Environment Agency

DRAFT

EVIDENCE FOR STERN REVIEW ON THE ECONOMICS OF CLIMATE CHANGE

SUMMARY

- We are directly involved in dealing with the impacts of climate change, particularly flooding and water resource planning.

- Costs of acting (mitigation) are often over estimated in economic methodologies and costs of not acting (impacts) are underestimated. The economic and social impacts of climate change will grow unless action is taken to reduce greenhouse gas emissions. The costs of environmental, social and health impacts have not been taken sufficiently into account in decisions on policy strategies. Early action to reduce impacts through adaptation measures will also avoid damages and the need for increased expenditure at a later date. It is also not clear whether we can buy our way out of "dangerous" climate change.

- There is sufficient evidence to show that transferring to a low carbon economy can be achieved with very small loss to GDP growth, and there are many other benefits to action. Science should inform climate change policy at global and UK levels and help establish targets for stabilisation. Science can help us understand the environmental limits and these limits need to be taken into account when setting targets. Economic analysis of environmentally sound technologies should show what are the most cost-effective pathways (policies, mechanisms and instruments) to achieve those targets. The review should set out guidelines and standards for sound economic appraisal of policies on mitigation and adaptation.

1.0 Where the Environment Agency fits in

1.1 The Environment Agency is the leading public body for protecting and improving the environment in England and Wales. It is our job to make sure that air, land, and water is looked after by everyone in today's society, so that tomorrow's generations inherit a cleaner, healthier world.

1.2 Climate Change is one of the nine priority themes in our current and new Corporate Strategies. Our role on climate change has been set out in Guidance provided by Department for Environment, Food and Rural Affairs. "The Agency contributes to the reduction of greenhouse gas emissions through its industry and waste regulation objectives, provides information on the effects of climate change under its data collection and monitoring objective, and plans for the likely impacts of climate change especially through its flood defence and water resources objectives. It also participates in regional and local initiatives to reduce greenhouse gas emissions and adapt to the impacts of climate change."

1.3 Our perspective on the global economics of climate change is derived from delivering core legislative responsibilities:

- We have to plan for the likely impacts of climate change on core functions such as flood defence and water resources;
- We are involved in international dimensions of global climate policy through administration of the European Emissions Trading Scheme;
- We have responsibilities in regulation, which impinge on some renewables technologies such as biomass and small-scale hydro;
- We expect to be involved in regulation of carbon capture and storage projects where they involve storage on land.
- We lead on water and air quality regulation and increasingly aware that climate change impacts could undermine hard won environmental improvements in these areas;

1.4 Our perspective on global, European and UK levels is also informed by our general advisory role to Government on the environment and work in partnerships on environmental protection. In addition we are developing a science programme, to develop an evidence base for our actions on climate change.

1.5 Our evidence for this enquiry is informed by our concerns about the impacts of climate change that we increasingly have to handle in England and Wales. We are aware that there is considerable evidence of global impacts, which we leave for others to cover.

1.6 We are aware that there are some limitations in our ability to use economics to tackle climate change. Valuation of environmental goods is problematic, as the recent attempt to revise the Government's social cost of carbon has revealed. This is particularly true of the valuation of potential of extreme events associated with climate change. It is also difficult to account for long-term changes in an economy, such as a shift to a low carbon future, and to appraise options where it is impossible for the science to be exact, such as in the patterns of future rainfall. We therefore offer some tentative comments on these aspects too.

1.7 We welcome this review which we think can help define the current state of the economic analysis of climate change and provide momentum for further crucial work to address the limitations in that analysis. In parallel to this, however, we believe that science needs to inform policy at global and UK levels, in particular setting targets for stabilisation. Economic analysis of environmentally sound technologies should show what are the most cost-effective policies, mechanisms and instruments to achieve those emission pathways.

2.0 Insights from science

2.1 Environment Agency Concerns: Global warming

2.1.1 In common with the rest of the UK Government, the Environment Agency is convinced of the reality of Climate Change. In view of our responsibilities on the impacts of climate change, we are particularly concerned about the increased risks of new extreme events and by the critical step changes, which were exposed at the Exeter Science Conference.

