Directorate of Economy and Environment
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Isle of Wight Shoreline Management Plan 2

Appendix C: Baseline Process Understanding

C1: Annex B
Climate Change and Sea Level Rise

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Coastal Management;
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C1: Annex B -Climate Change and Sea Level Rise

Contents

Summary of contents

This report provides an appraisal of climate change and sea level rise, including causes, effects and management at a global scale. The impacts of climate change vary spatially and so predictions of climate change are discussed at a regional scale. A summary of the likely impacts of climate change is provided.

The report continues by examining the likely impacts of climate change and sea level rise on the Isle of Wight, with particular reference to impacts of climate change on the coastal environment.

Current national government guidance on sea level rise predictions is outlined, and the predictions are applied to calculate future sea level rise for the Isle of Wight. Specifically, the Defra guidance ‘Flood and Coastal Defence Appraisal Guidance FCDPAG3 Economic Appraisal Supplementary Note to Operating Authorities – Climate Change Impacts’ was used in the production of this report.

Key sources of data used in the production of this report include various publications by the IPCC (Inter-governmental Panel on Climate Change) and the UKCIP (United Kingdom Climate Impacts Programme).

1. Introduction to Climate Change

Climate change is not a new phenomenon. The World's climate has always been changing. What is different now is that it is the belief of many scientists that man-made impacts on climate have become discernible in addition to natural change.

On a day-to-day basis we receive frequent reports of apparently exceptional weather conditions that have recently been recorded. This is not a new trend, it is fundamental to the recording of meteorological information that natural variability will lead to the recording of extremes from time to time, so such events alone cannot be considered as evidence of climate change. Indeed, it has not yet been proven that frequencies of extreme events are changing, although the IPCC 2007 Synthesis Report: Summary for Policymakers report says that it is very likely that we will experience regional-scale increases in the frequency of hot extremes, heat waves and heavy precipitation. The recording of such weather events does improve our understanding of the climate that we should expect. However, it is an acknowledged scientific fact that the composition of the atmosphere is changing significantly and that human activities that result in the emission of so-called greenhouse gases are implicated strongly. The greenhouse effect itself is a natural occurrence, which has operated for billions of years. Without the natural greenhouse effect the earth's temperature would be some 33°C cooler. The majority of scientific opinion now agrees that human influences on the global climate are beginning to become detectable above and beyond natural changes. This is particularly the case for near surface global mean temperature. Since the industrial revolution man has been changing the composition of the atmosphere, primarily by the burning of fossil fuels. Evidence from ice cores supplemented by direct measurements since the mid-1950s shows a steady rise in concentrations of greenhouse gases from the late 1700s changing to a rapid rise post 1950. Through the study of historical weather records and future projections with numerical models there is good evidence to suggest that human influenced climate change is taking place, and is likely to accelerate in the future.

Climate change is likely to impact on a wide range of issues from habitat survival or migration, through to water resource strategies, and adaptation of infrastructure design. Climate change could also trigger an agricultural response through changes in rural land-use and soil management.

Sea levels are rising globally with regional and local variations. However, owing to its inherent complexity, neither climatological observations nor present climate models are sufficient to project how the climate will change or sea level rise with certainty.

While changes in mean sea level should be of concern to coastal planners, it is the occurrence of extreme high water events that causes most problems with coastal erosion and flooding. It is possible that changes to the frequency and intensity of storm surges may occur under a warmer climate.

The coast of the Isle of Wight is vulnerable to storm waves of exceptional energy, particularly the exposed south-west coast. If the frequency and magnitude of storms are to increase, alongside sea level rise, then the Isle of Wight coasts (particularly the exposed south-west and north-west coasts) will be subject to increased erosion and cliff instability. A further consequence of sea level rise for the Isle of Wight will be overtopping of current defences, which although minimal at present, is likely to increase over the lifetime of the SMP. Tide-locking of floods is also an issue of concern. It is therefore paramount that climate change implications be taken into consideration when developing new coastal management and defence strategies.

SMPs and Strategy Studies follow national government guidance allowing for sea level rise withing their decision-making. Net sea level rise allowances were published by Defra in 2006: A variable allowance over time of 4mm/yr to 2025, 8.5mm/yr between 2025 and 2055, 12mm/yr between 2055 and 2085, and 15mm/yr beyond 2085.

2. The Global Response to Climate Change

Climate change is a global issue that will affect us all. Speaking at a press conference at the annual summit of the leaders of the eight leading industrialised nations, UN Secretary General Ban Ki-Moon called climate change the “defining issue of our era” and urged leaders to prepare for what is to come. Steps are now being taken by leading political figures to publicise the importance of preparing for climate change, and as quoted by Kofi Annan (2006), the changes caused by past greenhouse gas emissions can’t be rectified. The Environment Commissioner, Stavros Dimas from the European Commission (2006), stated that “the time of theoretical debates about climate change is over; we need practical and effective actions”. The British Government have heeded this and “have made it a top priority for this government, both domestically and internationally” (Blair, T., 2007). Local authorities have also become involved.

