relocation) can be mitigated by current development control procedures within the planning process. Agri-environmental schemes such as Tir Gofal have great potential for ameliorating impacts. Climate impact models with greater local resolution would help. For example the impact of sea level changes on archaeological sites will vary considerably from area to area according to local differences in topography and geomorphology. Organisations, which have responsibilities for recording archaeological remains, could shift their recording strategies to those sites threatened by potential impacts if they had more accurate predictions. Little thought has been given to ways of avoiding the impacts of climate change or of producing strategies for dealing with them, or whether sufficient funds would be available. The general option was that there were few measures which would lessen the impacts of climate change on the archaeological resource.

Needs in relation to climate change

More information regarding the potential damage to the archaeological resource by climate change is needed in order to prioritise work. Financial resources were a barrier, particularly if climate change meant that recording needed to be carried out more quickly. There may be insufficient archaeologists to do the work, and insufficient funds to subcontract recording work.

Direct opportunities or benefits from climate changes were limited and related to better conditions for recording and aerial photography.

Generally the stakeholders' organisations did not have any emergency plans, as there is a large element of 'fire brigade' work in archaeology. But some other historic monuments, such as country houses, do have contingency plans. There was general agreement that greater certainty in relation to the climate change impacts would influence the stakeholders to take action. In order to help them adapt, the stakeholders thought that better and more strategic guidance was needed from CADW and the National Assembly. Additional financial resources, particularly for staff would help with the work on threatened coastal sites. Such resources should come from government or its agencies. But there is a principle in archaeological work of 'developer pays', so perhaps this could be applied to any work related to climate change. All stakeholders felt that central guidance on the need for planning for climate change was an essential pre-requisite to any action being taken, since archaeology in Wales is effectively centrally financed.

Clear strategic policy is required from Cadw and the National Assembly on the issue of climate change. It will be difficult for the profession to adapt within the limits of current resources, and most felt that funding levels would need to be increased to meet the challenge of climate change impacts. However, few organisations show a desire to contribute to the creation of policy decisions or to long-term planning. Greater attempts should be made to promote communication with environmental bodies and to produce integrated management plans.

3.3.4 Recommendations

1. Integrate preservation of built heritage with the planning of other sectors affected by climate change, especially rural land use and construction of hard defences against flooding, and new build developments.
2. Incorporate the consequences of climate change for the built heritage into agri-environment schemes such as Tir Gofal.
3. Increase understanding of climate change issues in the archaeological community and prioritise sites at risk from climate change against the resource available to investigate them.

3.4 Health impacts

Impacts of climate change on health in Wales will need to be evaluated in the light of a UK-wide study which is in progress (Maynard R 2000). The determinants of health are many and multi-faceted, including the influence of factors such as genetic, physical, biological, chemical, socio-economic, behavioural and psychological. Assessing the likely adverse effects on health consequent upon climate change depends upon the production of possible climate scenarios against which predictions of the effects on health can be made.

A simple model for thinking about likely health impacts incorporates three key factors: *Agent, Host* (humans), and *Environment.* In a steady state these will be in equilibrium. A change in the *environment*, for example, a change in ambient temperature or water levels, may favour the proliferation of some *agents*, e.g. carriers of disease, and be detrimental to others. In addition, the change may be either favourable or detrimental to the *host*. In this way, new diseases previously not encountered by the host may pose a potential threat which may be heightened because of a lack of acquired immunity. For example, increased irrigation along the Nile Valley following the construction of the Aswan Dam favoured the proliferation of snails which carry the schistosomiasis parasite, and resulted in an increased prevalence of schistosomiasis in humans in the irrigated areas.

There will be *direct* and *indirect health effects* of climate-mediated environmental change (Table 9 McMichael and Haines 1997). We use this framework as the basis for exploring the likely health effects of climate change. Direct effects are easier to measure and to subject to modelling exercises. There is considerable uncertainty around the likely accuracy of predictions of the indirect effects of climate change. This is because these effects will be the result of changes in the complex interplay between a wide diversity of ecological systems, which are themselves often poorly understood.

Table 9: *Mediating processes and direct and indirect potential effects on health of changes in temperature and weather (McMichael & Haines, 1997)*

Mediating process	Health outcome
Direct effects	
Exposure to thermal extremes	Changed rates of illness and death related to heat and cold
Changed frequency or intensity of other extreme weather events	Deaths, injuries, psychological disorders; damage to public health infrastructure
Indirect effects	
Disturbances of ecological systems:	
Effect on range and activity of vectors and infective parasites	Changes in geographical ranges and incidence of vector-borne disease
Changed local ecology of water borne and food borne infective agents	Changed incidence of diarrhoeal and other infectious diseases
Changed food productivity (especially crops) through changes in climate and associated pests and diseases	Malnutrition and hunger, consequent impairment of child growth and development
Sea level rise with population displacement and damage to infrastructure	Increased risk of infectious disease, psychological disorders
Biological impact of air pollution changes (including pollens and spores)	Asthma and allergies; acute and chronic respiratory disorders and deaths
Social, economic and demographic dislocation through effects on economy, infrastructure and resource supply	Wide range of public health consequences: mental health and nutritional impairment, infectious diseases, civil strife

Direct effects

Exposure to thermal extremes

The current winter temperatures increase mortality rates above summer rates in the UK more than in other countries, largely because of a lack of preparedness. Warmer winters may therefore save lives. In the UK an average rise in winter temperature of 2.5 ^{o}C could result in 9000 fewer winter-related deaths. 50% of the reduction would be in death from ischaemic heart disease and stroke and 10-20% in death from chronic bronchitis and pneumonia (Langford & Bentham, 1995). Milder winters may therefore reduce morbidity and mortality in Wales, with a smaller reduction in demand on health services.

Increased summer temperatures may directly increase morbidity and mortality from heat stroke. Additional deaths from other causes e.g. asthma and chronic pulmonary disease may occur, probably as a result of increased pollution levels. Those most at risk would be the very young, the elderly, the frail, and those with pre-existing cardio-pulmonary disease. In Britain in 1995 the heat wave was associated with a 16% increase in all causes of mortality in London (Rooney *et al*, 1998). Increased mortality rates under heatwave conditions are more likely to be experienced in urban areas because of the concentration of populations and increased effects of urban-related pollution. In Wales, this will relate particularly to the urban areas in the south. There will be implications for health services under this scenario. Although there may be an increase in summer deaths this is unlikely to offset the reduction in deaths resulting from milder winters.

Wales is relatively sunnier and will become sunnier. Elevated exposure to ultraviolet radiation will result in an increased incidence of sunburn, skin cancers, corneal damage and immune system impairment. UV- B exposure is the main cause of sunburn and animal models suggest that it may be the main cause of non-melanoma skin cancer (McGregor & Young, 1996). UV- A also causes skin damage and may play a part in inducing melanoma growth.

Extreme weather events
Water *shortage* in the summer months may have direct implications for public health, for example: water restrictions leading to poor personal hygiene, sewage disposal problems, concentration of pathogens as a result of reduced river flows, and the need to abstract drinking water supplies from new, possibly more polluted, sources.
These may all lead to an increased incidence of diarrhoeal disease. Poor personal hygiene may also lead to an elevated risk of hepatitis A transmission.

Increased rainfall may cause inland flooding resulting in: increased likelihood of injury and trauma through accidents caused by structural damage and dangerous driving conditions, direct communicable disease spread via flood water, the risk of disrupted water supplies becoming contaminated from damaged sewerage pipes, wash-out of farm pathogens e.g. cryptosporidium and pesticides into water abstraction sites, exposure to toxic industrial substances, psychological disorders, loss of electricity and water supplies and other damage to public health infrastructure, increased public health risk through damage to homes leading to displacement of populations, overcrowding, poor temporary living conditions and poor personal hygiene. The increased precipitation will be accompanied by an increase in intensity of winter storms with the attendant risk of structural damage, injury and disrupted basic services.

Indirect effects
Vector-borne disease
Climate changes will cause shifts in the delicate Agent-Host-Environment balance. Warmer winters and drier summers may create conditions favourable to vectors of human disease not recently or previously encountered. (Shop, 1991; Southeast, 1993). *Malaria* was only eradicated from the UK in the middle of this century through mosquito eradication programmes. It is still endemic in some parts of Europe and climate change may introduce conditions which favour the re-emergence of malaria through transmission by the Anopheles mosquito which is the vector for malarial parasites. Climate change which favours a global increase in malaria may also result in an increased incidence of cases 'imported' into Wales through foreign travel. *Dengue fever*, another mosquito-borne disease, might be introduced.

Lyme disease, which may cause skin lesions, arthritis, neurological and cardiac problems, is already found in some parts of the UK, such as the Lake District, the New Forest and Richmond Park. It is caused by the parasite *Borrelia burgdorfei* which is transmitted by ticks whose activity is temperature dependent, peaking in spring and autumn (Craine et al, 1995). Climate change may extend the areas in which Lyme Disease is a problem. *Leishmaniasis,* which causes skin or visceral damage, is already found in southern areas of Europe. Climate change may result in favourable conditions for the sandfly, its vector, appearing in parts of Wales. Certain forms of *viral encephalitis* transmitted by ticks occur in Europe. The tick species which transmit the disease are already present in the UK.

Ecology of water-borne and food-borne infective agents

Food poisoning is a common problem with over 5,774 cases ascertained in Wales in 1998 (CDR, 1998). Despite being a statutorily notifiable disease there is considerable under-reporting of its occurrence. Temperature rise promotes the growth of food poisoning pathogens and food poisoning rates over hot summers are elevated by up to six times those of winter rates. This is probably due to poor food handling practice with less margin for error in hot conditions. Bentham and Langford (1995) noted an increase in reported cases of food poisoning with an elevated temperature occurring in the same month. In addition, they found that increased rates were also associated with an elevated temperature in the month preceding the onset of symptoms. They suggest that this implies that food may become contaminated early in the production process such as in husbandry and slaughter. They predict that by the 2050s there will be a 5-20% increase in food-borne illness as a result of temperature rise.

Other diarrhoeal diseases, including dysentery, are more likely to occur in warmer, wetter conditions which may prevail following climate change. Cryptosporidium is a parasite, often found in cattle, which causes diarrhoea in humans. Spread is via the faecal-oral route and the parasite is frequently water-borne. Human outbreaks of diarrhoea often occur when cryptosporidium-laden cattle slurry finds its way into water abstraction sources, such as aquifers, where water is abstracted for drinking supplies. Despite filtering and water treatment, cryptosporidia may still enter the drinking water supply. Excessive rainfall may increase the likelihood of slurry reaching water abstraction sites, whilst dry weather may make render the filtration treatment of water less effective.

Blue-green algae, which cause 'blooms' on recreational and other waters, proliferate during warm summers in nutrient rich water (the nutrients often derived from fertilisers from agricultural run-off). The toxicity of these algae vary but may be responsible for skin complaints, rhinitis, gastrointestinal disorders and atypical pneumonia. (Elder et al 1993) There are already periodic reports in the UK of users of recreational waters, such as swimmers and canoeists developing these conditions. It is also thought that the algae may shelter other pathogens such as the cholera vibrio.

Changed food supply
Countries in non-temperate zones are likely to experience most adverse effects on food production as a result of climate change or through the effects of climate on pests; Wales is unlikely to suffer a significant reduction in agricultural production and so will only be subject to food shortage if supply from other countries decreases.

Sea level rise
The predicted mean rise in sea level and increase in coastal flooding, which may result in: property damage and displacement of residents; risk of injury, other risks to public health.

Atmospheric pollution
Seasonal climatic variation affects pollution levels (Derwent, 1999): winter air pollution is characterised by higher levels of particles and NO_2; summer air pollution results in elevated ozone levels. *Respiratory diseases* such as asthma, hay fever and chronic bronchitis as well as other cardio-pulmonary disease may be precipitated or exacerbated by air pollution: increased concentrations of ozone may increase the incidence and prevalence of respiratory diseases such as asthma and hayfever; unfavourable weather, such as a change in rainfall, may affect the dispersion of pollens and spores; there may be an increase in the exposure to air pollutants in urban areas; plant aero-allergens are sensitive to climate (Emberlin, 1994) and climate change may favour particular plant species, causing a change in either the nature or the quantity of pollen production with a consequent change in hay fever and other allergic reactions (although it is unlikely that the cover of ryegrass will change significantly).

Social, economic and demographic dislocation
Health is more than just the absence of disease and there are well-recognised associations between health and socio-economic conditions (Townsend *et al*, 1992). It is likely that deprived individuals and communities will be more vulnerable to adverse climate changes than the better off as they will have less resource to fall back on. Following climate change it is conceivable that there will emerge groups of 'ecological refugees' i.e. people leaving a now inhospitable area looking for somewhere else to live. Such areas may be local, regional, national or international. Whilst there may be some areas in Wales, such as coastal areas, which produce such 'refugees',

under the predicted scenario it is more likely that Wales would be asked to receive such displaced people, with impacts on individual and public health.

Amelioration and prevention of the potential adverse health effects of climate change
Many effects of climate change could be ameliorated through the prospective and co-ordinated action of a range of sectors. There will be technical solutions to many of the problems. Other problems will require greater provision of services, either permanently, to meet the change in incidence and prevalence of disease, or acutely, to cover emergencies arising from natural disasters. Although the predicted adverse health effects may to some extent be ameliorated through technical solutions, this will be a luxury which many populations will not be able to afford. Public health strategies must include measures to prevent damage to the environment and to promote sustainability as well as prepare for the consequences of inevitable climate change. Health impact assessments could include consideration of climate change impacts. Development of strategies should be set against the view that climate change is likely to be a relatively minor challenge compared to the many others facing the health services.

3.4.1 Findings from stakeholder consultations

Some of the stakeholders had access to relatively good information on climate change, while others had found such information to be of limited availability. There was general agreement that climate change could impact public health in a range of areas including, exposure to UV light, altered incidence of disease vectors, increase in water and food borne micro-organisms, altered pollution impacts and changes in the seasonality of disease. There may also be benefits arising from people having a more active lifestyle and eating more fruit and vegetables. Although none of the stakeholders' organisations had specifically incorporated climate change in their plans, they felt they had good plans in place which could cope with many of the short term impacts of climate change.

Quotes:
'Patterns of respiratory disease may change with changes in air pollution.'
'In drier summers the incidence of disease vectors, rodents and insects, would increase.'
'The barriers really are to do with the political will in the medical profession and funding of the health service.
'There are difficulties in getting reasoned information into the public domain.'
'We have a very fluid working environment, and continually adapt to changing patterns of disease but the organisations we deal with e.g. agriculture ministries, private companies, the water industry, all these bodies have a scepticism sometimes.'
'Research is required on health impact assessment, we don't know the links between things like housing and energy consumption and health.'
'More co-operation with university departments, entomologists for example.'

Understanding of climate change and reaction to existing impacts
Climate change was generally understood. Consequences for the UK were uncertain because they would occur over a long time period and because the effect on the Gulf Stream is unknown. The stakeholders felt that the consequences of climate change could include:

i. sea level rise and its impact on highly populated coastal areas in the UK
ii. possible changes in the distributions of disease vectors and possible epidemics of diseases not previously seen in UK and rising temperatures may increase the incidence of food borne disease (2 stakeholders).
iii. changes in agriculture, and increase in damage to skin from increased levels of UV radiation

Information on climate change had generally been gained from the media, New Scientist and Scientific American. There were mixed feelings about the coverage of the issue in the medical literature. One interviewee gained his knowledge from the epidemiological public health literature and visited the Website of DETR, Met. Office and WHO.

In general, activities had not been influenced by any recent unusual weather patterns. The recent outbreak of Encephalitis in New York may be linked to global warming; there is some evidence that the malarial mosquito is breeding in the SE of England.

Reaction to potential impacts

activities could be affected by changing weather especially in the medium to longer term. For example, there might be a higher incidence of skin cancer, a change in the patterns of communicable disease in both humans and animals (especially vector borne and seasonal disease), and problems with waste disposal particularly during flood events A number of disease mechanisms could plausibly be affected by a change in climate, although this is difficult to predict. The mathematical models for predicting the distribution of pollution in the atmosphere were based on existing patterns of weather, and if these changed it would affect the way of approaching, calculating and handling large chemical accidents. Areas cited as likely to be affected include:

i. the requirement to turn off some of the water filters during droughts which may lead to increased levels of Cryptosporidia.
ii. Pollution of subaquifers and rivers affecting quality of potable water.
iii. Domestic and industrial pollution during and after flooding affecting water supply.
iv. Distribution of disease vectors and increased incidence of diseases not common in the UK.
v. Change in the seasonal range of disease.
vi. Food safety
vii. Care of those in sheltered homes and residential care.

Many varied measures were proposed in order to avoid or reduce these impacts, including the following:

i. Skin cancer – continue and extend advice and policies on sun protection especially for children.
ii. Training of environmental health officers and environmental risk managers to deal with the impacts of climate change.
iii. Enhance, or at least maintain, our surveillance strategies for early warnings about changing patterns of communicable disease.
iv. Basic research in fields of entomology and zoonotic disease.
v. Advise and assist residential homes, catering and food retail premises on refrigeration and air conditioning.
vi. Improve coastal defences and possible plans of managed retreat.
vii. Improve the integrity and biological quality of the food chain, vaccinate against Salmonella.

When asked if there were any barriers to them undertaking such actions, most of the stakeholders stated that lack of evidence and uncertainty and the long-term nature of the problem led to apathy. Other barriers suggested were as follows:

i. Poor communication with veterinarians and public health doctors and microbiologists
ii. Difficulties in translating information into action to prevent disease, especially where there is a lead-time whilst funds are found.
iii. Difficulties in getting reasoned information into the public domain
iv. Political and economic barriers, eg funding of the health service.
v. Difficulties in securing long-term funding, the long-term nature of change versus the short termism of governments.

Some working practices can be changed quite quickly, especially if the consequences were thought to be major however, change would require considerable resources and capital.

The following potential opportunities or benefits arising from a changed climate were suggested:

i. Some skin conditions are helped by sun.
ii. Work patterns may change for the better, patterns of industry may change, unemployment may decrease which would improve health.

iii. Differences in food production, availability of fresh vegetables,
iv. Climate may affect leisure and exercise.

Many of the climate-related public health issues are indirect in nature. But with major climatic change it is possible that the allergens in the environment may alter, in particular with different flora we might get a different range of contact dermatitis.

Long term planning

The stakeholders prepared for a variety of factors in their long term plans, reflecting their different areas of activity. Factors cited included:

i. Incidence of disease, skin cancer, food poisoning
ii. Requirement for teaching facilities and research
iii. Infectious disease patterns including animal diseases
iv. Food safety and occupational health and safety
v. Changes in human activity, socio-economic factors and physical geography which may affect patterns of communicable disease.
vi. Emergencies – chemical spills, epidemics

Most stakeholders cited 3, 5 or 5-10 years as their strategic planning horizon. Where their role was to react to accidents, they did research on preventing them. Long term plans include the 10-20 year time lag between changes in UV radiation exposure and its clinical impact. However, climate change issues were not universally featured in plants.