2.1.2 Compelling results emerged on the basic global systems and features, which are showing signs of already being affected by climate change:

- The West Antarctic ice sheets appear to be slipping into the sea;
- The carbon sink capacity of the soils and oceans will saturate and cause feedbacks;
- CO2 deposition in the oceans is causing acidification;
- If the Greenland ice sheet starts to melt it will be unstoppable and could cause sea level rise of 7 metres. It is likely to happen at around 2.7C degrees rise in global mean temperature;
- If the thermo-haline circulation shuts down there would be massive impacts everywhere with present patterns of both ecological and socio-economic systems being changed dramatically;
- Ocean temperatures are already rising - too much more and the methane deposits at the bottom of the ocean could start to get released. There is more carbon in gas hydrates in ocean sediment than in the entire reserves of fossil fuels.

2.1.3 The impact of this on the economic analysis is that it increases the need for more firm action on mitigation than we had previously expected. New science suggests that the climate is more responsive to greenhouse gas concentrations in the atmosphere than previously thought (climate sensitivity). Instead of aiming for 550 ppm to keep global temperature increases to 2 degrees it seems we shall have to aim for 450 ppm (i.e. CO2 at 400 ppm). Current levels are at 372 ppm.

2.1.4 Results are also accumulating that indicate a rise of over 2 degrees could trigger irreversible change, and be considered “dangerous” in the context of the UN Framework Convention on Climate Change.

2.1.5 The IPCC Third Assessment Report clearly stated that the greater the reduction in emissions and the sooner they are introduced, the smaller and slower the projected warming and the rise in sea levels. In order to avoid these dangerous economic consequences and constrain temperature changes to two degrees, global emissions need to peak in 2020 and decline to 3.1 GtC/ year by 2095. That means that we have to get significant action underway soon and investment paths changed.

2.2 The impact of climate change in the UK and extreme events

2.2.1 In the UK there has already been an increase of one degree Celsius over the past century, compared to the 0.6 degree change registered globally. This change has been manifest in a lengthening of the thermal growing season by about one month. Daily temperature extremes have changed with an increase in the number of very hot days and a decline in the number of cold waves. What causes most concern for the Environment Agency, however, is another part of the climate change package: the changes to precipitation patterns. We note that the contribution of the most intense rainstorms to total winter precipitation has increased during the last 40 years. Furthermore, prolonged heavy rainfall events (of 5 and 10 days duration) have increased in northern regions of the UK since the 1960's. It is these events which are most significant for widespread fluvial flooding.

2.2.2 Analysis from the Hadley Centre shows that there are certain characteristics of the oceans and ice-sheets which mean that we have already committed ourselves to sea-level rises for which we must plan for centuries. Even if we stabilise concentrations of greenhouse gases in the atmosphere with global surface temperature stabilising a few decades later, there remains an inescapable "commitment" to a further substantial rise in sea-level over many centuries [1].

2.2.3 If recent events have been associated with the one degree rise, clearly the threat of unmitigated climate change causes the Environment Agency concern. Potential impacts have recently been confirmed by results from the first European–wide study which applied the "best statistical and modelling techniques to determine the likely impact of climate change at specific sites" [2]. The study revealed that, "by 2100 sites in south-east and north-west England will see up to a 25% increase in heavy rainfall during five-day periods in winter- which leads to flooding- and up to a 25% decrease in summer rainfall causing drought" [3].

2.2.4 The UK Climate Impacts Programme (UKCIP) 2002 "high" scenario, projects that by 2080, temperatures in some parts of the UK will on average be as much as 5 degrees higher, with the prospect of temperatures reaching 40 degrees on some days. Rainfall will be subject to an increased seasonality with increases of as much as 25 per cent in winter and declines by up to 50 per cent in summer. Such impacts will create challenges for planning and adaptation, particularly when the knock-on effects at the global scale are taken into account. The UKCIP02 scenarios are far from a worst case because feed backs from the carbon cycle are excluded, and one of the middle climate sensitivities in climate models is assumed. We have attached a supplementary note, which illustrates that the Foresight scenarios, which are based on UKCIP 02, are not necessarily the worst we face. For the Environment Agency's regulatory operations there would be major ongoing effects across all environmental protection functions including impacts on flood risk, water resources and water quality.