The most authoritative reports on the science of climate change are those produced by the Inter-governmental Panel on Climate Change (IPCC), which brings together the leading scientists from around the world. The World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) set up the IPCC in 1988, with the objective of assessing the scientific, technical and socio-economic information relevant for the understanding of the risk of human-induced climate change. The IPCC does not carry out new research or monitor climate, but it bases its assessments on published and peer reviewed scientific technical literature. The IPCC 1992 report was fundamental to the development of the UN Framework Convention on Climate Change (UNFCCC), which was agreed at the Earth Summit in Rio de Janeiro in 1992 and has been ratified by over 170 countries. Under the Convention, developed countries agreed to return their greenhouse gas emissions to 1990 levels by 2000.

With more information and the results of Global Climate Models (GCMs), the UNFCCC recognised that further cuts in global emissions were needed to prevent serious climatic impacts in future. Each year, the countries that ratified the Rio Convention held a Conference of Parties (COP). In 1997 the 3rd COP meeting was held in Kyoto, Japan. After reviewing the original targets of the Rio Convention and finding them to be too weak, the countries came up with new targets. The text of the Kyoto Protocol was adopted in Kyoto on 11 December 1997. The protocol sets out to reduce climate emissions of developed countries by some 5.2% below 1990 levels over the period 2008-2012. Additionally, the Kyoto Protocol introduced mechanisms to allow developed countries to buy emission reductions that have taken place in other countries and count them as their own. These mechanisms are Joint Implementation, Clean Development and Emissions Trading. Carbon sinks for the sequestering of CO2, for example the proposed ‘Kyoto Forests’ are also allowed under the protocol. The protocol was first agreed in 1997, but required the agreement of countries responsible for at least 55% of global emissions measured in 1990. The US, the world's largest emitter of greenhouse gases, withdrew from the protocol in 2001, saying it would gravely damage the US economy. The Bush administration also criticised the protocol for not forcing developing nations including India and China to cut emissions immediately. Australia, which has a large coal industry, has also refused to ratify Kyoto. After the United States refused to ratify it, only Russia, responsible for 17% of emissions, could enable this threshold to be passed. In November 2004 Russian President Vladimir Putin signed the Kyoto protocol, finally allowing the protocol to be formally sanctioned. The Kyoto Protocol became a legally binding treaty on 16 February 2005. Countries that fail to meet the targets will face penalties and the prospect of having to make deeper cuts in future. “The entry into force of Kyoto is the biggest step forward in environmental politics and law we have ever seen," said Jennifer Morgan, director of the World Wide Fund for Nature (WWF) conservation group's climate change programme. The President of the UN General Assembly, H. E. Sheikha Haya Rashed Al Khalifa (2007), pronounced that “we have a real opportunity to raise our overall level of awareness about the science, the impact and the challenges we face from climate change, but also the opportunities ahead for a more sustainable future”.

3. Climate Change Evidence and Predictions

3.1 Introduction

It must of course be recognised that the earth's climate has always been changing, and this is evidenced particularly well through geological records. There is evidence that there have been ice ages at time intervals of some 150 million years or so and such ice ages last for several million years. The period from 1.6 million years ago to 10,000 years ago has been referred to as the age of Ice Ages. This was a largely ice age period however there were several interglacials lasting about 20,000 years during that time. It is believed that changes in planetary and solar orbits cause ice ages, and it is inevitable that the Earth will eventually enter another ice age, but this is over a much longer timescale, thousands of years, whilst that of human influence is hundreds of years. There are a number of other known 'natural' reasons why our climate varies in addition to the impacts of the so-called enhanced greenhouse effect. These include volcanic activity (which can release dust) and fluctuations in the solar output from the sun. However, these effects are believed to be minor when compared with the anticipated impacts of anthropogenic global warming.

It is estimated that for the next thirty years or more fossil fuels will maintain their dominant position in the global energy mix. Even if the concentrations of all greenhouse gases and aerosols had been kept at year 2000 levels, a further 0.1°C per decade would be expected (IPCC, 2007). The impacts of a changing climate will influence coastal related hazards by altering their frequency and intensity to become extreme events (Defra, 2007).

Although there has been much study of climate change, it is still not yet possible to relate individual extreme events, such as the heavy rainfall and subsequent major flooding events of 2000, 2007 and 2009, directly to anthropogenic changes to the atmospheric composition. However, consensus of expert opinion suggests that extreme events such as these will become more frequent and intense in a more energetic future climate as global temperatures rise.