Similarly, specific actions relating to climate change are uncommon, but people at risk of skin cancer were specifically advised to take care to protect their skin. The potential impacts of climate change were covered by the surveillance systems already in place.

Needs in relation to climate change

Greater certainty in the predictions about future climate would help as it would enable a more realistic hazard analysis and risk assessment of the environment, policies, procedures, operations of plants and so on. Certainty of the effects on patterns of communicable disease is needed. Political certainty, and understanding will be required.

Support for future planning and adaptation should come from the Assembly/Central Government because public health affects everyone and the infrastructure and resources required are so large. There may be a role for international bodies like the World Health Organisation. All stakeholders thought they could offer information, expertise and experience relevant at all levels. Particular expertise is available in the fields of dermatology, disease control, and communication of risks of disease.

3.4.2 Recommendations

1. The Assembly should consider how its policies and strategies for human health will be affected by climate change.
2. Research is required on the effects of climate change on insect vectors.
3. The public need to be informed of the relevant risks, such as increased probability of skin cancer.
4. The Food Standards Agency to consider whether modified advice on food hygeine will be required.

4. IMPACTS OF CLIMATE CHANGE UPON THE WELSH ECONOMY

4.1 Overview

This section gives an overview of economic data on the Welsh economy, sector by sector, and scenarios for changes. Table 10 shows a forecast of growth in industrial output for different Welsh sectors:

TABLE 10: Forcasts for growth in industrial output in Wales by Sector *(source: Cambridge Econometrics, Regional Economic Prospects)*

Wales GDP	***1996***	***1997***	***2000***	***2005***
Agriculture, Forestry & Fishing	453	462	488	544
Mining & Quarrying	114	108	86	78
Coal	85	79	58	52
Oil & Natural Gas	3	3	2	2
Other Mining	26	26	26	25
Manufacturing	6,278	6,529	7,417	8,775
Food, Drink and Tobacco	631	652	721	818
Text, Cloth & Leather	189	190	192	192
Wood & Wood Products	86	87	88	86
Paper, Printing & Publishing.	495	516	586	644
Manufactured Fuels	177	184	201	234
Chemicals & Man-made Fibres	746	772	851	978
Rubber & Plastic Products	314	327	378	457
Non-Metal Mineral Products	226	232	245	269
Basic Metals & Metal Prod.	1,413	1,455	1,597	1,841
Mechanical Engineering	252	268	328	419
Electronics., Elec., Inst. Eng.	914	964	1,170	1,527
Motor Vehicles	400	442	597	793
Other Transport Equipment	187	188	195	213
Other Manufacturing	248	254	268	303
Electricity, Gas & Water	673	691	730	796
Construction	1,260	1,272	1,374	1,477
Services	12,044	12,426	13,483	15,743
Retailing	1,341	1,383	1,485	1,691
Distribution	901	932	1,010	1,184
Hotels & Catering	680	707	789	915
Transport & Communications.	1,630	1,698	1,902	2,352
Banking & Finance	653	694	779	960
Insurance	129	133	140	152
Other Business Services	1,602	1,664	1,814	2,224
Public Administration & Defence	1,459	1,464	1,498	1,601
Education & Health	2,772	2,848	3,086	3,532
Other Services	876	905	979	1,132
Total GDP	21,321	21,963	23,965	27,618

Box 1: *GDP in Wales : recent and projected changes. Source: Cambridge Econometrics, Regional Economic Prospects*

	(£ 1990 millions)				(Per cent per annum)			
GDP in Wales	***1996***	***1997***	***2000***	***2005***	***1985-90***	***1990-95***	***1995-2000***	***2000-05***
Agriculture, etc	453	462	488	544	-1.6	-1.1	1.6	2.2
Mining & Quarrying	114	108	86	78	-1.6	-14.7	-6.0	-1.9
Manufacturing	6,278	6,529	7,417	8,775	7.7	0.8	3.9	3.4
Electricity, Gas & Water	673	691	730	796	-5.7	2.3	3.0	1.7
Construction	1,260	1,272	1,374	1,477	8.7	-2.0	1.0	1.5
Distribution, Hotels & Catering	2,922	3,021	3,284	3,790	6.2	0.2	2.8	2.9
Transport & Communications	1,630	1,698	1,902	2,352	5.4	2.2	3.8	4.3
Financial & Business Services	2,385	2,490	2,734	3,335	5.5	0.2	3.3	4.1
Government & Other Services	5,107	5,217	5,563	6,265	2.2	1.8	2.0	2.4
Total GDP	**21,321**	**21,963**	**23,965**	**27,618**	**4.5**	**0.7**	**2.7**	**2.9**

Cambridge Econometrics (1996) forecasts the Welsh economy to grow at 2.9% per year between 2000 and 2005. This growth is unequally spread across industry. The natural resource based industries Agriculture, Mining and quarrying and the Utilities (including the water industry) are forecast to grow at 2.2%, -1.9% and 1.7% respectively - below the projected rate of growth of the economy as a whole. Predicted growth is fastest in Financial and business services (4.1%), Transport and communications (4.3%) and Manufacturing (3.4%). The natural resource based industries especially Agriculture and Water services, are more dependent on climate than the Manufacturing and Service sectors. Superficially this suggests that in terms of overall output of the economy Wales will become less vulnerable to climate change over the next ten years. However, because the utilities are monopoly suppliers of crucial services, poor performance within these industries would have impacts elsewhere in the Welsh economy disproportionate to their small size. The NAW has set itself strategic targets for growth in GDP (National Assembly for Wales 1999). Wales is planning to attain 84% of UK GDP by 2002, 87% by 2006 and 90% by 2010, which will mean growing 0.78% faster than the average for the UK. Economic forecasts for Wales beyond the first decade of the 21st century are not available. Economic development is intrinsically difficult to forecast in the long term especially for small nations. Economic performance is influenced by economic activity and policies occurring outside the nation, for instance adverse exchange rates which discourage manufacturing investment.

As part of the UKCIP research programme, non-climatic scenarios were prepared by SPRU to assist in the conceptualisation of how the social and economic map of the UK might look by the 2020s and 2050s. The SPRU study uses scenarios developed for the Natural Resources and Environment Panel of the UK Foresight Programme. These consist of qualitative ("storyline") and quantitative elements. They develop macro-economic, demographic and social data for the 2020s and the 2050s for the 4 different scenarios and a business as usual trend rate. The scenarios assume differences in the extent to which people balance consumer and community interests and how international a nation becomes in its outlook (autonomy/interdependence axis). Variation along these two axes produces the following four scenarios.

- Local stewardship - LS (in the autonomy and community quadrant) ie low economic growth, priority on green issues
- Provincial enterprise - NE (autonomy and consumerism) ie private consumption values coupled with policy-making to reflect regional and local concerns
- World markets - WM (interdependence and consumerism) ie private consumption and a highly integrated world trading system
- Global sustainability - GS (interdependence and community)ie emphasis on global social and ecological values, with strong collective action in dealing with environmental problems

Unfortunately these scenarios have not been disaggregated below the level of the UK so no projections are available for Wales. Current or business as usual development is seen as leaning towards the consumerism side of the axis and about midway on the autonomy/interdependence axis. Some of the principal projections for the UK for today, business as usual (BAU) and each of the four scenarios is given in the table below.

***Table 11: Socio-economic scenarios for the UK for 2020**.BAU, business as usual; NE, provincial enterprise; LS, local stewardship; WM, world markets; GS, global sustainability (Berkhout et al 1999).*

	Today	**BAU**	**NE**	**LS**	**WM**	**GS**
GDP growth rate (%/yr)	2	2	1.75	1.25	3	2.25
Share of value added - services sector Share of value added - industry sector Share of value added - agric. Sector	71% 27% 2%	87.6% 11.9% 0.5%	74.5% 23.25% 1.25%	73% 25% 2%	80% 19.25 0.75%	78% 20.5% 1.5%
Population (million)	58.5	61	61	60	62	61
No. of Households (million)	24.5	28	25.5	23	31	27.5
Agricultural land (% cover)	75	72.5	73	76	71	71
Growth in water demand (%/yr)	0.2	0.5	0.5	-0.5	1.0	0.0
Area of SSSIs (000 ha)	2000	3800	1500	4500	2500	5500
Zones protected by coastal defences (000 ha)	240	No trend	235	220	240	225

All the five scenarios suggest that the economy is likely to carry on growing at near its trend growth rate. There is likely to be a further expansion in the share of the service sector relative to now and most likely a contraction in the agriculture and manufacturing sector. The population *of the UK* is forecast to grow but this growth is likely to be in the South east of England due to internal migration from Scotland and Wales and other regions of England. Devolution might change this pattern of migration.

The projections give a mixed view of whether the biodiversity indicator based on the area of land designated as a SSSI is likely to expand or contract.. Most project an expansion. Of course if the area of land in agriculture carries on shrinking and if agriculture becomes more intensive there might still be a diminution of biodiversity despite an expansion in designated area. Except for the Local Stewardship scenario (characterised by low economic growth rate and priority to 'green issues') all suggest a continued expansion in water demand for the UK. Again the Welsh picture will depend on whether migration occurs into or out of Wales.

4.1.1 Recommendations

1. Socio-economic scenarios need to be developed for Wales, taking account of the regional economic statistics to provide a more detailed picture of how the interaction of climate change and socio-economic scenarios might impact on Wales.
2. Organisations need to consider how corporate strategic plans should be informed by a wider range of issues than currently, due to the high degree of interaction between sectors which climate change will highlight.
3. The Assembly needs to develop economically viable strategies which recognise the interactions between climate change, agriculture, conservation and water resources.

4.2 Agriculture and forestry

In 1997 Agriculture, Forestry and Fishing accounted for less than 2% of the Welsh economy. Its rate of growth has been slower than that of the rest of the economy for the past 20 years and was actually shrinking between 1985 and 1995. It is expected that the industry will at least grow more slowly than the average for the Welsh economy (Table 10).

4.2.1 Impacts of Climate Change

The impact of climate change on agriculture and forestry in Wales may be felt at three levels. First there may be biological impacts on individual plants and animals. Second it may be necessary for farmers to alter the management of their farm in some way. Third there may be impacts through the global market place on the range of agricultural enterprises which would be profitable in Wales (market induced changes). Each of these changes will be considered in turn, and although they are treated separately it is important to realise that will be clear and important interactions between the impact of climate change on plant and animal species, the management of the farm, and the range of enterprises it includes. There have been a number of reports by MAFF on the inputs of climate change in agriculture

Biological impacts

Climate change can have an impact on the growth and well-being of crops and animals in several ways. These may include increased maximum and minimum temperatures, impacts of drought (in the summer) and waterlogging (in the winter), impacts of storms, elevated ambient levels of CO_2 and increased ultra violet radiation (Although the latter impact is not discussed in this report, it may have important impacts on plant growth). Whilst any of these changes (eg elevated CO_2) may have a certain type of impact on a crop or animal when it occurs in isolation (eg increased yield of cereals), when several changes (eg increased CO_2 and summer drought) occur together the impact may be very different. In understanding climate change impacts, it is important to recognise the interaction with other environmental challenges such as nitrogen deposition, ozone pollution, overgrazing and acid rain. The combination of confounding factors makes the interpretation of causes and effects complex.

Crops and grass

The basic impacts of climate change on all crops, including grass are basically the same, and are described below.

Cereals

When acting alone warm weather hastens crop development and brings earlier harvests. However in cereals, the reduced duration of the growth period tends to reduce yields. Similarly a shortage of water tends to slow growth development and reduce yield. However in the field, warm weather causes earlier flowering than usual and this causes yield formation to occur earlier in the summer, which is normally before soil moisture reserves have been exhausted. So historically in the UK hot dry summers have been associated with higher than average yields. However, the exact impact on yields depends crucially on the timing of the drought relative to the development of the crop, and this may vary from year to year and from location to location.

The exact impact of drought may be effected by the level of ambient CO_2, which by 2080 is expected to reach concentrations approximately double today's levels. Elevated CO_2 stimulates plant growth and may approximately compensate for reduced yields caused by elevated temperatures. Experiments suggest that the combined impact of elevated CO_2 and increased temperatures together should cause an overall decrease in wheat yields of about 1%, although there is still much uncertainty; some experiments suggest much larger effects. . This is against a pattern of historical annual increases in actual wheat yields of 2% achieved through improved varieties and management.

Pests

The impacts of climate change on the pests of crops are hard to predict, as the different pest species may react in different ways. However, generally weed problems should be reduced as weeds tend to suffer from drought to a greater extent than crops, as they root more shallowly. Warm weather leads to higher densities of insect pests, although prolonged drought can serve to reduce some insect populations. Aphids populations grow very rapidly in warm conditions and may have a larger impact than at present, both directly, and as vectors of viruses. Hot, dry summers should reduce the incidence of many crop diseases, which tend to be favoured by warm, wet weather between April and July. But the autumn and winter weather also has a major impact on the influence of many diseases (eg mildew, net blotch and yellow rust) as mild weather enables the levels of inoculum to develop unchecked and thereby increase infection rates. One final issue concerns lodging of crops which tends to be greater in wet summers, and should therefore be reduced in hotter, drier summers.

Grass and fodder crops

As with cereals, grass growth tends to be increased by higher CO_2 concentrations and slowed by hot, dry conditions, and both its quantity and quality can be severely effected by drought. Maize has become increasingly popular as a fodder crop in recent years. Under higher temperatures it tends to mature 3-4 weeks earlier than usual, and give yields of only 70% of normal yields. In addition it may make poorer quality silage than usual due to high dry matter content in the grains, which need to be cracked before feeding. In addition to complicating grass conservation and grazing management, climate change may have a direct impact on the quality of any silage. High temperatures tend to reduce silage quality through effects on the microbiology of the ensiling process

Trees
Trees tend to grow faster in conditions of elevated temperatures and elevated CO_2, although it is not clear whether or not they ultimately reach a larger size. Summer drought may cause some die-back of tree roots, and if this was then followed by periods of intense storminess in the autumn / early winter there is a higher risk of the trees being blown over (wind throw). Hot, dry summers increase fire risks. The exact response of trees to climate change will vary with species, and the competitive interactions with a forest may also be altered relative to the current situation. However, current data are too poor to predict exact species responses. A further potential impact of faster growth is an impact on timber quality. Whether or not this impact is positive will vary with tree species.

Forest pests
As in agriculture there is the potential for forest pests to increase in prevalance due to decreased winter mortality and favourable summer weather. Of particular concern is the spruce aphid (*Elatobium abietum*), which is the main defoliator of Sitka spruce in the UK. Populations of this pest can double on drought stressed trees, and this combined with improved winter survival may lead to major losses in the forest sector.

Animals
Perhaps the major direct impact of climate change on farm animals will be through heat stress. This has direct physiological impacts on animals, but also tends to reduce their feed intake, which then has knock-on effects on their growth, fertility and general health.

Heat stress
Dairy cows begin to suffer from heat stress when temperatures exceed 24 – 25 ^{o}C. This reduces their dry matter intake (by about 10%) and increases respiratory rates. Their energy requirements tend to be increased by up to 25%, and this may decrease yields by up to 30%. The cattle also suffer general deterioration of condition and increased susceptibility to disease. Similar effects occur in beef cattle and liveweight gain can be reduced by up to 25% in hot conditions as intake of food declines. Housed cattle may suffer more from heat stress, and associated health and welfare problems, than outdoor cattle. Heat stress in sheep tends to be greatest at times of gathering and handling. But also in early lambing flocks, tupping takes place in July/August and rams may be affected by heat stress. In this situation fertility and lamb birth percentages may be reduced too. The interaction of reduced food intake, caused by heat stress, and poor quality forage, can exacerbate the impact of heat stress acting in isolation. This may be particularly important in summer calving dairy cows, grass-based beef systems and suckler cows

Both pigs and poultry suffer from heat stress, and this can impact their productivity. Whilst high temperatures reduce pigs' food intake, and hence reduce growth, the degree of impact varies substantially with breed, nutrition, group size, body weight, bedding and floor type. Heat stress has been associated with reduced fertility in sows, with reduced egg size and quality in laying hens and reduced growth and increased mortality in broilers. Many of these problems can be offset through improved building design and management.

Pests and diseases
Many parasites of sheep tend to decrease in hot summers (eg roundworms, blowflies, ticks). However the impact of climate change on animal health remains largely unresearched and it is difficult to identify particular problems given present knowledge.

System level changes
The major impacts on Welsh farm systems will arise through a requirement to deal with intensive rainfall in the winter and to manage grazing resources during the summer.

Increased winter storminess and intensive rainfall may require redesign of farm buildings. It may be advantageous to increase the roofed areas of farmyards and to ensure that drainage and storage facilities are adequate to prevent localised flooding and pollution. Vehicular, and stock, access to land may also be problematical, and there may be a need for increased investment in farm tracks. There may be problems in disposing of slurry and manure which is traditionally done over winter, and there may be a need for increased slurry storage facilities in some situations.

The season of grass growth may be extended, with warmer winters stimulating earlier growth in the spring and a longer growth period in the autumn. This may enable stock to be outside for longer periods than at present, but the risk of poaching may restrict early spring grazing in some areas. However, after a dry summer it should be possible to utilise autumn grass for longer than at present. It may be necessary to change patterns of grass conservation and utilisation, particularly if cattle need supplementary feed in mid-summer. Autumn silage may become more popular, even though it is of poorer quality than earlier cuts. The impacts of climate change on swards and livestock in unimproved upland situations are largely unknown, and this remains an area for future research. In sheep systems, the warmer weather and earlier grass growth should enhance lamb survival and growth on many farms. Conversely there is the possibility that periods of storminess and intense rain may have a detrimental effect on lamb survival on some farms. But overall the prospects are positive. The major concern relates to the quantity and quality of summer forage available, and the impacts on lamb growth, and condition and fertility of ewes.

Other system-level impacts pertaining to animals are the need to supply shade, hence a programme of tree planting may be advantageous in the near future. Livestock will need an adequate supply of water, perhaps needing enhancing of on-farm water storage facilities. Pig enterprises may need to consider offering sprinkler systems or wallows in mid summer. It may also be necessary to alter the design of buildings which will house pigs, poultry or indoor beef.

Arable

Arable farms should see easier harvesting conditions and reduced drying costs (although there may be a need to cool grain after harvest). Growers of maincrop potatoes and other vegetables may need to invest in cool stores. The drier summers may lead to some difficulties in establishing good seed beds for winter crops, but the exact magnitude of this impact will vary with soil type and from year to year.