[1] Climate Change Scenarios for the United Kingdom: the UKCIP02 Scientific Report

[2] Press release November 22nd 2005. Stardex,December 2005 www.cru.uea.ac.uk/projects/stardex/

[3] Press release November 22nd 2005. Stardex,December 2005 www.cru.uea.ac.uk/projects/stardex/

2.2.5 We are advised that we must expect an increase in the frequency and intensity of extreme events [4]. Apart from the hot summer of 2003 in Europe, it has not been possible to statistically attach a climate change fingerprint to floods and droughts. But currently these estimates provide some guidance on what climate change will cost. The Autumn 2000 floods were the most severe widespread flooding we have experienced in the UK for almost 300 years with damage to nearly 10,000 properties and nearly £1bn in insurance claims (excluding uninsured losses) [5]. Costs of the 2003 summer in the UK are still being estimated (to agriculture, health, etc.) but subsidence costs in that year alone are estimated to be nearly £400 million [6]. We provide some information on current expenditure on water sector infrastructure below to indicate what levels of expenditure will need to be scaled up to cope with climate change.

3.0 Current operational problems and climate change

3.1 Flood risk management

3.1.1 Flood risk is already significant, and costly to deal with. Climate change is making this worse because of increased rainfall. There are a number of studies, summarised below, which make some estimate of these impacts.

3.1.2 However, although we know the general trend will be to increase flooding and therefore the direct costs of damage and of dealing with it, the precise effects are uncertain. This is because we cannot yet be sure of when and where the increased precipitation will occur. This in itself will raise the costs of dealing with climate change:

- We will need to significantly increase our specification of defences, or our pressure to allow managed retreat, to deal with the risk of extreme events;
- Because extreme events will begin to overtop existing defences, there may be an understandable public reaction to push more resources into defences against such extreme events, even if that is extremely costly;
- Finally, individual businesses and householders may have residual concerns that they will not be protected against future extreme events and so will face significant uncertainty about their property. They may respond by spending more themselves on resilience than they need, or by cutting back their business or other interests in areas at risk.

3.1.3 Therefore the costs of climate change to the economy are potentially even more costly than the increased risk of damage, or the costs of building more defences.

---

[4] IPCC 2001, Climate Change 2002 Synthesis Report of the Third Assessment Report.
[5] ABI 2004 A Changing Claimte for Insurance.
[6] ABI 2004 A Changing Claimte for Insurance.

Managing current and future flood risk

3.1.4 Managing flooding is a core activity of the Environment Agency. We receive funding of over £560 million/ year from the Government for this function, after a substantial increase in 2003/4. On average we manage 650 capital projects each year delivering across a spectrum of flood risk management activities including flood warning, mapping, strategic studies and asset replacement. New opportunities such as managed retreat are being introduced for example, in the Humber Estuary, which protects 300,000 people. To be effective, flood risk management policy has to mesh with agricultural strategies, spatial planning, and biodiversity conservation.

The impact of climate change on flood risk

3.1.5 Overall, the Foresight report states that nearly 2 million properties are potentially at risk and over 4 billion people and properties valued at over £200billion are at risk. Even with present flood defences we experience around £1,400million of damage each year.

3.1.6 Estimating additional costs of flooding due to climate change is difficult. One way of estimating it is by looking at the cost of current extreme events. A recent ABI report showed that claims for storm and flood damage have doubled to over £6billion over the period 1998-2003 with the prospect of tripling to 2050. Another ABI study shows that climate change could increase fluvial and coastal flooding in the sustainable communities growth areas by a factor of 8 to 12 times to £550-830million per year by the 2080's.[7]

3.1.7 The Foresight report made an overall estimate of losses – under their high scenario; losses could reach £27billion per year. However the Hadley centre's HADCM3 model which underpins the Foresight work is one of the drier models, with respect to both winter and summer rainfall. (See Annex 1 and Diagram 1), so that by no means represents a worst case.

3.1.8 Finally, a bottom up, national assessment of assets at risk of flooding and coastal erosion suggested that damages due to climate change could increase by approximately £1billion per year.[8]

3.1.9 The defence of London and the surrounding area illustrates the impacts of climate change on flood risk. Experience over the autumn and winter of 2000/2001 with the operation of Thames Barrier also gave a new momentum to the plans to increase its performance. We have established the Thames Estuary 2100 project that will develop a Thames Estuary Flood Risk Management strategy for the next 100 years. Flooding would obviously cause immense disruption to the capital's commercial activities, and could cause direct damage equivalent to around £30billion. Preliminary estimates for

---

[7] Ref to ABI report

[8] DEFRA National Appraisal of Assets at Risk from Flooding and Coastal Erosion incluidng the potential impacts of climate change . A report produced for the department by; Halcrow Gorup Ltd, H R Wallingford and John Chatterton Associates, July 2001.

maintaining current protection levels in the face of climate change are £4billion. A complicating factor is that the Thames Gateway region has been designated as one of the largest regeneration areas in Europe**.**

3.1.10 The table below is extracted from a short paper submitted to the Exeter Science Conference, which for the first time looks at the costs and benefits of meeting different stabilisation targets in relation to the Barrier. We can see that stabilising at lower levels of greenhouse gas concentrations reduces sea-level rise and damages due to floods.