3.2 Temperature

Due to the greenhouse effect global temperatures have risen by 0.76°C between 1850 and 2005 (IPCC, 2007) and are expected to increase by 2-3°C within 50 years (Stern 2006). According to the IPCC (2007) "eleven of the last twelve years (1995-2006) rank among the twelve warmest years in instrumental record (since 1850)". Research into the greenhouse effect and temperature rise has led to observations in ocean temperatures and results show "that the oceans have taken up around 84% of the total heating of the earths system over the last 40 years" (Stern, 2006) leading to thermal expansion. Temperature rise has influenced the melting of land based ice and "if the Greenland and West Antarctic ice sheets began to melt irreversibly, the world would be committed to substantial increases in sea level in the range 5-12m over a timescale of centuries to a millennia" (Stern, 2006) with an immediate affect of 1-3mm/yr rise. These contributions to sea level rise have resulted in a 10cm sea level rise since 1990 (UKCIP, 2007) in the UK with some areas of the world experiencing a 30cm rise. The action taken to mitigate and prevent catastrophic sea level rise must be long term because "both past and future anthropogenic carbon dioxide emissions will continue to contribute to warming and sea level rise for more than a millennium, due to the timescales required for removal of this gas from the atmosphere" (IPCC, 2007).

Over the last three centuries the mean temperature over central England rose by about 0.7º C, with 0.5º C of this rise in the last century (Hulme & Jenkins, 1998). When considering global mean surface temperatures, there has been a warming of about 0.7º C since the end of the 19th century, and some 0.5°C since about 1970 (Met Office, 2000). The temperature statistics also show that four of the five warmest years in the 340-year long central England temperature record were in the 1990s and that 1999 was the joint warmest year ever. Globally, 1999 was significantly cooler than the record year of 1998, primarily due to temperature changes over the Pacific due to the cyclic El Nino/La Nina circulation.

3.3 Rainfall

The IPCC (2007) predict that "heavy precipitation events and their frequency (or proportion of total rainfall from heavy falls) increases over most areas" and are virtually certain to occur within the 21st century. It has been observed that "winters over the last 200 years have become much wetter" (UKCIP, 2007) but it is predicted that climate change will increase the frequency of "heavy winter precipitation" with "more intense rainfall events over many Northern Hemisphere mid-to-high latitude land areas" (UKCIP, 2007).

As well as rainfall events increasing it is predicted that storm surges and thunderstorms will both increase and these factors added to the increase in rainfall all implicate flooding, coastal erosion and instability. According to Stern (2006) "storms are currently the costliest weather catastrophes in the developed world" and with an increase in their frequency and intensity this cost can only grow and "according to insurance industries weather related losses have increased by 2% per year since 1970" (Stern, 2006).

3.4 Sea Level Changes

The sea level occurring at any time is made up of the following primary components:

- Mean sea-level;
- A tidal component due to gravitation effects of the sun, moon and planets;
- Frictional effects on the propagation of the tidal wave and, occasionally, amplification due to bathymetric effects;
- A storm surge component due to meteorological effects and interactions between the above components.

When considering temporal changes in mean or extreme sea levels, it is important to also include changes in local land level due to tectonic or post-glacial geological influences.

While changes in mean sea-level should be of concern to coastal planners, it is the occurrence of extreme high water events that causes most problems with coastal flooding and erosion. The tidal forcing component is relatively fixed, but changes in mean sea-level can cause changes in propagation of the tidal wave. Changes to the frequency and intensity of storm surges may also occur under a warmer climate.

Changes in mean sea-level relative to land levels are clearly important for the design and management of coastal defences. Such changes may also impact on sediment transport and morphological change.

It is generally recognised that global mean sea-level has been rising for many years. Indeed, sea levels on the south coast of England were some 25m lower than present some 10,000 years ago, and rapidly rose to almost present levels about 5,000 years ago, since when there has been a slowing rate of rise. Whilst global sea-levels have been rising, local changes can often be dominated by movements of the land-mass. This includes recovery after loading during the last Ice Age, consolidation of soft materials, as ground water is removed, and tectonic movements etc. The Permanent Service for Mean Sea-level (PSMSL), which is operated from the Proudman Oceanographic Laboratory (POL), catalogue mean sea-level data from sites all over the world. The mean sea-level data are measured against a local reference datum, and so provide measures of sea level relative to the land.

Although most estimates available for future sea-level rise are globally based it is not expected that mean sea-level rise will be constant everywhere. This is principally because the heating up of the oceans will not be uniform. Geographical patterns of sea-level change due to differing thermal expansion have been estimated using general circulation models (GCMs) at the Hadley Centre. The present generation of GCMs do not represent the melting of ice sheets and glaciers internally, and such calculations are undertaken off-line and added to the results.