Irrigation

A common response to water stress in crops is to irrigate for some or all of the summer. This may be necessary for high value crops and potatoes, but its necessity on grasslands and other crops remains unclear. If the costs of water are low, and the cost of investment in the irrigation equipment can be managed efficiently, then it may be advantageous to irrigate grassland on some intensive dairy units. The need to irrigate in Wales will be far less than in parts of England, but even so on-farm water storage may be advantageous in some areas. However, the exact economics of irrigation depend critically upon prevailing market and legislative conditions

Forestry

The future of woodlands in Wales is the subject of current debate (National Assembly 1999). Four scenarios which incorporate socio-economic issues have been identified, but none of these includes potential impacts of climate change.

Market-induced changes

Land use is largely determined by the profit received by the land manager for that use. One important element of profit relates to the price received for the product, which in turn is affected by the supply of that good in the market. The profitability of commodities produced in Wales is a function of the supply from other countries, and international demand. Thus if climate change were to have catastrophic negative impacts on the sheep industries of New Zealand and Australia, then there may be a beneficial impact on the profitability of Welsh sheep farms.

A recent report (Parry *et al.* 1999) has considered the impact of global changes in supply and demand on several land uses in England and Wales under a range of future scenarios. This suggests that regardless of the state of the climate and world markets the unimproved upland grasslands, which dominate Wales, remain as unimproved grasslands. However, it is likely that there will be a significant emergence of arable enterprises in the east of Wales, whilst under certain scenarios there may be an increase in the amount of lowland leys in the more fertile areas of western Wales.

Relative importance of climate change versus other drivers of land use change in the 21st century
Generally the magnitude of climatic changes that are predicted for 2050 are well within the normal levels of annual variation that have been observed in recent decades. None of the effects are likely to have a catastrophic effect on agricultural production. The changes will happen gradually, giving farmers time to adapt. Good management should enable these adaptations to occur with the minimum of stress. When compared with other drivers of change which will impact land use in Wales in the next 50 years climate change is probably of lower importance than the impacts of globalisation, technology and policy. However several uncertainties do remain uninvestigated and should be addressed in the near future.

4.2.2 Findings from stakeholder consultations

Consultation was conducted with six professionals working for a range of organisations with a major involvement in land use – Forest Enterprise, FRCA, CCW, National Trust, CLA and FUW. All six have both a local and all-Wales presence, and are well placed to comment on climate change impacts on all aspects of land use.

Reaction to Existing Impacts
Consultees were asked whether recent unusual weather had influenced their activities. Half had noted a change in weather recently, but also questioned whether this was indeed 'unusual', or simply part of the natural cycle of climate change. This recent 'unusual' weather had caused a range of impacts:

i. increased flooding of agricultural land on floodplains creating management problems
ii. wet autumn weather affecting normal agriculture activities such as autumn drilling, hedging etc
iii. storms damaging upland conifer plantations in exposed locations
iv. hot dry summers causing fires and drought in conifer plantations
v. mild winters allowing over-wintering of spruce aphid, followed by spruce defoliation in spring.

When asked whether future changes in the weather were likely to affect their activities, they all agreed there would be profound effects on many aspects of land management. Representatives of the farming unions felt that all agricultural activities in the countryside would be affected. In particular, traditional winter activities would become more problematical, because of difficulties 'getting on the land'. Drier summers could affect the range of viable crops and reduce summer grass yields. There was also general agreement that sea level rise will inundate coastal properties, raising issues as to whether coastal defences should be heightened. Despite all these concerns, the issue of climate change is of low priority in the agricultural industry compared with more immediate problems of dropping farm incomes, EU agricultural policy etc. The forestry industry believe they will be profoundly affected, particularly with regard to the need to change tree species, the effects of increased storminess, and increased survival of spruce aphid. It was also thought that agri-environment schemes will need to adapt, and changes in agricultural regimes generally will require a corresponding shift in the technical ability of staff of the advisory services and farming unions.

Long term planning
Climate change is allowed for in strategic planning. The farming unions and FRCA do not produce strategic plans, whereas the National Trust and CCW produce plans which operate over a 3-10 year timescale. The forestry industry considers that forest management plans are strategic plans, and these encompass a period of up to 50 years for conifer plantations, and even longer for broadleaves. Because of this long timescale, there is little flexibility to allow for adaptation to climate change. There was a consensus that climate change should feature in strategic plans, and monitoring should be a component of these plans, providing information on change and needs for response.

The forest industry clearly has to plan its future planting very carefully. Much of Wales' conifer forest is due to be harvested in the next 10 –15 years, and much thought will be necessary prior to undertaking any major new planting. The issues of concern clearly relate to species selection (both for biological and market reasons), pest management, windthrow and carbon sequestration.

Reaction to Potential Impacts

There has been no action to deal with the likely impacts of climate change, but the interviewees were trying to get a better understanding of the potential impacts and identifying research needs, and keeping abreast of any evidence of change.

The impact of the predicted changes is often uncertain or unknown, so it is difficult to predict how activities might be affected. Despite these uncertainties, stakeholders put forward a wide range of issues which would affect their work and activities if they occur.

In agriculture, issues raised were:

i. warmer winters will allow greater success in over-wintering of pests and weeds
ii. warmer winters will affect seasonality of grass production
iii. hot, dry summers will limit yields of grass and other crops
iv. sea level rise will result in inundation of coastal agricultural land, which would be unacceptable to the farming community
v. increased flooding on floodplains will occur
vi. increased temperature and CO_2 concentrations should be beneficial for crop growth
vii. a range of new crops may become viable
viii. wetter winters will create problems of access to land
ix. wet winters will increase leaching of fertilisers to watercourses and increase erosion
x. management of upland heath by burning may become impossible
xi. dry summers may result in a need for supplementary feeding of stock

In the forest industry, the predicted changes in climate would be ‘across the board’; main issues were:

i. warmer winters will allow greater over-wintering of pests, especially spruce aphid
ii. increased storminess would increase windthrow risk
iii. hot dry summers will result in drying of peat and consequently root death
iv. trees not conditioned to cold may be devastated by a rare cold spell

Stakeholders suggested only a very limited set of measures to reduce the potential impacts of climate change. Actions might be limited to monitoring change, with little that could be done at the level of the individual. Plant breeding could ensure good cropping despite summer drought, changes in cropping patterns or tree species may be needed. The forestry industry will need more confidence that change will occur before it will respond, since changes in management will need to be seen as financially sound.

Major barriers to taking action are the uncertainty of the predictions, lack of information on the impacts of climate change, and financial resources. Inertia and lack of belief that change will occur also prevented action being taken. One view was that it would be probable that change would be accepted rather than take action to limit it. Other points raised were:

i. there is no overall strategy to ensure efficient use of energy
ii. climate change is a large scale problem and it is difficult to know what can be done in isolation
iii. there is a lack of commitment at Government level to issues of climate change
iv. there are always other, more pressing, commitments

Stakeholders involved with agriculture thought speed of change with regard to cropping practice and new enterprises would vary from ‘rapid’ to ‘gradual’; management can gradually alter in response to climate change. In the forestry industry, speed of change would be slow, as it is only possible at the replanting stage. Moving site by farming organisations, is only possible where land becomes unsuitable for agricultural production, eg if inundated by the sea.

As a group the stakeholders identified many of the important issues concerning the impacts of climate change on agriculture and forestry. However, the stakeholders were all national organisations, who we may expect to be well informed. A similar survey of farmers may provide very different results. However, several potentially important issues did not arise, such as animal welfare, food safety and market impacts of wide scale climate change in the UK and around the globe. This suggests that perhaps more emphasis could be given to communicating the points of importance in these areas.

A potential benefit from climate change, might be an increased range of enterprises and crops, including wider adoption of biomass forestry. Reliability of harvests may increase and theoretically there will be better rates of photosynthesis and productivity in forestry. These changes could require growth of advisory work on farm management. Agri-tourism might also become more popular. There were fire and storm contingency plans for forests and properties, which might be adapted to deal with climate change impacts, but in general contingency plans were more appropriate for local authorities.

Relatively little mention was given to the option of developing new enterprises under a new climate. Given the policy requirement to encourage diversification on farms, it is perhaps a little disappointing, but realistic, that this issue was not more prominent.

Needs in relation to climate change
If there was greater certainty in relation to climate change impacts, most consultees would be more likely to take action and more detail. Better information would allow them to decide how to respond and if necessary change skills. They would be able to use the information in defining their policies, in planning new agricultural cropping regimes or land use strategies, changing the nature and composition of forest plantations, and passing on advice to their members, the public, or other organisations. Greater certainty in the predictions would provide justification for the time and expense of taking action. An alternative is to demonstrate change by monitoring.

The general view wasthat support for actions in adapting to climate change should come from Central Government (at Wales, UK and international level), and where appropriate through the Agencies. This was necessary because climate change is such a major issue, because only Government can put in place measures to reduce greenhouse gas emissions, and because Government cannot expect companies or individuals to react if they themselves do not. All agreed that central guidance is essential, because a strategic approach is needed which considers land use policy as a whole. There was a degree of scepticism as to whether a strategic approach was possible as it had not been in the past, for instance regarding development on floodplains.

The consultees are probably right in suggesting that agriculture will be able to adapt gradually to changes. However, this is not a cause for complacency, as evidenced by the stakeholders' calls for more certainty in the climate predictions. It is perhaps disappointing that all of the stakeholders felt that support for the future changes should come from central government and that none felt that industry, Unions, or indeed land owners themselves could provide any funding input to the process. Perhaps this reflects the relatively low level of priority given to climate change by farmers, when compared with other current issues in the agricultural sector.

4.2.3 Recommendations

1. The Assembly should give strong support and adequate funding to agri-environmental schemes such as Tir Gofal, and such schemes should take full account of the impacts of climate change
2. The most important research needed by Welsh agriculture and forestry include the following:

   i. Impacts of climate change (including elevated CO_2) on grass growth and quality in improved grasslands, alone and in interaction with other environmental challenges such as nitrogen deposition, ozone pollution, overgrazing and acid rain.
   ii. Impacts of climate change (including elevated CO_2) and grazing pressure on the semi and unimproved grasslands of the uplands.

iii. Impacts on systems of grass conservation and on the ensiling process.
iv. Impacts of climate change including effects of elevated CO_2 on the pests and diseases of farm animals,
v. Impacts of climate change on the welfare of farm animals, eg effect of elevated CO_2 on animal performance
vi. Impact of climate change on the productivity of Welsh forests and woodlands

3. There is a need to increase understanding of how climate change will affect the major international competitors for products of importance to Wales, eg lamb.

4. The current debate on the future of Welsh woodlands should include consideration of climate change impacts.

5. Information on climate change impacts with greater predictability needs to be made available to the agriculture and forestry sectors.

4.3 Manufacturing industry and market services

The section describes the views of stakeholders in the manufacturing and market service sectors, which contributed £12.1 billion of Wales's £22 billion GDP in 1997. Transport, energy and water infrastructure are covered separately. Interviews were conducted in summer 1999 when climate change levy (CCL) was a more pressing concern to business than the impact of climate change. *Mitigation* of climate change is outside the scope of this report. For each broad sector we describe the **vulnerability of sectors** to climate change, an assessment of the **relative importance of climate change** compared to other business risks and **adaptation to climate change** undertaken by firms. There was a great commonality in the business requirements from central Government. These are brought together in Box 6 at the end of section 4.3. Firms in these sectors make up the majority of businesses operating in Wales. Interviews were skewed towards larger firms since it was expected they would have planning horizons long enough to include times when climate change impacts are likely to be discernible.

4.3.1 Findings from stakeholder consultations

The Box below summarises the main points made by businesses in manufacturing:

Box 2: Summary of main points made by stakeholders

- Climate change impacts were largely too far in the future to enter in the strategic planning process
- Some of the changes in weather arising from climate change can be of benefit: reducing the heating costs in winter, increasing the demand for outdoor and recreation products
- The most commonly stated cause of disruption due by to extreme weather events was transport links. This effected the supply of raw materials and the distribution of finished goods.
- The production of biological raw materials was influenced by climate.
- Power transmission equipment and critical heavy industrial plant was designed to withstand extreme conditions.
- Older and more standard structures were vulnerable to damage by weather; insurance was often the most cost-effective adaptation response.
- Aside from the uncertainty, there was no specific barrier preventing adaptation to challenges posed by climate impacts.
- The Insurance industry would seek to reflect the costs of climate change in its insurance pricing policy. Substantial changes in value of claims would result in higher premiums. The industry could geographically discriminate different densities of claims.

Generally, industry has a strategic planning horizon of up to 5 years. Market conditions and demand for goods, competition, raw materials supply and climate change mitigation policy were more pressing issues than climate change impacts. Box 3 describes some of the views expressed by firms. This sentiment was echoed by CBI Wales, which did not consider the impacts of climate change a high priority for industry. Climate change could have some impact on transport infrastructure, hence distribution of raw materials and finished goods, and on the supply of energy and water. In itself climate impact would be a minor direct influence on decisions of where to locate. For some firms changes in weather could also affect the comfort levels and structural integrity of their buildings. Most large businesses had a manager responsible for environmental issues on a day-to-day basis. They had a good appreciation of the likely effects of climate change. Consultees in the chemicals, metals and pulp/paper industries all had an excellent grasp of the subject. Firms that had experienced freak weather conditions in the recent past tended to be more interested in the issue.

One consumer goods manufacturer had taken a number of actions to reduce its vulnerability to extreme weather effects. Contingency arrangements had been made to deal with heavier snowfall, which might prevent workers from travelling to work. The site was fully protected against power failure, with 100% generating capacity on-site (and used on several occasions). Experiences from previous storm damage now underlie the company's insurance policy, by shifting the nature of cover. Finally, action had also been taken to improve the roof and upgrade other systems in light of previous storm damage. At another site, one manufacturer that suffered extensive damage in a 1988 storm has gradually re-roofed its 50,000 m^2 site, at considerable cost, to help prevent future roof damage.

Box 3: Views expressed by stakeholders

Attitudes towards Climate Change

"The rate of climate change is such that we don't need to plan ahead. We will take it as it comes, unless the rate of change increases."
"Climate change is such a gradually developing scenario, we would be able to see the train coming."
"Climate change is not something that impinges much on our consciousness."
"I don't think business is concerned quite frankly about climate change."
"There are bigger environmental "fish" to fry, for example, road traffic."
"Not too many people are taking climate change that seriously…there is nothing to relate to."
"There are lots of 'live' issues; climate change is not high up on the list."
"Realistically, it´s not an issue, since our business is not affected."
"Climate change is not on the horizon – there are more pressing issues."

How to get industry more involved

"There are no barriers to taking action against the effects of climate change, if it makes business sense to address these issues."

"If a study could show that there would be a temperature rise of x deg. C in 15 years time, this would be taken into account in our strategic plans and therefore our product ranges."

Pulp and paper production

Pulp and paper production is not seen as a 'complex' or 'temperature sensitive' operation, and companies have generally not been seriously affected by unusual weather. Overall, therefore, the sector does not believe it is susceptible to changing weather patterns in the future and has not instigated any adaptation measures. Possible threats mentioned included: power failures; rain damage to warehousing; and downtime on out-door wood chip conveyor systems and high sided wagons, during periods of high winds. At one plant, it was suggested that "4-5 days of high winds could lead to a cut back on production levels." Interestingly, a paper manufacturer had started a 'climate change awareness session' in 1999 as part of its general environmental awareness training programme for employees. Feedback from employees showed that they underestimated the levels of potential impacts.

It was felt that climate effects would have an impact upon forest plantations and product distribution.

An increase in summer temperatures could have implications for worker health and safety. Temperatures in mills are already high. However, many paper companies have sites overseas, in countries with both hotter and colder climates, such as Spain and Finland, so firms expected to be able to adapt. One company commented that opening doors for ventilation caused a potential noise nuisance.

Two particular process issues were mentioned:

i. An increase in the temperature of fresh water intake would raise process and effluent temperatures. Elevation of between 0.5-1 ^{o}C would not be a problem through design tolerances, however a rise of 5 ^{o}C would influence production.

ii. A board manufacturer considered more frequent rain to have an adverse impact, since increased moisture content of the wood lengthened drying times and elevated costs.

Companies planned up to 10 years ahead, longer than many other sectors. No company took account of future climate or weather conditions, although there was recognition that there could be some influences on their business from it. One company noted that: *"We've only ever thought of our impact on climate change, not vice versa."*

Chemicals/Petrochemicals

Chemical plants are designed to withstand extreme weather conditions including wind speeds of more than 100 mph. Although there appears to be little perceived threat from an increase in the frequency of gusting, any increase in actual wind speeds during storms might give cause for concern. Production facilities in this sector are generally not sensitive to ambient temperatures, since processes already operate at elevated temperatures. Elevated temperatures might even reduce costs. Industries in this sector tend to have smaller workforces operating in strictly (computer) controlled, air conditioned environments, with only small amounts of exposure to process production equipment.

Companies have generally not been affected by any unusual weather patterns. One company noted that during times of heavy rainfall the adjacent river backed up into their surface water system. However, this particular problem was now being rectified. Many plants in this sector are located on flat ground, often close to the coastline. However, there was no perceived threat from sea level rise.

One company noted that their surface water discharge might become significant if the flow in the adjacent stream declined in drier summers. However, their current discharge complied with Environmental Quality Standards (EQSs) to such a degree that normal discharges could be maintained even during extremely low flow periods in the river. Chemical companies tend to be located close to main transport networks, such as motorways or ports, with no apparent difficulties identified in maintaining distribution of product during extreme conditions. Some companies also utilise pipelines for distribution. Pipelines might experience certain problems from small-scale subsidence during prolonged dry periods.

Companies typically plan 5 years ahead (one company had a 25-year global plan) and look at a large number of issues though the impact of climate change is not one of them. Consolidation within the petrochemicals industry is leading to restructuring of operations, so long-term plans in Wales for all chemical companies are uncertain. Climatic impacts on UK companies in this sector may be felt more strongly outside the UK, for example in developing countries, where rapidly expanding markets mean faster growth in operations.

Consumer Goods (Food, Drink, Tobacco, Clothes, Toys)

Although climate change was really not perceived as a problem, manufacturing facilities differed widely in their susceptibility to changing weather patterns. One company had noticed the impact of hotter weather on daily operations, since their production process was sensitive to changes in humidity and temperature. Longer, hotter summers had increased the cost of cooling within another factory and a kilowatt/hour variation could be identified and correlated with ambient air temperatures.

A manufacturer of meat products, with a business integrated from rearing to packing, noticed that temperature changes could induce animal heat stress, and hence absolute performance. Ventilation and building design were therefore important to consider, particularly for new buildings. In contrast, a brewery noted that they were neither heat nor cold sensitive, having stable plant conditions.

Working conditions can be affected by process temperatures. In order to avoid worker discomfort, a clothes manufacturer who could not afford air conditioning scheduled production times to avoid hot periods of the day by introducing night shifts. The high residual heat from the process meant the heating system had not been used for 13 years.