Table 1: Flood risk estimates in the Thames Estuary for different stabilisation scenarios[9]

Scenario	Relative sea level rise (in m) in the Thames Estuary 2050 (relative to 2005)	Relative sea level rise (in m) in the Thames Estuary 2100 (relative to 2005)	Present Value (flood risk) (£billion)	Benefit of stabilisation (£billion)
S450	0.16	0.34	0.61	13.9
S550	0.19	0.40	0.62	13.9
S750	0.21	0.46	0.89	13.7
IS92a	0.24	0.61	14.6	-

3.1.11 Work undertaken as part of our Thames Estuary 2100 project has shown that without climate change, maintenance costs of defences in the estuary will be £3.8bn (discounted £1.1bn), with the UKCIP02 High scenario £5.3bn, (discounted £1.9bn) and the medium high scenario and storm surge £6.8bn (£2.8bn discounted).

3.1.12 Looking further ahead, the Thames estuary provides compelling messages of the need for action. The Tyndall Centre has recently completed work to study the implications to the year 3000 of six long-term carbon dioxide emissions scenarios. Sea level will still be rising at the end of the millennium and could reach 11.4m by year 3000, such that low-lying areas of the UK including much of London will have to be abandoned[11].

3.1.13 For some events, such as flash flooding like Boscastle, it will be impossible to prepare and defend. Improved flood warning schemes are the best option. Our autumn 2005 campaign, which started shortly after Hurricane Katrina, used the slogan "Devastating floods can happen here too" and focused on areas and groups particularly at risk. We know that as many as 40 per cent are still unaware that they live in a flood plain, and 69 per cent say they are unlikely to take measures to protect themselves. Almost one-third do not have flood insurance protection policies, particularly in low-income groups.

---

[9] Hall J., Reeder T. et al. 2005. Tidal Flood Risk in London under stabilisation scenarios
[10] Hall J., Reeder T. et al. 2005. Tidal Flood Risk in London under stabilisation scenarios
[11] Tyndall Centre, 2005. *Climate change impacts in the UK on a millennial timescale*. Final Report of Tyndall Project T3.18, under review

3.1.14 We have attached a short note on social dimensions of climate change, particularly flooding in Annex 2. Key points are:

- Flooding has a wide range of social impacts particularly on peoples' physical and psychological health, property and communities
- Victims describe flooding as traumatic
- Older people can suffer greater economic losses as a result of flooding
- Smaller businesses are likely to be hit harder and be more vulnerable than larger ones.

3.2 Water Resources

3.2.1 Water is a renewable but finite resource. Rainfall varies across England and Wales from over 4000 mm/year in Snowdonia, to less than 550mm/year in parts of East Anglia, with an average of 897 mm/year. Year-to-year variability in rainfall can be significant; the winter of 2004/05 yielded only 70 per cent of the long-term average rainfall and this is not the lowest we've ever seen. In some parts of the south east, groundwater levels are currently (early October 2005) below recorded minima and river flows are well below average for this time of year.

3.2.3 Although England and Wales are commonly perceived as wet, the high population density means that for each person there is relatively little water (1334 cubic metres per year (m^3) on average). Less, in fact, than in most Mediterranean countries (Spain 2775 m^3/a; Portugal 3878 m^3/a). Note that in the Thames basin there is only 266 m^3/a for each person, and that a threshold of 1000 m^3/a is often used as an indicator of water scarcity[12].

3.2.4 The overall situation does not give room for complacency. Across much of England and Wales (Map 1 in the Appendix) current abstraction accounts for all the water resources available in summer months. This means that the Environment Agency cannot permit any further summer abstraction because it would reduce the water available to existing abstractors and to the environment. Many licences already contain conditions to protect other interests during periods of low flow. Many groundwater bodies are also fully committed for abstraction.