Sea level rise may encourage enhanced deposition in estuaries and the lower reaches of rivers. However, this scenario will only arise if higher water levels and increased wave action increase the supply of long shore spit building material and fine sediment to the estuaries i.e. through erosion of unstable cliff material. Otherwise, the spits will be sediment starved and are likely to break down which would increase the tidal and wave energy within the estuaries leading to enhanced mudshore erosion

Low-lying areas will be subject to increased threats from periodic inundation, particularly where there is an absence of defences and/or where beaches suffer reductions in volume. Areas of intertidal mudflats and saltmarshes are at risk from increased erosion, especially if protective spits in the mouths of the estuary inlets are breached.

If the spits are breached, tidal and wave energy will increase within the outer estuary areas, which initially is likely to erode the muddy saltmarsh and tidal flat sediments. Eventually these areas may be lost and replaced by sand flats associated with the redeposition of the spit sediments, the greater wave exposure and consequent higher energy conditions in the outer estuary.

In cases where the backshore of estuaries and inlet are unprotected, saltmarsh and intertidal environments will adjust naturally to rising water levels by migrating landwards to slightly higher ground – thus maintaining their relationship with sea level.

Where defences exist fronted by fringing saltmarsh or mudflat areas, it is likely that these areas will be eroded and diminished as any remaining intertidal areas are “squeezed” between rising sea levels and static backshore defences. This process termed coastal squeeze, results in the rapid erosion and degradation of these natural flood defences and increases the risk of flooding and coastal erosion.

Sea level rise predictions can be found in section 4 below.

3.5 Storm Surges

There has been far less research on the frequency and magnitude of storm surges than there has been on changes in mean sea-level. Since there is considerable uncertainty over the influence of global warming on the frequency, magnitude and track alignment of depressions, there is much greater uncertainty over future changes in surges than for mean sea-level changes or tides. The most appropriate way to study the impacts of climate change on storm surges is to use predicted future climate data from the GCM experiments to drive storm surge models covering the northwest European shelf. Flather and Williams (2000) reported on earlier studies that had found small changes between control and $2xCO_2$ simulations, which were barely significant when natural variability was taken into account. They also described more detailed work still in progress using GCM output to drive a 12km grid size nested storm surge model. Preliminary results presented indicate small (<5cm) increases in the 1 in 50yr surge in the eastern English Channel, and even smaller decreases west of the Isle of Wight. However, the results were found to be very sensitive to the method of analysis adopted for extrapolating the extremes.

3.6 Modelling and Prediction

Given the potential importance of regional climate changes for the development of national policies, and the impacts of extreme, climate-related weather events such as droughts, floods, and hurricanes on agriculture and human safety, how reliable are the projections of future change?

Computer-run, mathematical simulations or models of the atmosphere and ocean are the principal tool for predicting the response of the climate to increases in greenhouse gases. The most sophisticated of these, called general circulation models, or GCMs, express in mathematical form what is known of the processes that dictate the behaviour of the atmosphere and the ocean. There are limits, however, to how much complexity can be handled by the computers on which the models are run.

Owing to this inherent complexity, neither climatological observations nor present climate models are sufficient to predict how climate will change with certainty. The most authoritive approach is that adopted by the Intergovernmental Panel on Climate Change, which is based on projections of the expected growth of greenhouse gases and the combined results of many GCMs.

Climate scenarios present coherent, systematic and internally consistent descriptions of changing climates. Scenarios are typically used as inputs into climate change vulnerability, impact or adaptation assessments. The climate change scenarios developed for use in UKCIP studies rely largely on two sets of GCM experiments completed by the Hadley Centre during 1995 and 1996. These experiments were undertaken using a coupled ocean-atmosphere GCM called HadCM2. This model has been extensively analysed and validated and represents one of the leading global climate models in the world. It features prominently in the Forth Assessment Report of the IPCC (2007).

Since no single climate change scenario can adequately capture the range of possible climate futures, four alternative climate scenarios for the UK are presented – Low, Medium-Low, Medium-High and High. For these four scenarios, the world warms globally by the 2020s by between 0.6°C and 1.4°C, a decadal rate of warming of between 0.11°C and 0.28°C per decade. For comparison, the observed rate of global warming for the past two decades has been about 0.14°C per decade. By the 2080s, the UKCIP98 scenarios generate a warming range of 1.1°C to 3.5°C. The global-mean sea-level changes and carbon dioxide concentrations associated with the four UKCIP98 scenarios similarly reflect a range of values that may be used in climate change impact assessments.

Scientists from the Hadley Centre for Climate Prediction and Research, part of the UK Met Office, recognise the limitations of global climate models resulting from the coarse resolution employed. Local climate change is influenced greatly by local features such as mountains, which are not well represented in GCMs. Regional climate models (RCMs) using a typical resolution of 50km, have been constructed for limited areas by the Hadley Centre, UK.

3.7 Potential impacts of Climate Change

The consequence of higher antecedent effective rainfall will lead to increases in coastal erosion, landsliding and re-activation of pre-existing landslide complexes. The UKCIP98 scenarios estimate an increase in mean effective rainfall. Other potential climate change effects, such as increases in the number and duration of wet year sequences, the intensity of rainfall events and sea-level rise are all likely to have additional significant effects on coastal instability.