The greatest potential impact of climate change is on the transport of both raw materials to the point of manufacture and the distribution of products. One food manufacturer in mid Wales had experienced problems from river floods disrupting traffic movement (e.g. major dislocation on the River Wye). Over the last three years, another firm had also lost around six production days due to flooded roads, which prevented employees getting to work. There was a belief among firms that more flood events would occur in the future, hampering distribution unless infrastructure was significantly improved. Distribution by another manufacturer had been affected by extreme, icy road conditions. This forced mid-Wales based companies, which serviced south Wales, to travel east, via Shrewsbury, “where roads are gritted well” and then on to the motorway network. Many companies operating away from the A55 and M4 were likely to experience similar distribution problems.

A range of other issues relating to climate change were mentioned by companies, including:

i. Supply of raw material – a tobacco manufacturer noted the biggest business threat from climate change was disruption to overseas production. It stored one year’s stock in case of a collapse in world production – a contingency against weather impacts (e.g. El Niño) on harvests.
ii. Market demand – hotter summers were considered important factors in changing consumer tastes, for food, drink and other consumer goods. For example, consumers might cook less, opting for more cold meats and salads. Drinkers might shift from consuming room temperature ales and beers to cold lagers, in response to hotter days and nights during the summer months. Outdoor toys and games represent around 5% of the UK market. Any change in temperature and rainfall is likely to affect sales patterns and hence patterns of production. For example, more bulky garden toys would be sold instead of smaller indoor toys.
iii. Design of buildings - to enable greater atmospheric control and increased resistance to storm damage (e.g. a South Wales manufacturer had suffered quite severe storm damage in 1993).
iv. Insurance – due to the size of its parent company, one company was self-insured to a large extent against future risks. Another company believed that it would be affected by climate change, primarily because it had suffered storm damage previously.

Companies are in general unsure of how they should adapt to climate change. Generally, firms commented that there were no barriers to action if there was a demonstrable impact on business operations. However, companies were unable to express any tangible benefits. Companies generally planned 1 to 3 years ahead, though one had a 10-year forecast. Market demand, raw material supply, environmental policy implications (e.g. effluent costs), insurance risk and energy demand/costs were mentioned. However, some factories have ‘crisis management’ procedures in place to deal with extreme conditions, such as, snow and ice.

Metals

Neither climate change nor weather are perceived as threats to companies in the metals sector. The only real effects, according to one company, would be the impact on the demand for metals if architects demand changes in materials. Potential effects mentioned include:

i. Increased rain – beneficial for one company since they collect and use storm water to reduce water charges. Some companies store raw materials outdoors, so any increase in rainfall might lead to higher water content of these materials. This in turn could increase drying costs.
ii. Increased wind – one firm already experienced the effects of gusting on stockpiles, with wind-blown dust becoming a problem at a local town. Prolonged windy periods (e.g. conditions similar to the Mistral in Southern France) would increase dust and product losses from stockpiles. Structures such as stacks were already designed with a high tolerance to wind.
iii. Distribution – an important consideration for one firm, where rail was being investigated as an alternative for the future.
iv. Subsidence – one company had experienced tilting of structures due to subsidence, although they had no reason to link this to changing weather patterns.

One firm had implemented measures to reduce dust and product loss from gusting: stockpiles are sprayed with latex sealant; roads are sprayed; conveying systems are covered; and the water content of raw materials is specified. Although there are generally no constraints to taking action, the sector sees no opportunity arising from climate change and will need very firm evidence to instigate preventative measures.

Electrical and Engineering Sector
Firms operating in Wales appeared to be susceptible to changing weather patterns. Although many sites do not operate high temperature processes, heat stress was an important issue. At one large manufacturer, workers had experienced uncomfortable working conditions and mild heat fatigue in 1999. Consequently, mobile coolers had been hired to ensure the production lines remained cool, at a cost of £800/week. The firm wanted to replace the existing roof, (which suffers large solar gain), before installing an expensive air conditioning system, since the solar gain would cause a substantial loading on the air conditioning. Any elevations in temperature in the future were seen by some as a possible threat to operations. For many companies, the cost of full air conditioning would present "an absolutely horrific cost" since sites can be very large. Conversely, milder winters could allow companies to reduce temperatures in the factory and save money.

Many sites currently suffer varying degrees of rain damage, primarily due to the poor quality of old roofs. At one company, a significant number of water leaks through old roofing presented a major capital expenditure and insurance problem, both from equipment damage and issues from worker safety. One incident resulting from a torrential downpour led to a production line being shut down with lost production of around 1,000 machines per day. The environmental manager was clear that bad weather conditions were getting more frequent: "I recall 1-2 cloudbursts during a winter, but we now seem to get them right through the year". Some companies discharge effluent into surface waters. At one site, recent prolonged dry spells had reduced the flow of surface waters to such an extent that there was excess loading of Total Suspended Solids (TSS) from their discharged effluent. If summers became significantly drier, Environmental Quality Standards (EQSs) might need to be tightened to prevent pollution. Conversely, companies that treat surface water run-off on site could face higher treatment costs from higher rainfall. The effect of climate change on distribution of products was felt to be minimal, primarily because this sector often uses subcontracted road haulage. Although it was deemed foolish to ignore any threat from climate change, the real barrier to the sector is cost and the paybacks - often there was a 2 year payback period on investments. The sector worked to a 2 to 5 year planning horizon. Payback criteria on investments might range from 1 to 5 years. Climate change is not explicitly taken into account. One manufacturer of domestic washing machines noted that the supply of their machines would be affected by wetter weather in the UK. If people were unable to dry their clothes outside as frequently as they do now sales of washer/dryers and tumble dryers would increase. There was good evidence for this trend from experiences in Scandinavian countries. Any impact on product type would influence capacity at production facilities, and hence long-term viability.

Construction
Wet weather hampers construction, primarily due to its effect on mortaring and brick laying. Staff attendance is poorer during bad weather conditions. A recent bad weather episode at one site had delayed groundwork and added around 10% to the cost of the project.

Windier conditions may require changes to design (e.g. new roof materials, bracing) particularly to structures built on high ground. The sector has several adaptation options: types of construction will probably need to change; roofs and building frameworks may have to be erected faster to enable fitters to start work inside sooner; and the timing of groundwork's could be limited. Longer, drier summers would enable construction projects to be completed faster. One firm reported saving time and money from an extended summer in 1999, which allowed a large area of green space to be laid out and seeded much quicker than expected. Such issues are explained in a recent report (Gavin et al 1998).

Changes in market conditions, and the effects of Health and Safety Executive regulations (e.g. on-site safety, landfill tax increases) were far more important than climate change, although the effects of weather did affect operations on a daily basis. The industry is investigating means for adapting to inclement weather and reducing the down-time on a site. For example, pano-block (pre-set concrete/gypsum composite boarding to replace timber frame in house), steel floors and frames are now being specified more frequently.

Retail & Distribution

Many distribution centres in Wales are located close to either trunk roads or motorways, so existing weather patterns rarely cause operational problems. Closures of the first Severn Bridge were a problem until the second crossing was opened. That said, a food distributor commented that snow and unexpected floods had occasionally affected their Welsh operations, where they have four distribution centres and 130 stores. Food distributors are affected by ambient temperature changes due to the resulting effect on both refrigerated vehicles and storage facilities (both in warehouses and supermarkets). Temperature changes even also affect consumer choice: one company noted that their marketing department tracks Met Office weather reports and produces 5-7 day forecasts. This helps achieve the right balance in-store of ‘hot’ day foods (e.g. salads) versus ‘cold’ day foods (e.g. soups).

The sector has a fairly broad strategic planning horizon, ranging from 5-7 years. Predicted trends in consumer tastes and changes in market conditions are by far the most important influence on planning. There are no real concerns about climate change. For clothes manufacturers, there is a diverse supply base (e.g. China, Venezuela and Zimbabwe) so shortage of supply due to climate change overseas is not perceived as an issue.

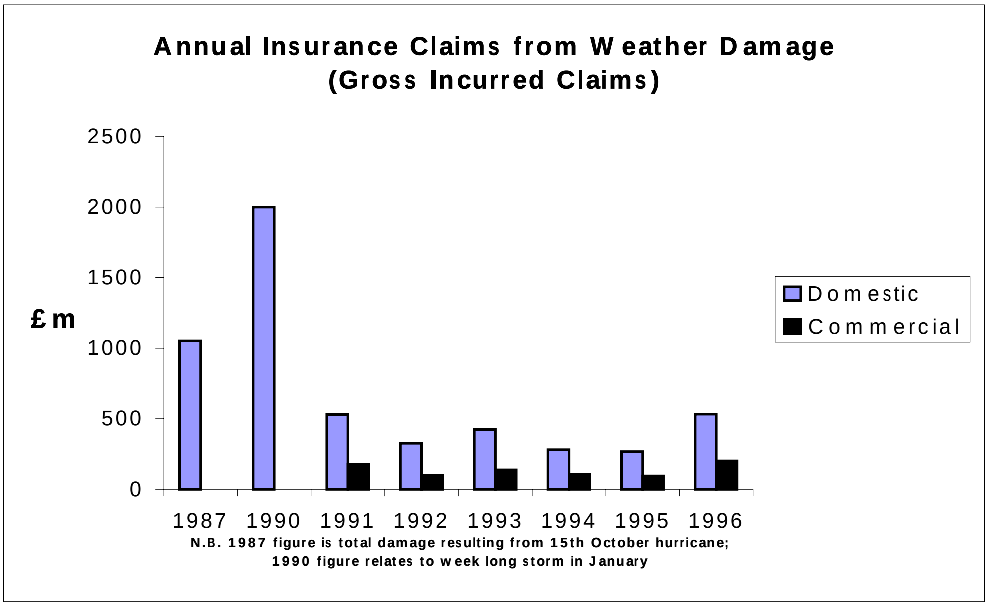
Insurance

The insurance industry has carried out a significant amount of work on climate change impacts. It identifies four risks from climate change: floods, storms, and extreme cold losses (i.e. burst pipes) and increased subsidence claims (following hot summers drying the earth). These events could arise either as one-off incidents (e.g. hurricanes) or as longer term ‘attritional’ losses. Companies determine future pricing and risk through risk assessment and modelling.

The Association of British Insurers (ABI) conducts research on behalf of its members. Halcrow has carried out a study of coastal flood impacts study in England and Wales on behalf of the ABI. Insurance companies are using geographic information systems “reinsurance” models to predict the potential damage costs of storms. Such models typically examine the effect on housing stock of a storm with a particular gust speed across a defined tract of land. From these results, certain parts of Wales could be isolated and classified as “at risk”, prompting preventative action such as transfer of risk, policy limitations or policy price increases.

Most unusual weather patterns, including events outside the UK, have an impact on the insurance sector. Indeed, the sector (Source: ABI and Lloyds TSB Insurance) can pinpoint the actual costs relating to weather damage claims. The graph below shows annual commercial and domestic claims compared to the massive anomaly from the 1987 hurricane that hit southern England.

TABLE 12: Annual Insurance Claims from Weather Damage



Subsidence claims correlate well with both sustained dry periods (sinking land) and prolonged cold spells ('heaving' land through ice crystal formation) during the winter months. Box 4 below shows the variability of subsidence over time.

Box 4: Subsidence Claims and their Relationship to Weather Conditions The long, dry summer of 1995 produced a 160% increase in UK subsidence claims (£326 million) compared to 1994. However, subsidence claims hit a high as a result of a very dry summer in 1991 with claims totalling £540 million.

In terms of overall impacts in Wales, the sector believes it has adequate time to react to long term effects, if and when these become apparent. Greater frequency of freak events will obviously impact on policy prices. Climate change could increase insurance costs in high risk areas, which in turn could threaten investments. It could also affect key sectors of the economy which are particularly susceptible – transport, energy, construction and marine industries. High cost of insurance cover could mitigate against particular developments taking place (for example Wye Valley or Gwent Levels) and could depress activity within a region. Communities near coasts or flood plains therefore might suffer blight due to effects on property prices and high insurance premiums. Businesses in such areas might also become affected leading to 'destabilisation' of the regional economy.

Insurance companies recoup the costs or reduce the liability to claims by either 1) increasing the premiums, 2) restricting the cover, 3) applying exclusions or 4) increasing the level of 'excess'. The UK insurance market is unique in that it does offer cover to subsidence (since 1994). An increase in claims from these natural events could cause the industry to rethink its approach. It could even withdraw from these markets. Actual refusal to grant insurance cover was seen as a very political issue – might a public organisation such as the National Assembly or WDA guarantee a loan in such cases? Climate change could also reduce the cost of some types of claim. Drier weather could reduce flood risks – although drier ground would prevent effective water infiltration and hence increase run-off. Warmer winters would produce fewer cold spells, reducing claims. However, this might be offset by more freak storm events. Box 5 below demonstrates the recent fluctuations in household insurance claims due to weather.

Box 5: Variability in UK Household Insurance Claims due to Changing Weather Patterns Figures from the ABI show that household claims in 1998 were 21% higher than 1997, rising to £1.8 billion. The increase was attributed largely to a 76% increase in weather damage claims, costing £663 million, which had resulted from a series of floods and storms throughout the year. This contrasts with half-yearly results for 1999, which show that household claims were down 13% on the same period in 1998. <u>One of the main reasons was the absence of any major incidences of bad weather</u>. Weather damage claims had fallen by 27%.

Most insurance policies are annual so pricing structures and on-going commitments can be monitored and reviewed regularly. The industry has historically tended to to weather-relatedevents, for example by increasing premiums after freak events. However, there is an acknowledgement that this will become an increasingly risky strategy. A more scientific approach to setting policy premiums seems inevitable. Changes in lifestyle have a big impact on the types and level of insurance demanded (e.g. annual travel policies are now becoming common) and hence the industry does try to predict these changes.

Needs of the manufacturing and services sectors
Many industries expressed a common set of needs from the National Assembly and central government. These are given in the box 6 below.

Box 6: Needs of industry from the National Assembly and Government • More quantified information with an overall summary of impacts for particular industries. Strategic decision making needs more certainty • More certainty with respect to the effects of climate change

- Information on extreme events such as gustiness and maximum wind speeds could be used to help design buildings
- Insurance industry believed long term planning policy might need to limit development on zones vulnerable to climate effects. Such areas could be identified now.
- Existing networks (e.g. Wales Environment Centre) were also seen as an efficient method of disseminating information on climate change, and facilitating sectoral discussion
- There is a need for funding to adapt buildings to cope with more extreme climates

4.3.2 Recommendations

1. More clarity on actual meteorological effects of climate change, including forecasted changes to: wind speeds, frequency of events, and likely areas to be affected.
2. Industry sector studies to determine specific impacts. These should include an appraisal of how industry in Wales may develop and the evolution of industry sectors. For example, foreseeable impacts on current industry base may become outdated if looking 20 years into the future - plant closures may reduce the significance of a particular sector in Wales.
3. Business needs to consider the opportunities as well as the threats offered by climate change.
4. The Assembly needs to ensure that DETR considers Building Regulations to ensure that they address climate change impacts during the lifetime of the structures being planned.

4.4 Transport

The transport network is Wales is characterised by major east – west transport corridors in the north and the south. These are generally of much better quality than north to south links. There are also many urban and rural roads in the addition to the strategic road network. Rail lines follow predominantly east – west corridors in North, Mid and South Wales. Rail travel from the main population centres of the north and south coast is only possible via England. Wales has one international airport at Rhoose, near Cardiff, which caters primarily for charter flights with some, mainly short haul, scheduled services. There are no airfreight services. There are a number of ports around the coast. The main passenger services are through Holyhead and Fishguard to Ireland. Freight ports are predominantly in Pembrokeshire and in the main towns and cities along the Severn Estuary. Transport infrastructure is summarised in Figure 10.

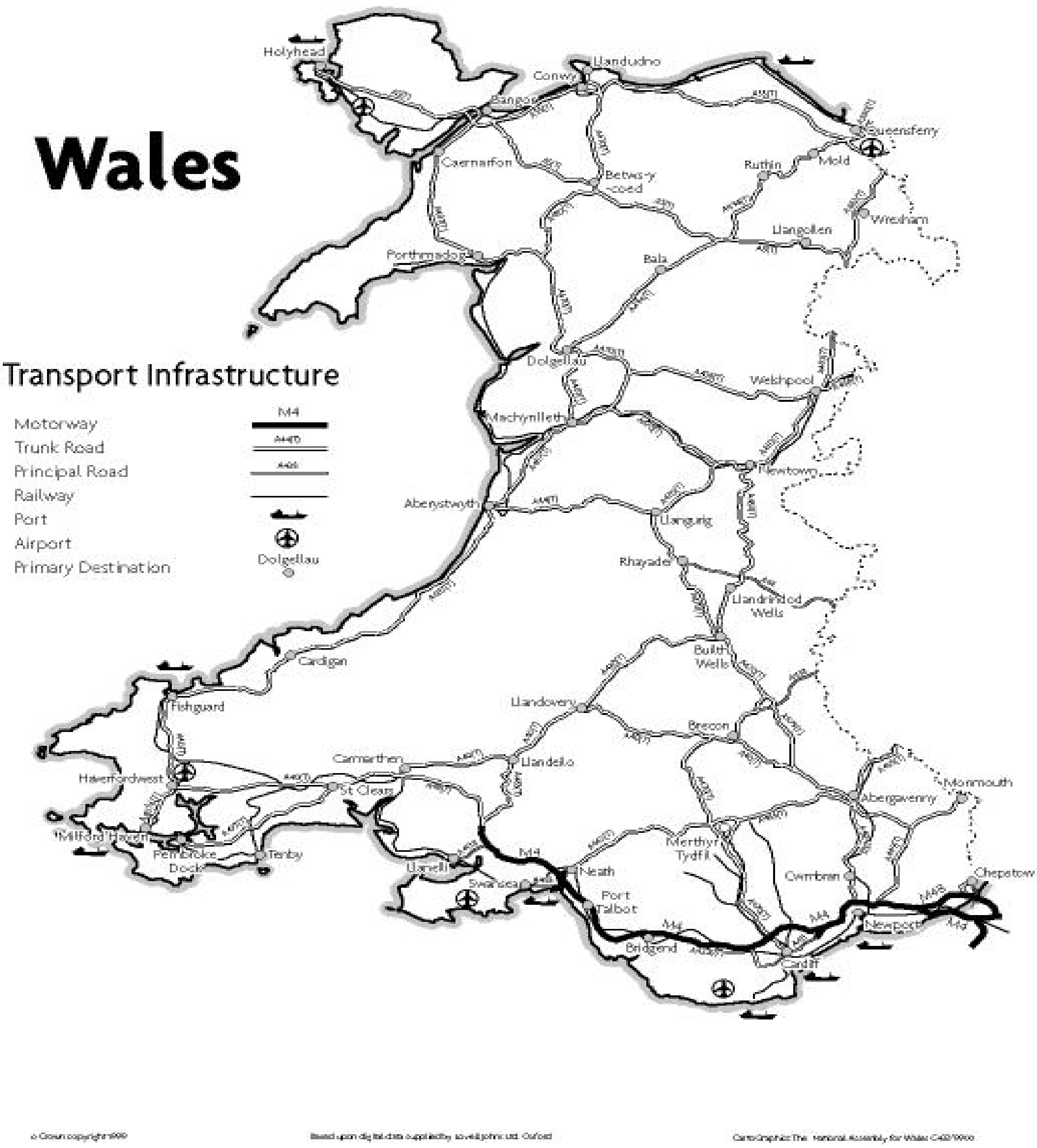


Figure 10: *Transport infrastructure.*

4.4.1 Findings from stakeholder consultations

There was little evidence that stakeholders in the transport sector in Wales had done much work to anticipate the impacts of changing climate. The exceptions were certain port authorities and Railtrack. In both cases the work undertaken was related to mitigating the effects of severe weather patterns. For example, the Welsh Coastal Forum was mentioned by one of the main port operators as an organisation that had already undertaken much work in relation to coastal management issues; it looked at flood protection and nature conservation, particularly in the Severn estuary. The forum has successfully involved the main port operators in its development of coastal protection and conservation priorities.