3.2.5 In some locations, abstractions authorised under licences granted years ago are causing environmental degradation. There are some 600 sites (Map 2 in the Appendix) where current licensed abstraction is causing problems, or has the potential to do so. Dealing with these damaging abstractions will be expensive. We believe that up to £450 million in compensation could be payable to licence holders if their licences have to be revoked or modified. In its recent report "Efficiency in water resources management" the National Audit Office commented that "the Agency's regulation of abstraction protects resources worth some £72 billion to licence holders. Clearly, water use is of such importance that its value to the economy as a whole is incalculable".

---

[12] Arnell, N.W. 2004. *Global Environmental Change*, **14**, 31-

Climate change and future water resource management

3.2.6 The major risks that climate change brings to water resource management are reduced availability of water resources, through longer drier summers and shorter wetter winters, and increased demand due to higher temperatures. However there is still considerable uncertainty. The timing and magnitude of impacts is uncertain. The predicted impact on water resources is small in the 2020s but becomes more significant in the second half of the century. Our most recent work suggests that we may start to see a decline in resource availability before 2030 There is also evidence that year-to-year variability of rainfall will increase, meaning the climate will be less predictable with more dry years and more wet years.

3.2.7 Our present management system tries to deal with our present understanding of extreme events, such as the 1976 drought. Thus we have withstood significant recent drought events, such as the 1995 shortages in Yorkshire.

3.2.8 However, our freedom of movement is limited. For example, in order to address the situation in Yorkshire, almost every liquid tanker in the country was used to deliver water to customers. Had two regions suffered a drought in that year, the capacity of the economy to deliver water without standpipes could have been over-stretched. Standpipes would have caused significant social and economic dislocation. Equally we would be severely stretched if a drought lasted for three years, instead of the two years that we have been able to manage to date.

3.2.9 Adapting water resource management to climate change will involve a number of elements:

- Increasing our predictive capacity may help reduce the impact of 2-3 year droughts, by enabling us to take action earlier. At present, we cannot credibly predict a 3-year drought in the first year, so if we react to a drought summer by imposing restrictions, we may be acting precipitously. This reduces our ability to impose restrictions early.

- There is scope for people to use less water. Current usage of 150l/day is significantly above the levels of 100l/day that would support the same utility that people enjoy from water today. Reducing water use to these levels in new homes can happen at almost no cost[13]**.** However it will be more expensive to retrofit water saving devices. This high level of usage also gives us some capacity to reduce water use in drought situations, e.g. by restricting garden watering. We also need to cope with the increased demand for water as a result of climate change due to garden and personal watering- overall by 2025 this is estimated to be an additional 1-2% but it only takes place over 20% of the year.

[13] See Sustainable Homes – the financial and environmental benefits, Environment Agency 2005, www.environment-agency.gov.uk

- Finally, we can build more resilience and flexibility into the system. Increasing our capacity to pump and deliver water, or to store water-using reservoirs could do this.

3.2.10 In the 2004 price review, climate change was taken into account in some assessments by water companies who either put an allowance in headroom for the 2015 - 2030 period or factored it into scheme size from 2015. Others did nothing, promising more work in the next five years. Overall, water companies' latest plans propose eight new or extended reservoirs between now and 2025. These will cost well over £1 billion. We believe that some of these may prove to be necessary and we are urging companies to develop the case for these so that they can undergo full public scrutiny. Climate change will probably reduce water availability overall, apart from increasing the frequency and intensity of drought events, but its extent is not yet clear. We believe that water companies must put much more effort into helping people to save water, with an investment of a similar order of magnitude. This twin-track approach will provide maximum flexibility and allow us to cope with whatever the future brings. f we had to develop 10 per cent more storage capacity for water resources, as provided in our current strategy by 2025, it would involve an outlay of £ 3 billion, excluding operating costs [14]. Under the current system of funding for water resources, water company customers would meet these costs.

3.2.11 New reservoirs are usually controversial. Suitable sites are hard to find and it is usually necessary to use compulsory purchase to acquire land. Local opposition can be substantial and we expect that in many locations planning inquiries would be prolonged and difficult. Reservoirs need to be filled with water. In lowland England this means pumping water from a nearby river. There are few rivers with substantial volumes of water that is reliably available even in winter, so the opportunities for significant new reservoirs are rare. Construction of major schemes can sometimes take years longer than expected. It is generally accepted that it will take fifteen to twenty years from initial design to deployment of a reservoir. On the other hand, new reservoirs provide a reliable source of water and could also reduce flood risk through the provision of additional storage capacity.