Extreme high water events will change both the intensity of flooding and erosion in coastal areas and according to UKCIP (2007) “extreme sea levels will be experienced more frequently” while the IPCC (2007) only predict it likely for an “increased incident of extreme high sea level” to be experienced during the 21st century.

The difficulty with flood risk planning is that flooding occurs spontaneously making it difficult to predict and costly to resolve (European Environment Agency, 2004) however without suitable action, flooding events, their intensity and damage will increase with costs increasing from 0.1% of GDP to 0.2-0.4% in the UK alone when the temperature increases by 3-4ºC (Stern Review, 2006). Between 1998 and 2002 48% of all natural disasters were due to floods (European Environment Agency, 2004). Flooding is determined by a combination of peak sea level (extreme sea levels), wave activity and storm surges.

Coastal erosion will also increase with extreme high water events however unlike flooding; erosion is a gradual process (European Environmental Agency, 2004). The EUrosion project (EUrosion,

2004) calculated that a fifth of Europe's coastlines are being actively affected by erosion, "with coastlines retreating by between 0.5-2m/yr… even by 15m". Response (2006) further calculated that along 20,000km of coastline in Europe 15,000km are actively retreating and 5,000km are artificially protected. Sediment transport, deposition and supply are an integral part of the coastal system and reflect the coastal changes and climatic influences. Due to the increase in coastal erosion it's predicted that sediment supply will also increase resulting in cliff instability.

Sediment transport is an integral part of the coastal system and its trends reflect coastal change and climatic influences. It is likely that sediment supply and transport will be influenced by climate change. As well as changes to sediment transport at the coast, the increased frequency in extreme climatic events could lead to significant changes in river processes, such as increased amounts of sediment supply and more frequent large discharge flood events capable of transporting significant volumes of sediment through the low gradient channels to the coast. Changes to the sedimentary system may carry a number of potential impacts for habitats.

4. National government guidance on sea level rise for use in coastal plans and strategies

4.1 Defra Guidance

In 2004 the Office of Science and Technology published the Foresight Future Flooding report, which took a long-term view of national flooding and coastal erosion risks to 2100. Foresight estimated that there were £130 billion of assets (homes, businesses etc) at risk of coastal flooding and also at least £10 billion of assets at risk of coastal erosion. The study predicted that future climate change could lead to potentially significant increases in future risk by the end of this century with annual losses due to flooding increasing to between 2 and 20 times current values and coastal erosion annual losses rising by 3-8 times. Of course, actual changes in risk will be highly dependent on patterns of growth and new development (which both affect the value of damages from flooding and erosion) and future flood and coastal erosion risk management activity.

In October 2006 the Department for Environment, Food and Rural Affairs (Defra -the National Government department responsible for coastal erosion and flood risk issues) published a Flood and Coastal Defence Appraisal Guidance Supplementary Note to Operating Authorities on climate change impacts (Defra, 2006). This Supplementary Note set a consistent and sustainable approach to tackling the impacts of climate change, especially in appraisal and decision making processes associated with flood and coastal erosion risk management. It is based on the High emissions scenario estimate from the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report.

The guidance recognises the need for adaptation to best manage the risk of sea level rise. This might be through re-alignment of infrastructure, or working with natural processes, or ensuring that our flood risk management systems can be adapted or strengthened further to accommodate the changes in risk faced over time.

The predictions of future sea level rise amounts that should be taken into account in any coastal scheme, strategy or plan are shown in Table 1. The latest guidance takes into account land movement and the effects of thermo-expansion of the sea, up to 2115. Additional contributions from tidal surge and waves are not included. The new sea level rise estimates predict an exponential rise, replacing the previous straight line graphical representations; the predictions are lower in the short term, but higher in the medium to long term.

Key points to consider are:

- Net sea level rise allowances incorporate thermal expansion of the oceans and melt from land glaciers and vertical adjustments of the land. Additional contributions from tidal surge and waves are not included.

- Global mean sea level rise projections up to the 2080s were taken from the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report (TAR) High estimates. Global mean sea level rise projections for the 2110s were extrapolated from the 2020s, 2050s and 2080s.
- Regional variations in net sea level rise allowances reflect latest information on vertical land movements.
- The baseline for calculating sea level rise for a given year is taken from 1990.
- There are significant uncertainties in climate change predictions and there may be studies that suggest allowances could be higher (for example, research from Thames 2100). However, figures in this supplementary guidance are considered most appropriate for flood and coastal risk management and planning, and should be used until further updates are provided.