Impacts of Climate Change upon Sector

In general, those interviewed thought that the transport network and services had some flexibility to adapt to the changing climate scenarios. Weather does impact on the maintenance and operation of the transport systems, and the increased prevalence of severe weather conditions is of most concern.

Road

Increased severity of weather was the main concern for the road networks. Highways are usually designed to accommodate occasional events, for example, 1 in 10 year or 1 in 100 year storms. Structures such as bridges having higher tolerances. Climate change may cause more frequent failure of the network (e.g. more road closures due to floods) if the incidence of freak weather conditions increases. Incremental increases, (such as 3% more rain) are less significant as highways are generally over-specified to cope with such variations. Higher rainfall may also impact on the ability of culverts and storm overflows to cope with water flows and could increase the incidences of pollution from foul sewers siphoning back.

Old roads such as country lanes were often not specifically designed, but have developed over time. These roads have limited foundations and generally poor or non-existent drainage. Increased rainfall can result in more run-off and the subsequent washing away of substructures, retaining walls and surfaces. Higher river flows associated with severe weather conditions and higher rainfall may result in increased scour around foundations of structures such as bridges, which will result in increased costs due to more safety inspections and maintenance to ensure that the bridge piers remain safe.

Drier conditions, such as those experienced in the drought of 1976, led to the collapse of dry stone roadside walls in some rural areas, attributed to peat drying out behind the walls. When the rains returned the peat did not expand allowing the water to run off. This run-off subsequently caused the collapse of the stone walls.

Hotter temperatures can weaken road surfaces by causing binders in the tarmac to rise to the road surface, known as ‘ponding’. These binders do not migrate back into the road surface when the temperature falls. Similarly, high temperatures cause expansion of steel and concrete. Design tolerances are crucial in determining impacts, but in some cases designs have proven inadequate. For example with concrete roads, commonly constructed 20 – 30 years ago, many of the expansion joints have failed.

Reduced frequency of frost may be beneficial. Frost damage due to freeze-thaw can cause deterioration in road surfaces and substructures. It can also loosen rockfaces in mountainous areas, in cuttings and along embankments. The need to grit roads in frosty conditions will reduce. One Highways Authority estimated that its annual gritting bill could vary from between £200 - £500k depending on the severity of the winter.

Sea level rise was generally seen as less significant than other factors. Specific areas may be at risk from more inundation, but this would depend on how sea defences developed. Impacts were most like to be of local significance (e.g. Towyn) rather than threatening the strategic network. More uncertainty was expressed about possible impacts on subsidence in the substructures of old roads.

Rail

Railways, like roads, are more susceptible to disruption due to the effects of severe weather conditions rather than changes in climate averages. High winds cause problems with overhead power lines, though this is not a direct issue in Wales as none of the lines are electrified. However. there may be indirect impacts upon Welsh services that travel along electrified lines to destinations in England (e.g. London Euston).

Railtrack have assessed the links between severe weather incidents and delays to train services. They have developed models to assess the influence of wind speeds and rainfall on delays. Wind, more than rainfall, gives rise to difficulties with overhead power lines. Railtrack are considering further work assessing links between high temperatures and incidences of rail buckling.

Increases in temperature may cause tracks to buckle. At the moment, this is primarily an issue in South East England though it may spread to other parts of the UK. Higher temperatures also increase the risk of locomotives overheating. This is primarily a loco design issue, as other countries with much warmer climates run railways services in high temperatures, so suitable traction units are available. Finally, higher temperatures may result in increased specification of air conditioning. This change will probably be driven by passenger demand for higher quality rail services, rather than responses to climate change.

Higher rainfall can cause problems with track drainage, particularly as much of the network is old. There was concern that current UK bridge design may not be adequate for climate change impacts. Rivers, swollen from higher rainfall, scour the foundations of railway bridges and may flood tracks. Areas of the North and Mid Wales lines at risk from flooding include the Conway Valley route to Bleanau Ffestiniog and around Dyfi Junction where the track along the Dyfi estuary to Aberystwyth floods.

Sea level rise may impact on the track at places like Towyn, on the north coast, which have already suffered from sea inundation. Rising sea level causes problems other than inundation. Some track signalling systems work by passing low electrical currents through the track, which can be short-circuited by salt water. Salt also corrodes track components.

Benefits of climate change are likely to be reduction in delays from snow, and quicker thaw. Warmer weather should increase tourism. Climate change mitigation policies should also benefit the rail industry by encouraging more rail travel as a way to reduce car journeys.

Ports

Port operators did not think that the climate change would have a huge impact on their operations. Those in the Severn estuary already operate with a 13 m tidal range, so did not consider that an extra 25 cm would make much difference. The ports consulted did not consider that they were vulnerable to increased flooding from higher sea levels. The main concern related to increased frequency of severe storms, which could cause large shifts in the distribution of silt, potentially blocking the channels into the ports. This would need increased dredging and could result in port closures while the channels are reinstated. Wetter weather may lead to increased need for covered berths, particularly for products like steel which are liable to rust. Shifting weather patterns may lead to changes in demand for products, the vast majority of which arrive by sea. Such trends are very difficult to predict and would be masked by other changes in consumer tastes and world trade.

Airports

Cardiff International Airport did not consider that it was particularly vulnerable to the effects of climate change. The weather profile in the airport is generally good and the runway aligned to make the best use of the prevailing winds. Dense fog is the only problem that affects the operation of the airport. Investment in more modern technology would make the airport able to operate in difficult conditions. Such investment is likely to be stimulated by increasing demand for airport services rather than changes in weather patterns.

Level of Knowledge and Preparedness

Knowledge of climate change and its potential impacts is not high, and is perceived as distant and uncertain. The impact of variations in current weather conditions on the transport network is much better understood. Those managing the transport system need to be able to keep the network open in a variety of weather conditions and respond to freak incidents to restore safe communications. The rail industry appears more aware of the potential of problems than the highways managers, possibly because all the track in the UK is the responsibility of one organisation (Railtrack).

National Assembly/Trade Associations

Most of those interviewed see increased certainty as to the impacts of climate change as the primary need. Without firm projections of changes in weather patterns, it was difficult for the transport sector to assess whether there was a need to make appropriate adjustments. One company were concerned that adaptation would lead to an increase in regulation and taxation. Others mentioned the need for more co-ordinated and effective partnerships to address the issues. Railtrack mentioned that it was generally involved in flood defence initiatives at specific localities. For example on the English side of the Severn a new line of flood defences had recently been constructed inland from a railway line. Railtrack felt that that there had been a failure in communication and consultation, and that they needed to be more involved in such planning at more strategic levels.

Climate Change Relative to other Business Risks

Climate change is seen as long term issue of uncertain impact and therefore of low priority. The lack of certainty makes planning for impacts difficult. For example, many train operating companies have franchises with only 5 years left to run. Since it is unclear whether the firms will exist by the 2020s, long term issues such as climate change do not figure in planning. For other sectors, such as the ports and airports, changes in market demand for goods and services were the main business risks and could quickly and radically alter the need for services. Companies had enough problems anticipating such fluctuations and planning investment accordingly. For example the steel industry's imports and exports of raw materials and finished products changes radically in short time periods and were much larger uncertainties than climate change.

4.4.2 Recommendations

Three specific recommendations were made by those in the transport sector in relation to climate change. These were to obtain:

1. More specific projections of the changing severity and frequency of unusual weather events.
2. More specific studies scoping the impacts of climate change on the roads network and further development of Railtrack's work on the rail system.
3. Review of the design standards required for transport infrastructure to accommodate changes in climate.

4.5 Energy

4.5.1 Structure and regulation of the energy industry within Wales

At privatisation the English and Welsh electricity industry was split into regional electricity distribution companies (RECs), the National Grid (owned by the RECs) and two major fossil fuel power supplies (nuclear generation was privatised later). The gas industry was privatised without breaking up the industry. Electricity and gas have both seen substantial and sustained liberalisation and an increase in competition. Mergers have occurred within the sector, the new firms often straddling both the gas and electricity market. The National Grid now has a monopoly in distributing high voltage electricity.

Economic regulation of the industry is conducted by Office of Gas and Electricity Markets (OFGEM) formed in 1999 following the merger of the separate gas and electricity regulators. Environment regulation is undertaken by the EAW. It licenses the abstraction of water (used for cooling thermal plants and supplying hydroelectricity generation) and emissions of substances into air and water. The electricity industry is by far the largest user of water in Wales, largley in pumped storage hydro-electric schemes which remove and then re-instate water between reservoirs at different altitudes.

There is a surplus of power generation capacity in the north of Wales and a deficit in the south. Excess generation in the north is exported to England. There is one coal-fired power station in operation, at Aberthaw, with a capacity of 1360 MW. Wales has three combined cycle gas turbine power stations, ranging from a capacity of 1,400 MW to 230 MW. These are located in Connah's Quay, Deeside and Barry. There is also one nuclear power plant in Wales, at Wylfa on Anglesey, with a capacity of 950 MW, supplying power to north east Wales and to large energy users, such as Anglesey Aluminium, in the north west. There are a number of small hydro schemes in various stages of development within Wales. There are two large pump storage hydro-electricity plant that supply power to the grid.

Wales is linked to England through the National Grid by one connection in the north and one in the south. Low voltage electricity transmission and distribution is the responsibility of the regional electricity companies MANWEB (a subsidiary of Scottish Power) and SWALEC in north and south Wales respectively. Urban areas in Wales are generally well served with high voltage electricity supply, but there is no high voltage connection to mid-Wales. There is a general issue of "peripherality" – remoter areas of Wales are a long distance from sources of power generation and so have limited access to high voltage power. Figure 11 summarises electrical supply.

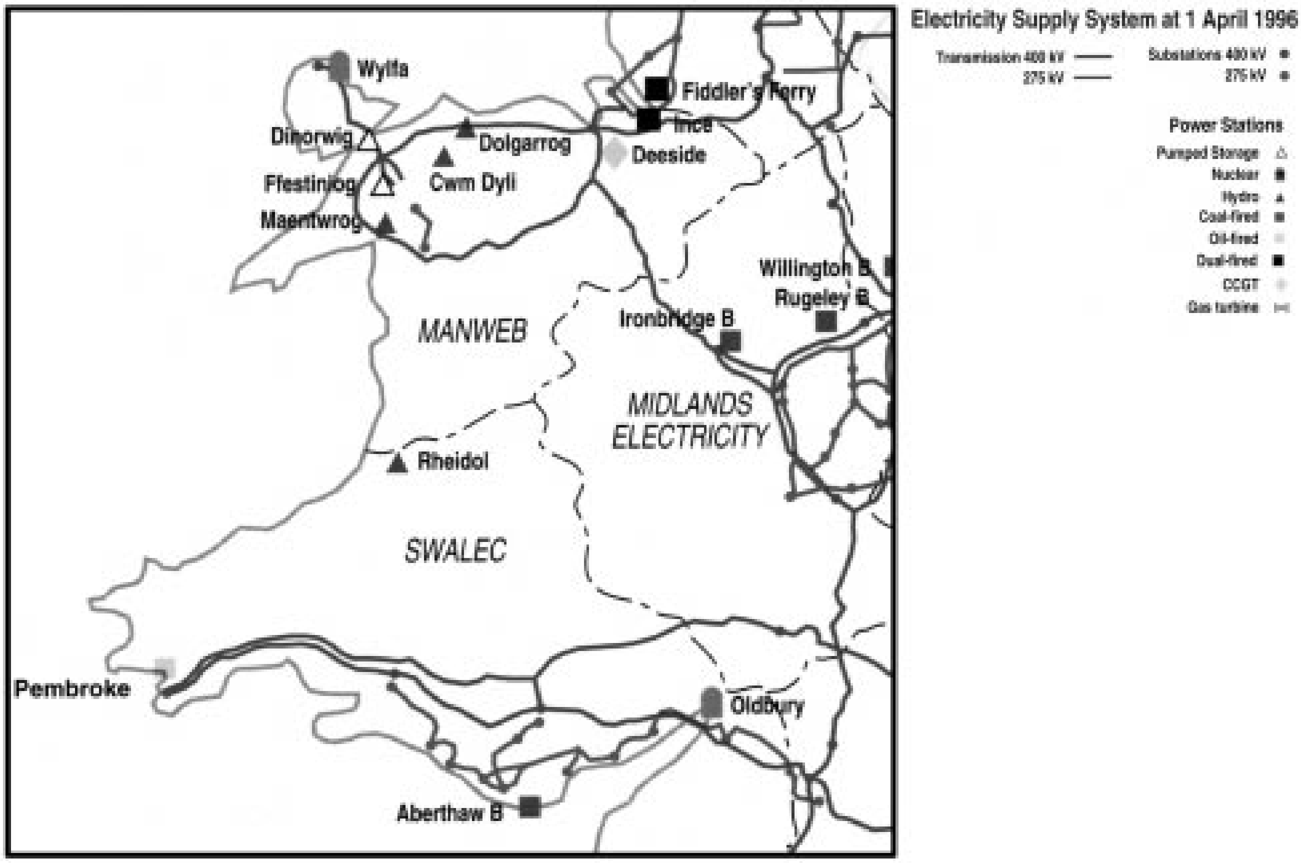


Figure 11: *Electricity supply.*

The high pressure National Transmission System (NTS) gas distribution network supplies all the pipeline gas within the British Isles – with two main entry routes for gas into Wales, north and south. The NTS network is the responsibility of TRANSCO, which supplies gas to intermediary shippers, who provide a gas supply service to customers. Many customers in Wales are on contracts where they pay less for their gas but are subject to interruptions in supply at agreed times. In north Wales, TRANSCO consider that in general they can provide adequate supplies to most urban, and to the major industrial, areas. Supplies to more rural areas are more limited and areas such as mid Wales have no access to any mains gas supply. In south-west Wales there is insufficient gas to provide commercially viable quantities to industrial customers.

Consultation with stakeholders suggests that the impacts of climate change on the existing supply and distribution of energy are limited (UKCIP 1998, Sivell 1999; North West England and Scottish reports). The increase in average temperature would reduce demand for winter heating, but this may be offset by the installation and use of more air conditioning in summer.

Extreme weather events are a major threat to energy distribution, and must be seen in terms of the long lifetime of the equipment, where capital investment in the energy sector is for assets lasting as long as 70 years. High and unusually dry winds can deposit salt on electric plants near the coast, adversely affecting insulation so that when it next rains they may be a shut down. Threats from weather include damage to pylons at high wind speeds, drying out of the soil preventing the cooling of underground cables, performance of small hydropower plants reduced by low summer rainfall, and increased storminess necessitating change to the design of wind turbines. High winds are a particular problem for remote locations in Wales.

4.5.2 Findings from stakeholder consultation

The energy sector has a high degree of awareness of climate change and its impacts, accepting that GHG emissions contribute towards global warming. Stakeholders from nuclear and renewable energy firms were more aware of the issues – both made reference to IPCC reports. The climate change levy, and particularly the non-discriminatory manner it was being applied to all electricity sales was much on the minds of the consultees. Stakeholder consultation occurred before the November 1999 pre-budget announcement exempting renewables.

Long term planning

Business planning has a five year time horizon largely dictated by the economic regulatory system. The energy regulators have tended to focus on reducing retail prices of gas and power. Long term strategic planning is necessary because of the large costs of energy infrastructure, with long life spans. The industry needs to plan for both the quantity and location of future demand. The economic regulator OFGEM requires a high degree of certainty and confidence in long term forecasts to approve any new infrastructure planning. Typically strategic planning in the industry can be as short as 10 years and as long as 100 years and considers a vast range of business issues. Weather is a considered in long term strategic planning but, with the exception of wind and hydro generation, is not a particularly high priority. Weather could impact on safety: for instance decisions on cabling need to take account of rising ground water levels. So far, changing weather patterns have not influenced these decisions. For the wind energy industry, accurate and detailed forecasts of weather patterns, including wind speed and direction, are critical considerations in the preparation of a strategic plan. Weather is one of the most important long-term strategic factors, influencing turbine design and location, and revenue streams.

The potential impacts of climate change on the sector

Stakeholders in the energy sector are confident that the impacts of climate change fall within their current operating range. The industry allows for a wide operational tolerance, including extreme weather conditions. One stakeholder stated that their supply network is planned to meet "1 in 20" winter conditions. Current and potential impacts identified by stakeholders included:

i. Storms have caused unplanned plant shut downs, and in some instances considerable damage.
ii. A combination of severe icing and high winds has destroyed overhead lines, particularly to rural villages and small villages.
iii. A combination of high rainfall and winds (in late spring when trees are in leaf) has brought down trees onto overhead lines.
iv. Changes in peak wind speed and wave heights will influence the thinking on offshore wind power.
v. Rising sea levels may increase the number of underground cable faults.
vi. Shifting patterns of energy use from heating to cooling.
vii. Higher wind speeds and wind variations will affect wind turbine design and wind farm location.
viii. Higher and more concentrated rainfall will increase output from Welsh hydro-electric stations, but in warm drier summers their or output will fall.
ix. Warmer weather may reduce the necessity of reinforcement of infrastructure currently anticipated due to rising demand.

The stakeholders feel that these types of impacts can easily be factored into the strategic planning process. The industry has responded to some incidents to avoid repetition of problems. The introduction of a Rural Care Programme, which promotes the regular pruning of trees and the growing of shrubs, is geared towards reducing the damage caused by weather felled trees, and overhead cables have been strengthened.