3.2.12 The water industry is a big user of electricity and power stations also use large amounts of water to generate electricity. We therefore should need to evaluate carefully supply options which require significant amounts of pumping in cross-regional transfers and which use technologies such as desalinisation, before assuming these should form a key element in future supply strategies.

3.2.13 The unpredictability of climate change, and in particular the increased risk of extreme events may impose costs. Past bursts of activity in water resource investment have been on the back of significant droughts, e.g. in 1933/4 and

[14] Current water supply - 15000 Ml/d; 10% 1500 Ml/d, approximately £2 million per Ml/d = £3 billion capital.

1995. Without early expenditure on predictive capacity and cutting back water use in houses, it is likely that extreme events will cause droughts, leading to calls for reservoir developments, which might not have been necessary had we acted earlier.

3.3 Climate Change and other environment functions

3.3.1 Climate change will impact on other environment functions -

- Air quality protection would be undermined with climate change: ozone formation increases with warm weather and high concentrations of hydrocarbons, with consequent damage to people's health.

- Soil quality will be diminished with increased erosion. There could also be re-mobilisation of toxic wastes with increased heavy rainfall events and changes to soil chemistry with increased temperatures (not all of which are fully understood yet).

- We have responsibility for freshwater species under the Biodiversity Action Plan. Suitable climate space for habitats and species will move. Fragmented habitats may lead to inability of species to migrate and adapt; some species are likely to be lost altogether. Natural systems are especially vulnerable and with their limited adaptive capacity may undergo irreversible damage. With only 0.6 degrees Celsius change so far, it has already been observed that egg-laying dates of 20 bird species have become 4-17 days earlier over the past 25 years and a discernible downward trend can be detected in the dates of leaf emergence of oak trees. Whole ecological systems could be disrupted with a major knock-on effect for underpinning economic activities such as agriculture, forestry and fishing. We are already noticing changes to fish stocks on recruitment and survival with the incursion of exotic species. Fishing is a £3billion/year industry involving 3 million anglers.

- Climate change will impact on our ability to deliver the objectives of the Water Framework Directive in achieving good ecological status. There will be direct impacts on ecological status from temperature and flow changes although these are complex and not yet well understood. Indirect impacts may occur as rivers and lakes are likely to become more sensitive to anthropogenic pressures such as diffuse pollution and abstraction with impacts on ecological status. Measures may become more difficult or expensive to achieve. It is not yet clear which water bodies are most sensitive but is likely to be those of high conservation status such as headwaters and shallow lakes.

- Environment Agency research has shown that some waste facilities may be vulnerable to climate change, e.g. coastal sites may be at greater risk of flooding and erosion, while other sites may be vulnerable to changes in the water table. While these costs do not reach the level of the other issues identified above, they may have a significant impact at a local level, e.g. to a coastal local authority, which has to move an affected landfill. Some of these costs may be borne by waste companies (which will pass the costs on to their customers) while others may be borne by local government.

Water Quality

3.3.2 We have less cost information available on what climate change will mean additionally for the costs of delivering water quality policy, which will be embedded within approaches to deliver the Water Framework Directive. Improvements to water quality will be prejudiced if climate change is not mitigated. Water quality will be affected in a number of ways. The problem of combined sewer overflows (where sewage and rainwater flow through the same pipes, which can overflow into water bodies after storms) will be exacerbated by increased rainfall events. Possible increased algal growth and algal blooms will mean that water quality will need more monitoring, reduced flow with droughts worsens quality, and overflows of sewers in floods cause health and social problems too. Costs associated with the treatment of raw water could also rise. For example, removal of Dissolved Organic Carbon (DOC) represents the single largest treatment cost to the water industry, and has become an increasing source of concern in recent years due to rising concentrations across much of northern Europe[15].

3.3.3 Additional expenditure will be needed to reduce the pressure on drainage infrastructure e.g. by requiring developers to install Sustainable Urban Drainage systems. However there will still be a need to increase the capacity of the system to deal with high flows. This could be achieved by separating the two storm water and sewerage systems, or installing larger pipes or storage units.