Administrative or Devolved Region	Assumed Vertical Land Movement (mm/yr)	Net Sea-Level Rise (mm/yr)				Previous allowances
		1990-2025	2025-2055	2055-2085	2085-2115	
East of England, East Midlands, London, SE England (south of Flamborough Head)	-0.8	4.0	8.5	12.0	15.0	6mm/yr* constant
South West and Wales	-0.5	3.5	8.0	11.5	14.5	5 mm/yr* constant
NW England, NE England, Scotland (north of Flamborough Head)	+0.8	2.5	7.0	10.0	13.0	4 mm/yr* constant

*Updated figures now reflect an exponential curve, and replaces the previous straight line graph representations.

Technical notes supporting Table 1, Regional net sea level rise allowances

(i) Global mean sea level rise projections up to 2100 were taken from the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report (TAR) under A1FI emissions (Table II.5.1), noting that the values for A1FI and A1T are incorrectly transposed in the IPCC report. Global mean sea level rise projections for 2115 were extrapolated.

(ii) Net sea level rise allowances are sensitive to assumptions about thermal expansion of the oceans, melt from land glaciers and ice caps, melt from Antarctica and Greenland, climate model sensitivity, greenhouse gas emissions, and vertical adjustments of the land.

(iii) Differential heating of oceans and changing ocean currents are not taken into account, but regional variations in sea level rise could be as high as ±50% about the global mean11.

(iv) Recent glacier mass balance modelling suggests that the contribution from melting mountain glaciers and ice caps may be half that used in the IPCC projections12.

(v) Recent model evidence suggests estimated contributions from Antarctic and Greenland ice melt to sea level rise will need to be revised upwards13 by as much as 5mm/yr14.

(vi) The IPCC mean sea level rise projections reflect high emissions and high climate model sensitivity.

(vii) Regional variations in net sea level rise allowances draw from latest information on vertical land movements around the UK15.

(viii) Contributions from tidal surge and waves, or the joint occurrence of fluvial and tidal flooding are not included. These effects are localised and model projections show mixed results16[,17].

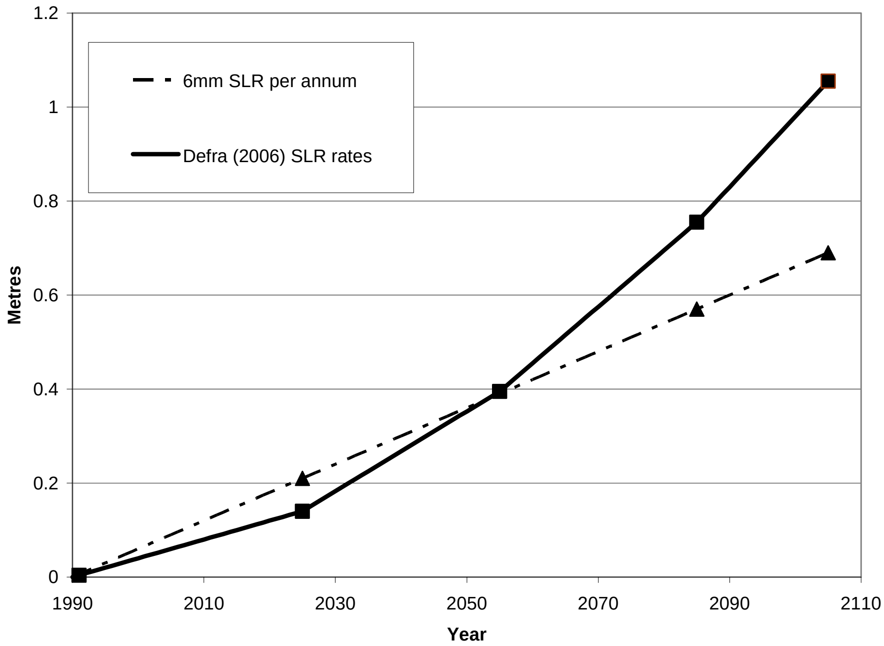
(ix) All values are given with respect to 1990 and rounded to the nearest 0.5 mm/yr.
Calculation of sea level rise is worked out using the following two examples.

For the **south west region** sea level rise in **2020**:
3.5mm/yr * [30 years from 1990) = **105mm.**
For the **north east region** in **2065**:
2.5mm/yr to 2025 = 88mm; 7mm/yr between 2026-2055 = 210mm;
10mm/yr between 2056-2065 = 100mm Total = 88 + 210 + 100 = **398mm.**

There are significant uncertainties in climate change predictions. However, figures in this supplementary guidance are considered appropriate in relation to flood and coastal risk management and planning, and should be used until further updates are provided.

Table 1: Sea level rise predictions published by Defra in 2006 as a supplementary note to Operating Authorities, defining the allowances to be used in coastal management schemes and plans.

The graph below illustrates the latest predicted sea level rise compared with previous old 6mm per annum allowance.