Barriers to action and potential opportunities

Since the forecast degree of climate change falls within the current operating range of this sector, it has not given rise to any changes in practice. If the safe operation of energy infrastructure were to be compromised by climate change, action would be taken. Firms are aware of the sorts of actions they might need to take to react to climate impacts.

The liberalisation of energy markets in the UK has made the industry more cost conscious. The pressure to increase shareholder returns inhibits capital projects that do not make any clear returns. The majority of the industry does not anticipate major benefits from climate change. Climate change may help to smooth out peaks and troughs in energy demand over the annual cycle, which may contribute to better planning of assets, and delivering efficiency gains. The wind energy industry sees concern about climate change as enhancing their appeal.

4.5.3 Recommendations

There is a need for a co-ordinated approach, with both central and local government supporting a coherent climate change strategy. For example planning applications for wind power generation need to reconcile the direct merits for the economy and for mitigation with possible negative effects on the tourist industry and local concerns.

Predictions of extreme events such as peak wind speeds need to be incorporated into such decisions as whether power cables are over- or under-ground, and the design of wind turbines.

There needs to be careful reconciliation of adaptation and mitigation strategies. Stakeholders identified the following possible actions relating to mitigation: promotion of “Green Energy”, including hydro-electric and the utilisation of Renewable Energy sources to reduce CO_2 emissions; increase “Dispersed Generation”, thus having smaller scale generators but more of them, thus lowering transmission wastage; commercial options for sustainable energy supplies from a range of renewables.

Provision of information about, and contribution to the wider discussion of, climate change is needed by this sector. The sector would like more detailed weather/climate forecasts, especially of particular combinations of weather. Accurate forecasts of temperature can be used to adjust loads.

The industry regulators need to ensure that the power utilities place sufficient emphasis on measures to assist adaptation to climate change. They need to recognise that the regulatory regime may be hindering a response to climate change impacts.

4.6 Water resources

Environment Agency Wales (EAW) has the statutory responsibility of managing the water resources of Wales and safeguarding the quality of fresh and coastal water. It delivers the former duty primarily by licensing abstraction . Almost all types of abstraction require a license under the Water Resources Act 1991. The majority of water abstracted is for hydroelectricity generation (73%) and is returned to rivers down stream of the abstraction point. Industry accounts for a further 8%, agriculture 3% and public water supply 16%. The EA also inspects the composition and volume of outflows from sewage treatment works to ensure that limits on the biological oxygen demand and water contaminants are not breached. Since May 1997 the Agency has been charged with developing long term demand and water resource yield forecasts based on population, per capita consumption, industrial and commercial usage, leakage targets, agricultural water use, and land use changes. In addition to the public water supply industry there are 4,250 licensed abstractors in Wales, who use the water for spray irrigation and most forms of industry and 30,000 unlicensed (exempt) abstractors who rely on springs and boreholes to maintain supplies to their farms and homes.

4.6.1 Public Water Supply & Sewage Treatment

Structure and regulation of the industry

The public water supply industry is responsible for abstracting, distributing and supplying fresh water to commercial and domestic consumers. Water is drawn from controlled sources: rivers and lakes, reservoirs and ground water sources. The industry receives waste water and treats it before it is returned to rivers and the sea. Since privatisation of the water industry in 1989 the companies have existed as regional monopolies with the exclusive right to provide water and sewage treatment services for their customers.

The industry is regulated by the Environment Agency Wales (EAW), the Office for Water Services (OFWAT) and the Drinking Water Inspectorate (DWI). To overcome the lack of competition within the water industry OFWAT the economic regulator sets the average price that water companies are permitted to charge for water supply and treatment services for their commercial and household customers. The water industry is highly capital intensive using assets that last in many cases for over 100 years (e.g. reservoir dams). The industry is required to ensure that assets are adequate to meet the demand for water and sewerage services, and to meet the legislative requirements placed upon the industry for environmental and drinking water quality. To meet these requirements the companies produce asset management plans to cover 25 years of strategic forward planning. OFWAT works to a shorter timescale and reviews all water companies funding requirements at 5 year intervals and has to take account of the likely changes to infrastructure that will need to be made over the next 5 years.

Within Wales the sector comprises Welsh Water, Severn Trent and Dee Valley Water. Welsh Water is the largest supplier. Annual supply is currently (1998) 980 million litres per day (Ml/d), of which some 308 Ml/d leak from pipes. Severn Trent services an area of mid Wales coinciding mainly with the Severn Catchment area. There are few customers in this small rural area. It has the capacity to transfer about 400 Ml/d to the English Midlands from the Elan Valley and the lower River Wye (and has total leakages of 344 Ml/d). There are also substantial transfers of water from the Lower Dee to Merseyside and Crewe areas (705 Ml/d) and from Lake Vyrnwy to Liverpool (220 Ml/d) by North West Water (who have total leakages of 510 Ml/d). Dee Valley Water supplies about 73 Ml/d to the Wrexham and Chester areas (with a total leakage of 12 Ml/d). Of the 2378 Ml/d abstracted under license in Wales, 59% goes to England.
The Environment Agency's operational areas follow water catchment areas. The Upper Severn catchment lying inside Wales is managed by EA's Midlands region. Conversely, parts of the Dee and Wye basins are managed by EAW but lie in England.

General water resource operation
The region receives more rainfall than any other EA region at 1310 mm/year on average, but the distribution of rain is far from uniform. It is particularly high in Snowdonia, about 4000 mm/year , compared to 700 mm/year in the Welsh Borders. The majority of demand for water is met from surface water abstraction. there are about 150 reservoirs supplying more than 550,000 Ml of water storage. The flow of water in the rivers Dee, Severn, Wye and Tywi are heavily influenced through regulation. Water stored in upland reservoirs is released at times of low flow to maintain the river and enable downstream abstraction for public water supply. Although the water undertakers own the assets involved they are operated under agreements drawn up between the water companies and the Environment Agency. Less use is made of aquifers than most other EA regions. However, where groundwater exists it forms an important local resource, particularly for the environment and many smaller abstractors.

4.6.2 Prior work on water resources and climate change

The Department of the Environment (1991) carried out the first major UK study on the impacts of climate change on different sectors of the economy. Its study drew attention to the pressure that hot, dry summers are likely to place on both effective rainfall and demand. Joint research, by the UK Water Industry Research group (UKWIR) and the Environment Agency (UKWIR/EA 1997) examined the impacts of twelve climate scenarios on 60 water catchments across the UK. Four of the scenarios used the HADCM1 model (used to create the DETR report). The next four used the updated HADCM2 model (see Section 2). The objectives of the study were to produce regional factors to apply to historical data on rainfall, temperature, potential evaporation and the resulting changes in monthly river flows and in groundwater recharge by the 2020s. The results help the water industry to assess reliable yields. This research has been used by the water industry to estimate impacts of climate on water yield, and is reflected in the water companies' water resources plans (1999). A report looking forward to 2021 provided detail on future water requirements in Wales (NRA 1996), and a document on providing sustainable water resources has recently appeared (EA 1999). A report by Friends of the Earth - Cymru (1997) says that demand for water in England and Wales will rise by 12% for non-climatic reasons and, a further 5% for climatic reasons. They report that the additional cost to Welsh Water of supplying drinking water during the hot summer of 1995/96 was £1.5 million. The North West study (Climate change in the North West Group, 1998) concluded that more water will have to be collected over the winter months to sustain demands in the North West area in the hotter and drier summer months. This will necessitate an expansion in reservoir capacity. Water supply in the NW region is highly integrated with aqueducts and other facilities which allow transfers of water within the region. Experience in the North West during the hot summer of 1995/96 resulted in low flows in rivers and an increase in concentration of pollutants in surface waters and consequent pressure on the abstractions for public water supply. For sewage discharge it is the likely effects of increased winter rainfall which will cause problems as esting waste water output is already putting NW sewerage capacity under a strain which may become worse if winter rainfall increases.

Impacts of climate change upon the water industry

The water industry relies upon the climate to supply water. In summer the climate change scenarios predict gross rainfall will be lower and evapo-transpiration higher, reducing the amount of effective rainfall. Climate change also has an impact on the demand for water, especially for spray irrigation in agriculture and household watering of gardens, and increased demand in areas with high tourist concentrations. In winter, projected higher rainfall can assist water resources by recharging aquifers and reservoirs. Some English companies believe it may be necessary to increase the amount of reservoir capacity towards the middle of the next century to increase the volume of water that can be stored between winter and summer, unless there is a reduction in demand.

The operation of sewers and storm drains is highly susceptible to flooding. In built up areas, high intensity short duration falls of rain do not soak into the soil but run straight into rivers without refilling aquifers. Surges in water flow through trunk sewers can lead to flooding in streets and overflowing into rivers. Surges of water through sewers can handicap the operation of sewage treatment works. Sea water floods and storms at sea may cause salt water intrusion into fresh water aquifers. Climate change can also have an impact on the degree of treatment needed to produce water suitable for drinking in part because of the reduced flow rates in rivers from which water is abstracted (which tends to concentrate solutes) and through impacts on water borne pathogens such as Cryptosporidium.

4.6.3 Findings from stakeholder consultations

The water companies have a sophisticated understanding of climate change. Two firms were undertaking research to understand how climate change would impact on their business. One has asked the Hadley Centre to develop modelling tools for high impact, short duration rain showers. Research was taking place to downscale the output from Hadley Centre modelling to predict inflows into local reservoirs and rivers. Severn Trent has integrated the output from the HAD-CM2 GCM to its own surface water modelling for the years 2020 and 2050. Each of the four scenarios was independently analysed. GCM outputs, along with historic climate data and physical and geological data are used to create a catchment model. This is used to generate river flows for each of the resource zones. The environmental and distribution system constraints are overlaid on top of this model to evaluate the resource available to use as deployable output. This model has been used to calculate water yields from the Elan reservoirs.

Both OFWAT and EA have a sophisticated understanding of the impacts of climate change. Output from the HAD-CM1 modelling is used to assess the average impact of the four climate change scenarios making use of research published by UKWIR/EA that translated meteorological data into water yields. Similarly OFWAT recognise the inherent uncertainty in the climatic modelling and use the average of the scenarios for asset management purposes. The industry publicly acknowledges the possibility of climate change and incorporates it in long term planning. However all consultees agreed that climate change was one amongst many long-term factors they consider in their decision making, and not the most important. In the short to medium term (5 to 10 years) EU directives (such as the Habitats Directive) will be more important. For periods more than 10 years ahead changes in population, household formation, agriculture and higher expectations from consumers are more important. Water UK, the industry’s trade association, plays a role in co-ordinating work on climate change impacts. Two of its working parties, water supply and wastewater, discuss the issue. A decision was taken in early 1999 not to create a separate working party for the climate change but to deal with it within existing arrangements.

The water industry is very aware of the weather and weather-related incidents and keeps records of both to improve their own forecasting capabilities. They have considerable in-house information and expertise. Contrary to common belief, Wales could go into water deficit in 17 out of the 42 Welsh Water and Dee Valley supply zones over the next 25 years. None-the-less water companies operating in Wales have had a better performance in meeting demands for water than most regions of the UK. There have been few restrictions over the past nine years on public water supply customers though the EA imposed a spray irrigation bans on the Wye in 1995 and a drought order on the River Dee in the winter of 1995/96. Few systems are vulnerable to a drought lasting just one year, though several would be threatened by a three year drought. The drought of 1995/96 was the most extreme weather event of recent years. This was exacerbated by poor rainfall in winter 1995/96. No controls had to be imposed on Welsh Water consumers. One company had experienced substantial problems with urban flooding following downpours of rain. Since most of the water is supplied from reservoirs, winter rain is essential useful because of its role in recharging reservoirs and aquifers, although there comes a point when refill is complete and additional rain ceases to be useful. There is some exploitation of limestone groundwaters, which emerge close to the tidal levels in South Wales. Although storms at sea and flooding can lead to intrusion by sea water, our stakeholders did not feel this to be a major concern.

The 'water summit' of October 1997 clarified the roles of the EAW and water companies in preparation for drought. Water companies have to develop, drought contingency plans in agreement with EAW. These will address climatic conditions worse than those built into recent water resource plans. Similarly EAW are developing drought management plans which set out procedures and monitoring requirements for severe droughts across all water uses. Over the past decade companies invested in infrastructure, under-took leakage controls and encouraged customers to conserve water. Though not motivated by climate change concerns, these measures would reduce any negative consequences of climate change on water resources. Options which explain how water companies propose to operate successfully through drier summers will be published in April 2000 in the Drought Contingency Plans.

Water companies expressed disenchantment with the lack of 'joined up thinking' by the regulators and especially OFWAT's insistence that the average of the climatic scenarios rather than the extreme be used to develop the asset management plans and water resource plans. They felt OFWAT to be placing too much emphasis on short-term price reductions and too little on long-term planning. The regulators point out that the yield forecasts already incorporate climate change.

None of the stakeholders felt that drastic measures were needed in the short term. Lack of money was a barrier to further research. The draft price determination issued by OFWAT was severe and the industry expected that research budgets would be trimmed.

The stakeholders did not believe that they could benefit from climate change impacts in the short term. The expertise gained through integrating the HAD-CM2 output into modelling water yields and flooding was highly catchment specific and it would take considerable resources for another water company to tailor it to their own situation. It was recognised that climate change, coupled with growth in demand for water in SE England, might create an English demand for Welsh water,in the future. The main impact of climate change was that it made long term planning of resource and demand more uncertain. The stakeholders all recognised that the overall increase in rainfall was likely to be benefiting. However different scenarios gave markedly different results. The increased likelihood of short duration rain and storms adversely affecting the sewerage network was difficult to plan for. To date climate change considerations had not changed behaviour although they gave greater impetus to matters such as leakage control and demand side management which were good in themselves.

4.6.4 Recommendations

There is a need for different public and private sector bodies to be involved in planning for the impacts of climate change on water resources.

The water industry, either as individual companies or through Water UK, are able to directly liaise with climatological modellers to obtain the best and most up to date advice on climate. They urge DETR to continue supporting the core products produced by Met Office and the Climate Research Unit at UEA. The industry hopes the scenarios become more robust and weighted for thus relative likelihood

The Environment Agency and water industry should provide strategic advice on the drivers for water demand, particularly issues such as promotion of tourism (which causes a rise in water demand in summer) and new industrial demand, and to encourage water conservation and promote demand side management. EA is well placed to give objective advice on demand forecasting, optimal management of water resources and water efficiency.

Local Government has a role to play in providing local area expertise in how demand for water is likely to change bearing in mind their development and housing plans. NAW has a role to play in co-ordinating these plans and ensuring they are consistent.

The regulators need to ensure that the water utilities place sufficient emphasis on long-term measures to assist adaptation to climate change. They need to ensure that the conditions under which the utilities operate do not mitigate against adaptation. Some water companies feel that the continuing drive to reduce water bills is likely to jeopardise their in-house research.

4.7 Tourism and recreation

4.7.1 Structure of tourism in Wales

Tourism is a major contributor to the economy of Wales, generating some £1.9 - 2.0 billion in direct visitor spending. This translates to 10% of the jobs in Wales (c.100,000 jobs supported directly and indirectly by tourism) and 7.5% of the GDP. This is generated by staying visitors from within the UK and overseas, and by day trips. The tourism sector in Wales is more dependent on overnight stays than other parts of the UK and is increasingly depending on day visits and short breaks. Tourism (and leisure visitation) is characterised by a very strong multiplier effect, with a wide economic impact via associated spending in shops, restaurants, garages, theatres, recreation facilities and others. The recipients of such supplementary spending will in turn spend their money on other local services. Many local services would not be viable, at least in the winter months, without the additional income derived from tourism. Tourism further supports the environment, culture and heritage of Wales and plays a vital role in the creation of a distinctive international image. This image has a further multiplier effect in the attraction of new business and investment. The image is enhanced by the presence of three National Parks within Wales; furthermore the Park authorities have invaluable experience of management which encompasses environmental issues.

There are numerous sources of data on tourism and recreation and the Welsh economy. The primary sources are from the Wales Tourist Board.(The key objectives and priorities for 2000 - 2006 are a reflection of the European Commission's own priority areas, namely competitiveness, sustainability, social inclusion and human resources. There is a need for better data in a number of areas. Current thinking does not include a consideration of climate change and its possible impacts. There is a dearth of information on its likely effects on tourism and leisure activity at both institutional and personal scales. The remedy may lie in the instigation of research coupled with better data capture. Improved governance and the development of integrated and sustainable philosophies demand information which is detailed and focused at community and local levels. Such high definition data will facilitate precise management and will establish credible and socially inclusive information sources.

Trends in Tourism

Information on trends for the period 1992 - 97 is based on WTB (Wales Tourist Board), IPS (International Passenger Survey) and UKTS (annual UK Tourism Survey) sources.

Overseas visitor spend in Wales grew by 71% from £132 million in 1992 to £226 million in 1997. After RPI adjustments the growth in visitor spend was some 50.7% compared to the UK at 37.8%. This growth rate is also higher than competitor regions such as Scotland, Cumbria, and the West Country. Overseas visitors stayed for slightly shorter periods (fall from 7.2 to 7.0 nights) but spent more [rise from £197.01 - £245.65]. **Overseas holiday** trips to Wales grew from 0.38 million to 0.47 million (22%); this is slightly less than the UK average but the length of overseas stays increased slightly from 5.5 - 5.7 nights. Overseas holiday visitor spend grew from £63 million to £104 million (66%) and the average spend per trip rose from £163.92 to £223.84. The growth in real terms was c.46.5% compared to the UK at 29.5%, but the growth is from a very low base. Overseas visits are of crucial importance in the strategic development of tourism. They represent a higher spending, culturally aware market group and are not dictated to by the traditional UK July/August holiday compulsion. They may also be less sensitive to climate.

Domestic tourism grew from 8.3 million to 10 million trips/year. Wales' share of the overall UK trip market fell from 8.7 to 8.3%. The principal growth is in non-holiday trips. The average length of stay in Wales fell from 4.8

to 4.2 nights (4.2 to 3.5 UK). **Domestic tourism holiday** visits grew from 6.6 to 7.0 million with average length of stays falling from 5.3 to 4.8 days, again mirroring the general trend to shorter holidays. Domestic tourism and domestic holidays account for a spend of £932 rising to £1,126 million and £215 rising to £355 million respectively in the period 1992 - 97. There is a clear decline in long holidays and an increase in short holidays. Increasing work and financial pressures, and the increasing predominance of foreign holidays as the primary break, may account for this change.

Seasonality is a major problem for Welsh tourism. An increasing number of holidays are being taken in the shoulder periods (Jan Feb March - Oct Nov Dec) in the UK overall. In Wales the seasonal element is far stronger. In 1992, 20% of all trips commenced in the shoulder period, with 25% currently. An ameliorating climate in the shoulder months would certainly influence the seasonal distribution of visits.

Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis.
A SWOT analysis undertaken by WTB (Tourism in Wales - a position paper) lists the strengths, which include scenery, natural environment, heritage and culture in a stress free, affordable and secure context. Also incorporated are wide ranging events and activities, improving accommodation, beaches which are clean (designated Blue Flag) and increasingly sophisticated marketing, strategic planning and governance. The weaknesses include outdated and stereotypical negative image: a lack of awareness of Wales and the absence of strong icon images. The traditional seasonality is combined with images of unpredictable weather during the peak summer season. Many people are unwilling to risk their main holiday in a fickle climate. The search for guaranteed sun is particularly damaging to the coastal resorts. Guaranteed sun is of course as much to do with image as reality. In reality there may only be a slight difference between two places, in some the difference may be based on image alone! Any evidence which might help in recreating a more positive climatic image will prove to be a major marketing tool. The common image of Wales as wet and windy is belied by the reality: a west coast climate with relatively high sunshine incidence, high January average temperatures (6^{o}C+), high July average temperatures (16 ^{o}C), and low coastal frost incidence. There is an opportunity to extend the tourism season when many facilities either operate below capacity or are closed. Careful marketing and development coupled with a milder climate should provide substantial rewards for both coastal and inland resorts. Activity and event based holidays and breaks as an addition to the main vacation are an obvious attraction. The threats are numerous and may well include climate change. The need for precise information and credible weather and climate forecasting is increasingly important to reduce barriers to action. Increased precipitation in shoulder periods is a threat to a policy of extending the main tourist season.

4.7.2 The impact of climate change on tourism

One of the strongest assets of Wales is its tremendous variety. The physical variety stems in part from a complex geology. This is a rapid transition from coast to uplands in vegetation, wildlife, agricultural practice, settlement structure and building style. Wales is endowed with a range of climates which are a complex reflection of landscape, orographic divides, slope aspect, drainage and river catchment parameters, prevailing winds, proximity to the sea and ocean currents (Crowe 1940). These climatic or natural sub divisions have little to do with administrative divisions. Yet they are fundamental to an understanding of regional and sub regional climate and associated environmental process. Wales has a tremendous micro and meso climatic fabric which results in weather changes from one side of an island, valley, peninsula or hill to the other: this makes local predictions particularly important.

There is a need to develop a refined data gathering structure for weather information with a degree of community involvement to reflect regional variation and raise awareness and credibility of climatic predictions. This would involve educational initiatives. Natural sub divisions or cells may form the basis for integrated planning, development and marketing of resources in a sustainable manner. They might also assist reliable and credible predictions for weather and climate.

Impacts of climate change
The impact on tourism will be strongly influenced by the changes wrought by climate change on alternative holiday destinations, both in the UK and internationally. Some effects some involve “real” and quantifiable factors and others which deal with probable impacts, perception and possible consumer behaviour. Some will involve

operational issues and others will be of strategic importance. The number of uncertainties make prediction very difficult indeed. Detailed impact assessments will require substantial investment. Some of the likely impacts, and those areas which require further attention, follow:

What might be the impact of sea level rise by 2050?
The seaside in Wales retains its position as the leading visitor destination, claiming a consistent 60% of holiday nights (c.61% of total domestic holiday spend £503 million in 1992 increasing to £601 million current). The regeneration programme for coastal resorts emphasises the need to improve beach standards and beach management and to promote good water quality standards. There are over 350 beaches in Wales ranging from relatively few large commercial resorts to the many small and remote retreats. In 1999 Wales had 70 designated bathing beaches, 69 of which complied with the EU Bathing Water Directive A variety of initiatives ("European Blue Flag", "Seaside Awards", The Heinz Good Beach guide, and a number of others) attempt to assure the public of the quality of the beach environment. Perceptions of beach quality and cleanliness have a major impact on consumer behaviour.

Rising sea levels coupled with increased storm severity and frequency are likely to place increased pressure on the maintenance of quality beaches. Clean sandy beaches as well as clean bathing water feature highly on the coastal visitors list of priorities. The various agencies concerned with sewage discharge and water cleanliness have undertaken major investments in this area but little attention has been given to the maintenance and presence of sand. Increased erosive capacity plus dated sand entrapment structures mean that large reductions may occur in beach sediment. Thus the coastal resource is jeopardised by increased sediment transport and erosion, loss of sandy beaches, deterioration of dune/beach interface, loss of paths and loss of land. Shallow beaches such as Trearddur Bay and Llanddona may be at high risk.

Detailed assessments are required at site and cell levels to identify areas at risk and to ascertain the condition and effectiveness of sea defences and sediment entrapment structures. Similarly sewage and associated ground water links may require re-appraisal especially in the case of large seasonally variable holiday parks at or near sea level. Some freshwater supplies may be affected. The main considerations relate to location and the designation of areas at risk. Clearly this will involve policy guidelines for new developments and existing facility (housing, retail and amenity).

What might be the impacts of rising temperature and changing precipitation?
Rising temperatures and precipitation will undoubtedly cause changes in landscape and ecology not all of which will be positive. Some environmentally valuable resources will be lost. Recreational impacts will include operational and strategic issues involving carrying capacity of paths and amenity areas, which may be radically altered by extremes of drought and rain. Rural areas may require control of numbers and urban resorts will see large increases in the cost of amenity maintenance (parks and promenades The other impacts of rising temperature and precipitation revolve around human behaviour and human perception. Recreational behaviour is strongly related to temperature thresholds and a number of activities have distinct temperature triggers. These thresholds will be exceeded with increasing frequency. Bathing should increase in the holiday peak periods but during the shoulder months the main effects are likely to be in other activities. These include golfing, walking, bird watching and fishing. The extension of the tourist season will have related effects on the more passive elements of leisure. Changes in consumer behaviour in retailing and eating will need further study.

Wales, along with much of Britain is often perceived as a wet and windy destination only reprieved by a short and fickle summer. The British holiday maker can be forgiven for seeking an assured hot and sunny refuge for at least part of the year; and while foreign destinations are able to offer such solace at a competitive price then the fate of Welsh resorts is in jeopardy. The predictions that the Welsh summer will become warmer suggest that the long stay, higher spending and discerning tourist will return. Their return will be more likely after a succession of superb summers. Convincing data may demonstrate that some areas or cells do have good weather with some degree of certainty. Increased tourism in dry summers will place a new demand on the supply of water. If hot dry summers are infrequent then wet weather facilities may provide a better quality experience. Indoor or covered water and steam facilities, half covered eating areas and air conditioning may be a feature of many establishments but will require major investment. Wet weather facilities may appease the visitor but will not ensure his return.

4.7.3 Findings from stakeholder consultations

The tourism and leisure stakeholders had not specifically considered the longer term impacts of climate change, but they were acutely aware of the importance of climate on tourist activities. Current planning centres around the need to provide wet weather facilities for tourists. The potential impact of climate change on coastal communities and caravan sites was raised, as was the impact of flooding. An indirect impact of climate change could be a rise in fuel prices, which may affect tourism in Wales, but also other destinations. Generally the stakeholders felt their organisations would be slow to adapt to climate change; they needed greater certainty about the predictions, and expected central government to take the lead in adapting.

Quotes:

'Flooding in Spain led to the European Federation of Campsite Organisations producing a leaflet on the management of external risks to campsites.'

'The coastal communities that are dependent on tourism will be significantly affected by climate change.'

'It might influence the way in which we invest in the tourism industry in terms of helping it to adapt.'

'We would open and close according to demand. We might use more alternative energy sources, provide more wet weather facilities. Our insurance premiums for flood and storm damage would increase.'

'There would be a tendency against floodplain development in response to guidance from the Environment Agency.'

'Infrastructure issues are key considerations as far as climate is concerned, e.g. covered walkways.'

'There is a lack of information on winds, which affect visitor numbers.'

'Guaranteed hot summer weather might influence people to holiday in the UK rather than abroad.'

'

'Although everyone would like drier summers, Britain's green landscape is popular and we wouldn't want it to become parched, landscape issues and a viable agricultural sector are important to tourism.'

Understanding of climate change and reaction to existing impacts

There was reasonable understanding of climate change by the stakeholders. The stakeholders generally agreed that climate change would alter weather patterns, with the likelihood of increased frequency and severity of storms leading to increased of flooding. Information on climate change had largely been gleaned from the media. Limited use was made of scientific literature, government reports and the Internet. There was little coverage in industry reports. None of the stakeholders had undertaken any deliberate consultation on issues of climate change, although one organisation had informal discussions with organisations like the Environment Agency, Countryside Council for Wales and National Assembly.

Their activities had been affected by recent unusual weather patterns. The need for all-weather facilities was mentioned, but as a long-term plan and not specifically a response to change in climate. Some stakeholders recognised the changes in patterns of demand on the tourism industry, for example, that weather patterns currently influence peoples' behaviour day to day, and so demand on National Parks varies on a short term basis. Thus, if weather patterns change significantly it will change the number, nature and type of use of tourism resources such as National Parks. The weather in one year affected where people took their holidays in the next year and the trend was for people to take their winter short break in the UK. There was a general feeling that changing weather would affect the stakeholders' future activities, but some stressed the need for evidence of trends before significant changes were put in place. Climate change might increase investment in the tourism industry to help it adapt.

Long term planning

There was a high level of strategic planning amongst the stakeholders, with plans ranging from 3 to 10 years with other plans being updated annually. However, apart from the general requirement for economic and business plans, there was little consensus on the issues which were included in long term plans. It is difficult to include climate change in plans because the impact is too uncertain. Future climate features in one plan, in relation to providing wet weather facilities.

Reaction to potential impacts
Specific actions to deal with climate change had been taken, although the need for wet weather facilities was flagged up, this was probably a general response to the wet Welsh climate.

Several areas of responsibility were likely to be affected by the predicted changes in climate in Wales. Coastal communities, particularly caravan sites, which are a resource base for visitor attractions, might not be viable in 20-30 years time as a result of sea level rise and increased strength and frequency of storms. Flooding will have an impact, probably through planning and the location of development and utilities. The tourism season might be extended and if this was known for certain then it might trigger investment in all-weather facilities. Less snow might deter people from visiting the mountains in the winter. The landscape would be affected in terms of design of new landscapes, vegetation patterns, patterns of agriculture and biodiversity.

The measures that the stakeholders could take to avoid or reduce these impacts included the following: provide wet weather facilities; promote outdoor activity holidays if the weather was milder; market facilities regardless of weather, raise public awareness to what we offer; avoid development on the floodplains, and use technological knowledge to deal with issues in construction, land reclamation and landscape.

Insufficient finance was identified as a barrier to taking any such actions. There were conflicting views on staff attitudes. Some stakeholders felt that there was flexibility to change but others felt that apathy and inertia were barriers, along with uncertainty and lack of information. Several stakeholders felt their organisations would be slow to change, mainly because of the way in which the organisations are structured and decisions are made. None of the stakeholders could adapt by changing the location of their activities.

When asked if they could see any direct opportunities or benefits arising from these changes some stakeholders thought it might enable them to review their use of resources, particularly energy, with alternative sources such as wind and solar power becoming more viable. It might encourage people to holiday in the UK rather than abroad and might extend the UK holiday season. Some interesting views were expressed on the potential indirect effects of climate change, specifically the effects of increased taxes on fuel. Increased fuel prices were predicted to have a negative effect on the UK tourist industry, especially if public transport wasn't improved. Petrol prices also affect staff costs significantly.

Needs in relation to climate change
Most stakeholders thought greater certainty in the predictions of climate change would influence them to take action. It would be a long process and there are other conflicting priorities, and how much action would depend on how they perceive the direct threat. Some stakeholders felt that they would need high, i.e. Assembly, level, agreement and policy in order to help them adapt to the new climate. Advice of a practical and technical nature rather than theory, plus financial assistance, were needed. Without central guidance it wasn't going to be an immediate issue for anyone because the changes are outside the usual planning horizon. All stakeholders felt they could offer expertise and data on how the industry currently functions and technical advice on how it might be affected by climate change, as wellas how the industry could react to those changes.

4.7.4 Recommendations

1. The tourism industry needs to examine its policy of expanding into the shoulder periods in the light of the seasonality of climate change.
2. The industry needs to consider the likely impacts of sea level rise and storms on beaches important to tourism.
3. The industry needs to consider improvements to its processes of gathering data to facilitate adaptation.
4. The Assembly should consider adequate support for the three Welsh National Parks to plan for climate change in their roles of environmental care and being foci for tourism.

5. COMMUNICATING CLIMATE CHANGE

5.1 Challenges in communicating climate change to the public

Communicating ideas about adaptation to climate change to the general public involves two key elements:

1. Raising awareness about the issue i.e. What is climate change?
2. Encouraging individuals to change their personal behaviour to respond to possible impacts.

Communicating within Wales needs to be in the context that the lower mean GDP and qualification base limits the ability to change. Research into public attitudes showed that an increasingly high percentage of the public is concerned about the environment (DETR, 1996/7), although the environment in itself is not a great enough motivator for change for many people. It also showed that people are optimistic and believe that 'a lot could be done' to improve the situation. However, the same study shows that the issues that concern the public most are those that have direct, immediate and scientifically well-understood impacts e.g. water and air pollution. For example, 65% of respondents said they were 'very concerned' about the chemicals put into rivers and seas whereas only 35% were 'very concerned' about global warming. The study also showed that the public is generally reluctant to alter their behaviour to actively improve their environment. Part of the reason for this could be attributed to confusion about the causes and effects of climate change. Many feel that the problem does not or will not affect them directly. The impacts predicted occur over the long term and may not even be noticed within our lifetime.

Individuals also feel that they cannot make a difference. In the DETR survey, 56% and 45% of people correctly identified the destruction of forests and emissions from power stations as causes of global warming, However, only 12% identified use of gas and electricity in the home as a cause. There are also problems with misinformation or misunderstanding: more than half the people surveyed also wrongly identified the hole in the ozone layer as a cause of global warming.

Climate change is seen as a virtual risk. The lay public is confronted by uncertainty in that there are different scenarios, and prediction of climate variables are given as ranges, not single values. Climate change issues are the subject of debate and controversy, unlike the tried-and-tested science found in textbooks. According to Gregory and Miller (1998), "This puts strains on everyone involved in the process of public understanding of science: on scientists, in knowing what to claim; on journalists, in assessing what is reliable and significant; and on the public and their representatives, in matching the new facts and ideas to what they already know and how they already live, and in deciding what to do."

Even when the experts have clearly identified the risks associated with certain behaviours and communicated them widely, the 'authorities' find it difficult to manage risks at national or international levels. We see this with smoking, sunbathing and drinking and driving. The public does know about the potential risks: information campaigns via the mass media have raised awareness effectively. Individuals are their own risk managers and over-ride the judgements of experts. The safety authorities are less appreciative of the *rewards* of risk taking (Adams, 1997). Effecting change requires an understanding of what motivates people to change and how they perceive the costs and rewards of taking risks. The nature of climate change presents a significant challenge to those wishing to communicate the issues to the public, and to effect change.

5.2 Possible mechanisms for communication

Mass media (television, radio and newspapers)

The mass media are obviously a key vehicle for communicating information to the general public. This can be on several levels: awareness raising campaigns funded by public bodies (for example, the Are you Doing your bit? campaign run by the DETR), news coverage and specialist programmes or documentaries. Television is the most effective medium for communicating with a wide audience, but can be very expensive. In general the mass media are limited with respect to the level of detailed information they can provide; most news items only last a minute or two. Radio and television documentaries and extended interviews provide scope for expanding arguments and for debate, but audience numbers are much lower. Even the mass media do not reach everybody. For example, readership of The Sun is only about 7% of the British population.

Are you doing your bit? – DETR campaign

Launched in 1998, this campaign was designed to communicate elements of sustainable development. It encourages small but important behavioural changes to everyday actions to benefit both ourselves and the local and global environment. The campaign focuses on four priority areas:

- Transport with links to air quality and health
- Climate change mitigation and energy efficiency
- Water use
- Packaging and waste

Each of the four priority areas feature more heavily at certain times, in parallel with other organisations' promotion campaigns on the same themes and key policy developments, such as the international climate change negotiations. Well-known celebrities feature in television advertisements. These have been reinforced by radio advertisements, the press (including consumer interest and women's magazines), poster sites and bus sides. PR has been used extensively to ensure that the campaign is covered by all media at both national and local level. A series of 23 regional roadshows have been organised in partnership with local authorities. The roadshows begin with a high profile media launch with a reception for local dignitaries and local stakeholders. The public can visit the campaign's travelling exhibition. The campaign has eight general guiding principles:

1. People respond to personal requests best
2. Open their heart. Then open their minds
3. Set up the problem but give a solution
4. Set achievable targets
5. Make the issue tangible to encourage full involvement
6. The most important two words are 'Thank you'
7. Encourage consumers to identify with the issue
8. Get yourself talked about. Advertisements are not enough

The campaign has been informed by research and evaluation of its impacts. 58% of those surveyed say they have seen the adverts and about 4 in 10 people remember their messages. Awareness of the messages has increased.

Community campaigns and initiatives

Activity within local communities has increased recently, particularly with regard to environmental issues. Some of these activities centre on local projects whilst others are part of public consultation which informs decision making. These use the local knowledge and expertise that residents and local businesses have, often under the banner of Local Agenda 21.

The Sustainable Communities Programme is run by Going for Green in Wales. The results to date have been variable. In some areas, the programme has been very successful in involving local people and sustaining interest. In others, it has been difficult to engage people in the activities and to establish a meaningful dialogue. This type of awareness - raising activity tends to attract those already interested in the issues. The European Awareness Scenario workshops developed by the European Commission's Innovation Programme (DG-XIII D) are now being used extensively by the Sustainable Towns and Cities Campaign (DG-XI) and for a green jobs initiative launched by DG-V. The workshops' main aims are to initiate dialogue between citizens, local businesses, politicians and environmental experts and to raise awareness of issues surrounding sustainable development, at the local level. The participants use scenarios to create a common vision for the future and discuss who should be responsible for change (individuals, neighbourhood groups or public authorities) and how change should be implemented (through technological solutions or organisational solutions that require a behaviour change). Finally, participants create an action plan for their community. The initiative began in 1994 and over 100 workshops have been organised around Europe. (www.cordis.lu/easw). Pledges and 'adoption' schemes can also help raise awareness about the impacts of global climate change at a local level.

School and family initiatives

Children can be a key motivating factor for parents to adopt a more sustainable lifestyle. Educating and involving children and families is one way to build awareness in future generations. Going for Green already promotes the

European Eco-schools programme where schools work towards changing lifestyles to reduce consumption and increase conservation. The schools develop and adopt an environmental code and are then audited against this code. Information and advice should be made available at places which attract family audiences, including entertainment venues, public libraries and museums. Outreach programmes aimed at younger audiences should also be considered.