3.3.4 In London, where it is prohibitively expensive to reduce need or build a separate system, there is already a proposal to install larger capacity on the existing system. The "Thames Tideway" project is estimated to cost £1.5billion. This scheme is vital if we are to avoid any repeat recurrences of flash flooding such as the August 2004 event when 10,000 fish were killed. The Thames Tideway scheme would be the first major investment in London sewers since Sir Joseph Bazalgette's which were built in response to the great stink of 1858 and cholera outbreaks. Climate change has the potential to take us backwards on environmental quality.

3.3.5 Under the current system of funding for water quality, water company customers would meet these costs. Capital costs of wastewater were agreed at £8.8billion for the period 2005-10 in the most recent water pricing review. In general costs of dealing with wastewater (which with climate change is likely to increase in volume due to increased precipitation in winter and increased frequency of heavy rainfall events in summer and winter) considerably exceed costs of providing new water resource capacity.

---

[15] Worrall F, Burt T, Shedden R (2003) Long term records of riverine dissolved organic matter. *Biogeochemistry*, **64**, 165-178.

General comments

We make some comments here on:

Constraints on economic analyses

- Economic feasibility of mitigation
- Further work

4.1 Constraints on economic analyses of climate change

4.1.1 The Environment Agency has reservations regarding the way that economics has been used in the discussion of climate change. Much of the analysis has focussed on a cost-benefit analysis, in which a range of models has been used to estimate the cost and benefit of climate change. While all the analyses acknowledge the uncertainty associated with such an approach, there does not appear to an adequate discussion of how this uncertainty influences the model results and hence the outcomes of the analysis.

4.1.2 A variety of models have yielded a variety of estimates of the costs of mitigating climate change, which range from almost negligible to approximately 4% of GDP. The differences stem from -

The type of model used; whether the focus is on the direct impact on the relevant sector(s) (partial equilibrium models) or on the full impact across the economy (general equilibrium models);

The level of GHG concentration targeted; i.e. from 450 ppm to 750 ppm;

The path of adjustment; whether firms take the most cost effective means initially or replace existing capacity even though it may not have been fully depreciated.

4.1.3 The results from such models are then compared with models that seek to estimate the net damage from climate change. The House of Lords 2005 report into the Economics of Climate Change referred to four such models -

1IPCC (1995), which showed overall damage of 1.5 to 2% of world GNP;
Mendelsohn et al (2000), which showed overall benefit of 0.1% of world GNP;
Nordhaus and Boyer (2000), which showed overall damage of 1.5% of world GNP;
Tol (1999), which showed overall benefit of 2.3% of world GNP.

4.1.4 The Tol study shows that a 2.3 per cent benefit arises when the results for the regions are averaged using output as weights, however, this changes to a detriment of 2.7 per cent of world GNP when the average is based on population weights instead.

4.1.5 In addition to the great variety, and ever-contradictory results, these models are at least five years old and do not take into account the most recent developments. In particular, the findings presented at the Exeter Science Conference in early 2005 suggesting that 450 ppm was a more appropriate concentration target than 550 ppm for limiting temperature changes to less than 2 degrees Celsius. Given the above discussion regarding the costs that are beginning to be incurred to deal with some of the events that are associated with climate change, the Environment Agency is sceptical about the conclusions of the studies referred to in paragraph 4.1.3, that damage will be relatively low in terms of world GNP.

4.1.6 One of the difficulties in using such models is that they cannot be used in a like for like manner. Take for example the speed of adjustment, there is no doubt that it is more costly to seek a faster adjustment than a slower one, as it will involve writing off assets that have not been fully depreciated and; is likely to disrupt the overall investment cycle for the relevant organisation.

4.1.7 On the other hand, evidence indicates that due to the cumulative nature of GHG in the atmosphere, earlier reduction of emissions will have a more profound effect than subsequent reductions, which cannot be studied using the models presented. While the Environment Agency accepts that analysis is limited, there should be fuller discussion of these limitations and how this affects the conclusions that can be drawn.

4.1.8 Another concern with the cost-benefit approach is the idea that there is some "optimal" level of mitigation and that we can decide to stop at this point. However, the evidence suggests that climate change may not be possible to stop once it commences. Examples are:

- The longevity of GHG in the atmosphere suggest that once GHG concentrations are stabilised, they will take considerable time to fall and there is a risk that an unforeseen event will increase the concentration above this level
- Global warming can speed up further global warming. For example there are large areas of frozen peat bog in Russia that are currently thawing. These bogs contain many millions of tonnes of methane, which are being released.