Graph showing sea level rise predictions published by Defra in 2006 as a supplementary note to Operating Authorities, defining the allowances to be used in coastal management schemes and plans. The new exponential curve (based 4mm/yr, 8.5mm/yr, 12mm/yr then 15mm/yr over successive future 30-year epochs, as defined in Table 1 above) replaces the previous allowance of 6mm/year. Courtesy of North Solent SMP.

4.2 UKCP09 climate change predictions

UK Climate Impacts Programme published a new set of climate change predictions for the UK on 18th June 2009 (known as UKCP09). It is a comprehensive update on climate change for the UK and will improve the understanding of future coastal extremes and future rainfall and river flows. UKCP09 not only gives data for different emissions scenarios, but across a range of probability levels.

The future coastal extremes in UKCP09 have been largely derived from work commissioned by the Thames Estuary 2100 Strategy (the TE2100 project). This research showed that current Defra guidance on sea level rise is still suitable for planning for flood risk in the tidal Thames.

Defra and the Environment Agency are considering whether supplementary guidance is required for use in future coastal strategies and management plans. All SMP2 Action Plans will have an action to consider the plan findings in respect of key new information, with UKCP09 being one of the key issues.

5. Sea level rise predictions for the Isle of Wight

The Isle of Wight SMP2 assumes that sea will rise in accordance with the allowances published by Defra (2006), in line with current guidance.

Table 2 below shows sea level rise predictions for the Isle of Wight coastline, used in the development of this Shoreline Management Plan (allowances sourced from Defra, 2006). The amounts of predicted sea level rise (in centimetres) are displayed as increases above the standard 1990 baseline sea level, or alternatively as increases from the start of 2009, until 2105.

Epochs	Sea level rise in cm:	
	From 1990 (standard baseline):	From 2009:
By 2025	+14cm	+7cm
By 2055	+39.5cm	+32cm
By 2105	+105.5cm	+98cm

Table 2: Sea level rise predictions for the Isle of Wight (based on Table 1).

The consequences of sea level rise on the Isle of Wight coast are assessed in detail in Appendix C3.

6. Managing the Isle of Wight Coast in a Changing Climate

6.1 Introduction

Climate change records from the Ventnor Undercliff lend support to the conclusions of the IPCC. An increase of 150mm or 20% in annual rainfall was recorded between 1839 and 2000 at Ventnor. Strong links between antecedent rainfall, coastal landsliding and ground movement have been reported by Lee and Moore (1991), Ibsen and Brunsden (1994) and Brunsden and Chandler (1996). These studies demonstrate the significance of wet year sequences, which are probably of greater importance than increases in average conditions and the occurrence of extreme precipitation events, although the latter are clearly important as a trigger of ground movement and landslides. In this respect, it should be noted there are many preparatory and triggering factors other than climate effects that can contribute to coastal slope instability (Jones & Lee, 1994; Hutchinson, 1988; McInnes, 2000).

It is likely that climate change impacts will include changes to the rainfall pattern, with wetter winters and drier summers. Within the context of climate change, the potential for reactivation of coastal slopes mantled by relict landslides due to increased toe erosion resulting from sea level rise and elevated groundwater levels due to increased effective rainfall requires consideration. Such slopes are identified around the Undercliff and north coast of the Isle of Wight. The exceptionally wet winter of 2000/01 resulted in intensification of reactivations at some locations and is an analogue of the conditions that might be expected to occur more frequently in the future.

Coastal erosion, land instability and flooding can impact human society and the biodiversity of the coastal zone. According to research by UKCIP (2007) the existing flora in the coastal zone has extended its growing season by a month since 1900. Climate Challenge (2007) revealed that over the 350 years of coastal water temperature records there has been a temperature increase and subsequent change in the distribution of marine species. As well as changing the distribution and growth pattern of flora and fauna, climate change can lead to the destruction of habitats and possible extinction of rare species such as the Autumn Squill found in St Helen’s Duver and the Glanville Fritillary butterfly found on the south-west of the Island at Hanover Point.

The Isle of Wight Council, along with other local authorities, have taken steps towards an active approach to the challenges of climate change. The Nottingham Declaration (2000) was developed with the view that the major role belonged to the local authorities. The Declaration acts as a ‘pledge’ towards their active role in climate change by working towards three main approaches:

- Acknowledgement of climate change;
- Welcoming international and national policy as well as benefits climate change can bring;
- And a commitment to work with international and national councils as well as communities.

In May 2007 the Isle of Wight Council made an important and lasting commitment to address the causes and impacts of climate change through its signing of the Nottingham Declaration, recognising in doing so, that climate change is likely to be one of the key drivers of change within the Isle of Wight community over the next century. The Declaration will commit the Council to a significant decrease in greenhouse gas emissions from its own operations as well as encouraging all sectors of the local community and its partners to take the opportunity to act in a similar way.

Understanding the risk management framework and the broader social and political context provides a basis for speculating about how climate change and sea-level rise will impact upon the European coastline over the next 100 years or so. It should be stressed that because of the nature of social systems, there is probably more uncertainty as to how society and politicians will respond to these changes than their impact on coastal processes.