5.3 Stakeholder views

The stakeholders interviewed in this exercise all agreed that the mass media are the most effective way to reach the public. Media surveys show that the public wants environmental stories covered in the news. The stakeholders agreed that the issue should be covered in the news because it effects everyone, not just certain sections of the population. However, for climate change to be included in the news, information providers need give the story a new angle, making it fresh and current. This means putting the environmental facts and figures into a relevant, local context with which the public can easily identify. “In some ways, climate change is a little esoteric. But, if you can show how the change will affect people’s lives, it makes all the difference.” Material should be presented to the media in concise, accessible, jargon-free press releases. “There isn’t usually enough time to go into a lengthy debate on the news. People want crisp, concise information that they can easily digest. Complicated or confused messages don’t get through.”

If information is seeking a change in behaviour, the public should be given an incentive to make that change: “They should be able to see what’s in it for them.” There was mixed opinion about the use of shock tactics in the media. Some of the stakeholders saw that ‘doomsday’ scenarios spark an interest in the public while others felt that “doom and gloom should be countered with success stories that show how individuals or communities can tackle environmental problems.”

News editors requested that information be fed into the media more thoughtfully. “Most organisations now realise that they have to move their findings into the wider domain. But they just send us everything and it is sometimes impossible to judge what is big news and what is not.” The uncertainty of climate change also concerned some of the stakeholders as “the public can equate uncertainty with the ‘cry wolf’ factor. Twenty years ago, everyone was reporting that there would be no oil left by the end of the century. People remember this and it hasn’t happened.”

Media representatives also stated that they would be able to cover climate changes much more sympathetically if they were given more advance warning about key conferences and events. Extended coverage would be possible as longer lead times and off-the-record briefings help researchers to find supporting case studies that can be included as additional information. With the Internet and increasing numbers of channels on television, the target audience is becoming more fragmented. Information providers such as research institutes and government agencies will have to continue to work at understanding how the media operate and what makes a good story to raise and maintain public interest in climate change.

5.4 Recommendations

1. The Assembly and other organisations need to consider how to increase public awareness of climate change issues whilst taking account of the attitudes of Welsh people to environmental issues.

2 The Assembly needs to consider setting up a forum of local stakeholders and experts to exchange information , concerns and ideas, to act as a focus and facilitator for the climate change debate, and to start building networks within Wales.

6. GLOSSARY

ABI	Association of British Insurers
CCL	Climate Change Levy
DETR	Department of the Environment, Transport and the Regions
DoE	Department of the Environment (now DETR)

DTI	Department of Trade and Industry
EA	Environment Agency
GCM	Global circulation models
GHG	Greenhouse gases
HAD-CM1/2	Hadley Centre Model 1 or 2
ICPP	Integrated control and prevention of pollution
IPCC	Intergovernmental Panel on Climate Change
NAW	National Assembly for Wales
NFFO	Non-fossil fuel obligation
OFWAT	Office for Water Regulation
UEA	University of East Anglia
UKCIP	United Kingdom Climate Impacts Programme
UKWIR	United Kingdom water industry research

7. ACKNOWLEDGEMENTS

We are grateful to the following organisations who provided us information in the course of our stakeholder consultations.

Archaeology
CADW
Clwyd-Powys Archaeological Trust
Countryside Council for Wales
Glamorgan-Gwent Archaeological Trust
National Trust
Royal Commission in Ancient and Historic Monuments for Wales

Biodiversity
Biovidersity Officer, Countryside Council for Wales
Conservation Office, Glamorgan Wildlife Trust
Ecologist, Snowdonia National Park
Head of Species, Countryside Council for Wales
North Wales Wildlife Trust
Pembrokshire Coast National Park Authority

Business and financial services
Association of British Insurers
Lloyds TSB General Insurance Ltd
Willis Corroon

CBI Wales

Flooding and Coastal Defence
Carmarthen Bay Coastal Engineering Group,
Environment Agency Regional Flood Committee
Planner, Monmouthshire County Council
Stena Line
Usk Flood Defence Committee
Ynys Enli Llandudno Coastal Group, Environment

Food and Drink
JR Freeman & Son Ltd
SA Brain Brewery
Sun Valley Foods

Construction
Redrow plc

Chemicals and Pharmaceuticals
BP Amoco Chemicals

Clothing and Footware
Laura Ashley Holdings plc

Electronics and Electrical
Hoover
Matsushita Electric (Panasonic)
Newbridge Networks

Engineering and Vehicles
BICC Cables Ltd (Mains Cables)
Calsonic International (Europe) plc

Energy
BNFL (MAGNOX)
MANWEB
National Wind Power
SWALEC
TRANSCO

Metal Manufacture (Ferrous/Non-Ferrous)
Anglesey Aluminium Metal Ltd - Penrhos Works
ASW Holdings plc - HQ
Corus (British Steel)

Paper and Printing
Kimberley Clark
St Regis
UPM-Kymmene UK plc (Shotton Paper)

Freshwaters
Agricultural Policy, Countryside Council for Wales
Dee Angling Association
Environment Agency
Freshwater Ecologist, Countryside Council for Wales
RSPB
The Wye Foundation

Health
Department of Microbiology, Wales Public Health
Glan Clwyd District General Hospital
Llandough Hospital
Public Health laboratory, Gwynedd NHS Hospital
Public Protection, Flintshire County Council
Regional Epidemiologist, CDSC Wales
The Welsh Collaboration for Health and Environment
University Hospital Wale
WHO Centre, University of Wales Institute

Hotels and Catering
Haven UK - Rank Holidays

Land Use, Agriculture and Forestry
Agricultural Policy, Countryside Council for Wales
CLA
Forest Enterprise
FRCA
FUW
National Trust

Media
Are you doing your bit? (campaign for DETR)
BBC Radio Wales
Going for Green (Wales)
HTV Wales
Red Dragon Radio
Techniquest
Wales Today (BBC Wales)
Western Mail

Retailing and Distribution
Hasbro UK Ltd
Iceland
Somerfield/Kwik Save

Rubber and Plastics
Rexam Custom Ltd

Timber and Furniture
Kronospan Holdings Ltd

Transport
ABP (Cardiff, Swansea, Newport, Port Talbot)
Caerphilly CBC
Cardiff Wales Airport
English Welsh and Scottish Railway
Gwynedd Council
Neath canal navigation
Pembroke Dock
Railtrack

Tourism
British Holiday and Home Parks Association
Snowdonia National Park
The National Caravan Council
Welsh Association for Visitor Attractions
Welsh Development Agency
Welsh Development Agency
Welsh Tourist Board
Youth Hostel Association

Water
Dee Valley Water
Environment Agency (Wales)
OFWAT
Severn Trent
Water UK
Welsh Water

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ANNEX 1: OPPORTUNITIES TO CO-FINANCE R&D ON CLIMATE CHANGE IMPACTS

This study has identified some of the most important climate change impacts likely to occur in Wales. We have identified numerous areas where our knowledge is not sufficient to fully inform decision making. Further work will require the securing of funds for research. The following organisations can provide the Welsh Assembly with opportunities for further research, and potential partners who would either lead, collaborate or co-finance work on impacts of climate change. Each of these organisations has an interest in some aspect of the environment, with some pursuing specific climate change agendas.

European Commission
Within the European Commission there are various directorates such as DGXI, DGXII and DGXVI that have environmental, economic, and R&D links that relate, in part, to climate change issues.

DGXVI – Regional Policy
DGXVI is the department of the EC that is responsible for Regional Policy – community action to reduce the gaps in socio-economic development between the various regions of the EU. DGXVI's policies and programmes contribute towards stability in the EU and aim to promote high employment by tackling the regions' uneven capacities for generating sustainable development and their difficulties in adapting to new conditions on the labour market and to global competition. DGXVI's main responsibilities are the management of two major funds, the European Regional Development Fund (ERDF) and the Cohesion Fund (CF)

The Cohesion Fund provides assistance to projects in Greece, Ireland, Portugal and Spain. The ERDF is however available to all member states. The ERDF is one of the EU's four structural funds [3] that aim to promote economic and social cohesion by creating jobs through fostering competitive and sustainable development. It is by far the largest of the EU's structural funds, representing almost half of the total budget of ECU 154.5 billion at 1994 prices for 1994-1999. Top priority is given to Objective 1 regions, which receive around two thirds of the budget. West Wales and the South Wales Valleys has Objective 1 status and is eligible to apply for structural funds. Financial assistance from the EDRF is mainly targeted at:

- Supporting small and medium-sized enterprises
- Promoting productive investment
- Improving infrastructure
- Furthering local development

The National Assembly can approach DGXVI for funding from the ERDF on aspects of climate change that relate to competitiveness and job creation in the region. The focus should be on SMEs and the impacts climate change may have on business and job creation (and destruction) through the long-term effects of climate change. Emphasis may need to be on the Objective 1 status of West Wales and the likelihood of widening disparities between the region and other regions in the EU, due to economic and social consequences of climate change.

DGXI – Environment, Nuclear Safety and Civil Protection
The actions of DGXI are carried out within the strategy defined by the EC Fifth Programme of Policy and Action in Relation to the Environment and Sustainable Development "Towards Sustainability". DGXI stands for:

- A high level of environmental protection
- Improvement of the quality of life
- Increased environmental efficiency
- Preservation of the rights of future generations to a viable environment
- Ensuring equitable use of our common environmental resources

[3] The EU has four Structural Funds through which it channels financial assistance: The European Regional Developments Fund (ERDF); The European Social Fund (ESF); The European Agricultural Guidance and Guarantee Fund (EAGGF) Guidance Section; and The Financial Instrument for Fisheries (FIFG).

The main policy areas within DGXI are General and International Affairs; Integration Policy and Instruments; Nuclear Safety and Civil Protection; Environment Quality and Natural Resources; and Industry and Environment. Climate change is covered within the first of these. Funding available through DGXI includes:

- LIFE
- Publication of funding opportunities for 'ad hoc' proposals
- Environmental information and awareness raising
- Financial support for European environmental organisations
- SMAP/Euro-Mediterranean Partnership

The last two of these are not relevant to an agenda of climate change impacts in Wales and the third has been frozen for 1999. The funding of 'ad hoc' proposals can cover any subjects within the 5th Environmental Action Plan (which includes climate change and environmental data) and those that relate to the policy areas of DGXI. Support can be provided up to 50% of total expenditure.

DGXII – Research

The research activities of the European Commission are the responsibility of DGXII. The aims of DGXII are:

- To develop the EU's policy in the field of research and technical development and thereby contribute to the international competitiveness of European industry.
- To co-ordinate European research activities with those carried out at the level of Member States.
- To support the Union's policies in other fields such as environment, health, energy and regional development.
- To promote a better understanding of the role of science in modern societies and stimulate a public debate about research related issues at European level.

The main instrument for the implementation of this policy is the multi-annual Framework Programme that helps to organise and financially support co-operation between universities, research centres and industries – including SME's. The Fifth Framework Programme covers the period 1998-2002 and has a budget of close to •15 billion. It has been structured around seven major programmes including "Quality of Life and Management of Living Resources" and "Energy, Environment and Sustainable Development"; the latter covers global change and climate. The targeted fields of research include evaluating and understanding process of global change; improving knowledge of ecosystems; and scenarios and strategies. The programmes provide financial support for collaborative research in areas where collaboration at European level provides added value. The FP5 may provide an avenue for the Welsh Assembly, via funding to local authorities, academia and business to build upon its knowledge of climate change. The international transfer of findings would add additional value to the entire EU.

The Ministry for Agriculture, Fisheries and Food

The aims of the Ministry for Agriculture, Fisheries and Food (MAFF) are to ensure that consumers benefit from competitively priced food, produced to high standards of safety, environmental care and animal welfare and from a sustainable, efficient food chain; and to contribute to the well being of rural and coastal communities. Amongst the numerous MAFF objectives are:

- To sustain and enhance the rural and marine environments and public enjoyment of the amenities they provide and to promote forestry.
- To enhance economic opportunity and social development in rural and coastal communities in a manner consistent with public enjoyment of the amenities which they offer.
- To reduce risks to people and the developed and natural environment from flooding and coastal erosion.

MAFF holds the Government's agricultural research budget for Wales and England. It commissions scientific research and economic policy evaluation. The Department funds a wide and varied research programme and each Policy Group within MAFF has its own budget for R&D.

- To inform and implement its current policies
- To provide scientific foresight
- To contribute to the identification of future policy options

MAFF's 1999/2000 research budget is around £125 million. Research is used either directly in policy formulation or implementation, or the results are transferred to the industry for whose benefit the research in supported. In terms of MAFF's objectives. 86% of the 1998/1999 research budget was spent on three objectives – public health, thriving markets and environment. 2% of the budget was used for R&D into flooding and erosion issues. MAFF also develops links with research in other countries and the EU where this can help achieve MAFF aims. It is involved in the EU's multi-annual Framework Programme for Research and Technological Development.

Environment Agency

The Environment Agency (EA) has a wide range of legal duties and powers relating to different aspects of environmental management. It is required to use its duties and powers to support sustainable development, thus taking a more integrated and longer-term view of environmental management. The Environment Agency's R&D section aims to contribute to a better environment by delivering practical research and development. The EA has identified nine key themes:

- Addressing climate change
- Regulating major industries
- Improving air quality
- Managing waste
- Managing water resources
- Delivering integrated river-basin management
- Conserving the land
- Managing freshwater fisheries
- Enhancing biodiversity

EA has 13 Commissioned Programmes of R&D projects, each reflecting the policy and operational interests of one of its core functions. The size and balance of policy and operational research for each Commissioned Programme varies – the largest are for Environmental Protection Functions. The overall budget for 1999/2000 is around £10.7 million. One of the nine themes is "Addressing Climate Change". Key climate change effects relevant to the EA include rise in sea-level, stresses on coastal zones, changes in rainfall, changes in severity of floods and storms and associated impacts on flora, fauna and environmental quality. The key R&D issues in addressing climate change are, to help to ensure the UK GHG emission reduction targets are met; to understand and assess the impacts of climate change on the environment; and to investigate how best the EA might respond to climate change effects. This focus on climate change may provide the Welsh Assembly with further opportunities to secure funding for further climate change research. The obvious importance (and interest) demonstrated by the EA suggest that they may be sympathetic partners for collaborated work.

Department for Environment, Transport and the Regions (DETR)

The aim of the DETR is to improve the quality of life by promoting sustainable development at home and abroad. The DETR is made up of several Groups with a wide range of policy responsibilities:

- Environmental Protection
- Housing, Construction, Regeneration and Countryside
- Local and Regional Government
- Railways, Aviation and Shipping
- Planning, Roads and Local Transport
- Strategy and Corporate Services

DETR encourages and funds science, engineering and technology (SET) in support of Departmental policy, statutory, operational regulatory and industrial sponsorship responsibilities. Research Programmes in DETR are planned and procured by research managers within policy divisions, and its research strategy is driven by policy objectives. Its main aims are to:

- Monitor and evaluate the effects of existing policies and earlier decisions.
- Ensure that new policies and decisions taken at home and abroad are evidence based.
- Encourage innovation in the private sector to meet policy objectives.
- Assist the industries, which it sponsors and supports, to make best use of the opportunities of new technologies and innovations.
- Deliver with other partners, a coherent UK vision of the future challenges within DETR's policy responsibilities.

The 1998 Comprehensive Spending Review resulted in many major new policy directions, including more resources to improving home efficiency and to delivering Kyoto commitments. This review resulted in an 8% real increase in funding for research by DETR in support of its policies. Research in support of Integrated Transport policies and Environment initiatives account for the bulk of budget increases over the next 3 years. Planned expenditure for all DETR programmes for 1999/2000 is around £112 million (£131 including SET programmes) and this does not include the extensive monitoring and research programmes of the Health and Safety Executive, the Environment Agency, the Highways Agency or Maritime and Coastguard Agency. There is a "Global Atmosphere Research Programme". The key research objectives are to improve the scientific and technical information to inform decisions on climate change and to meet national and international commitments for environmental monitoring and measurement. Almost £12 million has been allocated for "Global Atmosphere" research in the year 1999/2000. Much of the DETR's research has an international dimension and thus has a direct interest in a number of international research programmes and initiatives including the EU Framework Programmes, COST and research activities of the OECD.

ENTRUST – The Regulator of the Landfill Tax Credit Scheme
The Landfill Tax came into effect in 1996. The Landfill Tax Regulations enable Landfill Operators (LO) to claim a credit for 90% of landfill monies voluntarily donated to registered Environmental Bodies (EB), subject to a maximum of 20% of the landfill tax collected. ENTRUST is the statutory body charged with approving Environment Bodies wishing to access landfill tax credits.

The funds may also be used by EB's to finance the running costs of the Body and for investment purposes (although interest income must also be spent on approved purposes). The EB's wishing to participate in the scheme need to demonstrate the following conditions:

- They must be non-profit making.
- The work they carry out must not benefit any of the landfill site operators making the contribution to the EB.
- They must not be controlled by a local authority or be a corporate body controlled by local authorities or site operators.
- None of their work is required to be done by the site operator under any enforcement notice, planning consent or other statutory consent.

Two years into the venture, completed and on-going projects have accounted for an expenditure of £44 million out of the £135 million contributed. Research and Development/Education for Sustainable Waste Management (37%) and Public Parks/Other Amenities (51%) comprise 88% of the total spend. The aims of the environmental bodies vary considerably and existing organisations along with single and multiple scheme EBs and umbrella EBs are all likely to benefit. The types of projects eligible for funds are relatively broad ranging. Environmental Bodies can fund projects qualified as 'approved environmental purposes'. These include:

- Research and education to encourage more sustainable waste management practices.
- Where it is for environmental protection, creation or improvements to public parks or other amenities provided they are in the vicinity of a landfill site.
- Reclamation, remediation or restoration of land, whose use is prevented by a previous activity.

- Projects to reduce or prevent pollution of land, whose use is prevented by a previous activity.
- Maintenance, repair or restoration of buildings used for religious worship or which are of historic or architectural interest, where in the vicinity of a landfill site and for environmental protection.

The Welsh Assembly may need to create an independent EB, to secure funds for further climate change research. The landfill sites, as producers of methane (a greenhouse gas - GHG), contribute to global warming, and thus climate change. There is an avenue for the Welsh Assembly working in collaboration with a non-profit making environmental body to pursue funding for research and education focusing on interactions between climate change and the waste industry. Ideas might include mitigating emissions of the GHG methane from land fill sites or the impacts of climate change on waste disposal options.

Recommendations

1. The Assembly should consider creating an independent Environmental Body to work with ENTRUST.
2. The Assembly should assist those seeking to initiate research relevant to climate change impacts in Wales to acquire co-funding from EU and UK bodies.
3. The Assembly should consider prioritising its research needs for climate change impacts to facilitate its support of the research community.
4. The Assembly and other Welsh organisations need to ensure that Welsh issues are fully incorporated into UK-wide research on climate change impacts.