6.2 Increased Demand for Coast Defence Funds

Over the next 100 years, climate change and sea-level rise will result in an increase in the probability of damaging events. However, it is uncertain as to how the operating authorities will be able to manage the increased risks. To maintain the current standards of coastal protection will require considerable investment in defence improvements and maintenance. The risk management framework will need to adjust to increased competition for financial resources.

One possible consequence is that defences that are currently protecting marginally economic and clearly uneconomic sites will either be abandoned or maintained at a lower standard of protection. It is possible that there will be modifications to what are considered to be acceptable risks and suitable standards of protection. It should be appreciated, however, that society has become less risk tolerant. It follows that there may be a need to improve the standards of protection in high-risk urban areas to reflect these trends. This would lead to increased polarisation in the exposure to risk experienced by individuals in built up and rural areas.

6.3 Biodiversity

The vast majority of the English landscape is fragmented. As a result, many of our important species are effectively constrained to relatively small, isolated wildlife areas, with sharp boundaries between them and adjacent land sites of unsuitable habitat. This makes species unable to move in response to a rapidly changing climate (Environment Agency, 2007).

However, it should be noted that a changing climate presents opportunities as well as risks. Though some habitats will most likely be lost in a particular area due to climate change, other habitats may thrive under the new climatic conditions.

6.4 Increased Competition for Coastal Resources

Climate change and sea-level rise is likely to generate additional pressures on a variety of coastal zone uses, from tourism and amenity uses, marine aggregate extraction (e.g. for beach feeding programmes), port and harbour operations to nature conservation and the protection of historical sites and monuments.

These and other pressures will be manifest in heightened competition between different interest groups over how best to manage coastal resources. As society's values and political attitudes towards social welfare change, so the rationale behind the public subsidy of private property may be challenged. It seems likely that the debate over the true costs (financial and environmental) and benefits of coastal defence to society will develop and intensify. This could lead to modifications to the risk management framework, especially greater emphasis on environmental and social costs in the project appraisal procedures.

The need to reconcile competing demands on limited resources will probably lead to the risk management framework becoming more complex, with a greater need for formal consents and consultation, with more formal public participation in the decision making process. There may be greater opportunity of trade-offs and bargaining. Further delays and increased expenditure on plan development and implementation are, perhaps, inevitable. The ever-increasing complexity of the framework will reinforce the institutional barriers to innovative solutions to coastal defence issues, favouring the status quo.

It is clear that both the physical environment (increased hazard) and cultural environment (changing attitudes and priorities etc.) will be sensitive to the effects of climate change and sea-level rise. The legislative and administrative framework, however, is likely to be relatively insensitive, being the product of gradual evolution rather than radical change. Thus, there will be a tendency to attempt to address climate change and sea-level rise within the existing legislative and administrative framework.

6.5 Co-ordinated Decision Making

There is a need to consider the possible compoundment of risk due to continued management of the coastline, i.e. raising flood defences, toe protection measures. Clearly this is idealist, but the point should be made that defences do fail, and the stresses to be placed on defences in the future will clearly be greater given climate change and sea-level rise. This means that the chance of catastrophic failures will be increased, especially if funding and engineering designs are not factored up to accommodate these stresses. At the same time we have increasing pressure for development in hazardous places which often takes place where defences are in place giving a false sense of security - the risk remains; consequently the potential losses are also increasing. Decisions by planners, developers and the engineering fraternity are often taken in isolation, when clearly there is a need to consider these 'holistic' consequences at an early stage of decision-making (pro-active) rather than dealing with the disasters and clear-up that may well have been avoided.

There are two responses to climate change – mitigation and adaptation. Mitigation measures are actions to reduce human impacts on the climate system, by reducing our emissions of greenhouse gases. Adaptation measures are actions in response to climate changes. Mitigation and adaptation measures may be interrelated. The Environment Agency’s Guidance for Practitioners states “Our response to climate change needs to include both adaptation and mitigation: we should aim to manage the unavoidable and avoid the unmanageable” (Environment Agency, 2007).

7. Conclusions

There can no longer be any doubt that our climate is changing. Whether this change is caused by anthropogenic or natural factors is not the issue – the impacts of a changing climate are already being felt globally. Extreme weather events are a major source of climatic-related impacts and it is predicted that climate change may increase the frequency of severe weather events. Given that there exists strong links between weather patterns and coastal processes, there are clear implications associated with our current knowledge of climate change. Risks associated with climate change are increasing and will continue to increase according to most global climate change scenarios.

Key Strategic Issues

- Climate change is a key driver of flood and coastal erosion risk; this will be an integral consideration in strategic decisions;
- Climate change has the capacity to alter almost all coastal processes and landforms;
- Coastal management policies should aim to be sustainable in the context of this long term change.

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