4.1.9 Analysis undertaken by the OECD[16] has also shown there are large uncertainties in estimates of impacts or of monetised benefits, particularly due to the problem of extreme events or the risk of "surprises". It shows there are also problems in comparing different types of impacts and that monetising them or aggregating them may be misleading. It suggests that benefit-cost methods alone may not be adequate to resolve many problems and that risk-based methods should be used as a complement with information presented using both monetary and non-monetary metrics of change.

4.1.10 And finally, a recent assessment of the issues associated with costing climate change in order to derive a social cost of carbon, has recently been completed for Defra by AEAT. We note that it states that "very few studies

[16] OECD 2004. The benefits of climate policy: Improving information for policymakers, OECD, Paris.

cover any non-market damages or the risk of potential extreme weather, (floods, storms etc)". And, it states that "none cover socially contingent effects, or the potential for longer-term effects of impacts and catastrophic events" [17]

4.2 Economic feasibility of mitigation

4.2.1 The Exeter Conference showed that the challenge is manageable and achievable. However, most papers recognised that we need to assume now that a portfolio of methodologies is needed (i.e. including nuclear and carbon sequestration and storage) to reduce costs. Multi-gas strategies, emissions trading optimal timing and strong technological development and diffusion and transfer of technology are needed to keep costs of low-level stabilisation relatively low. Excluding options can be costly. The big problem is overcoming political, social and behavioural barriers to implementing mitigating options - not the economic and costs of actions.

4.2.2 The Intergovernmental Panel on Climate Change suggested in its last assessment, that action aimed at stabilising carbon dioxide atmospheric concentrations at no more than 550ppm would lead to an average GDP loss for developed countries of around 1 per cent in 2050. New work undertaken by the Netherlands Environmental Assessment Agency, shows that stabilising greenhouse gas concentrations at low levels, in order to meet the 2 degree target, is technically feasible using a portfolio of options, and that abatement costs are in the order of few per cent (1-2 per cent) of world GDP[18].

4.2.3 From our reading of the key economic literature on climate change, we do not see there is any conflict between promoting sustainable development with sound livelihoods and economies, and tackling climate change so we avoid dangerous interference with the climate system. Research has shown that the impacts on energy prices of delivering a low carbon economy are likely to be relatively small. The UK Energy Review estimated that the 20 per cent renewables target by 2020 could be achieved with an increase of electricity prices of 5-6 per cent. The Inter-departmental Analysts Group (IAG) report into 'Long-Term Reductions in Greenhouse Gas Emissions', concluded that moving to a carbon-free generation system by 2050 could result in anything from a 20 per cent increase to a slight fall in electricity prices.**[19]** The Group estimated the overall effect on the economy of delivering carbon-free electricity would only be between +0.1% to -0.2% of GDP (with GDP having grown three-fold by then). The Carbon Trust's research also shows that a 60 per cent reduction is technologically feasible and would require sustained innovation over a long period.

---

[17] AEATechnology November 2005 The Social Cost of Carbon Rreview: Methodological Approaches for Using SCC Estimates in Policy Assessment. page ii.

[18] Van Vuuren et al, Stabilising greenhouse gas concentrations: Assessment of different options and strategies using an integrated assessment framework (forthcoming).

[19] IAG (2002) Long-term Reductions in Greenhouse Gas Emissions in the UK. Report by an Inter-departmental Analysts Group. DTI.

4.2.4 Nevertheless, whilst a low carbon economy is feasible, it will not happen without commitment. Clear signals on the long-term low-carbon economy, notably in the EU ETS, are vital to guide technological development across all sectors. For example, the CEOs of United Utilities, Scottish and Southern Energy, Scottish Power, British Gas, RWE npower, E.ON UK, EDF Energy and the National Grid wrote to the Prime Minister on July 29, calling for the Climate Change Programme to contain 'bold action now'. In particular for the allocation of emissions allowances for Phase 2 of the EU ETS 'to send clear signals to encourage investment in low carbon technologies and services.' One of the main findings from a stakeholder consultation on the EU emissions trading scheme is that companies across sectors demand longer-term certainty and predictability about the scheme and in particular the allocation of emission allowances. The more certainty and lead-time they have, the easier it will be for them to invest in the right technologies for the future [20].

4.2.5 However, the need for policy frameworks to effect mitigation policies has been identified, for example by the International Energy Agency (IEA) who have stated that without determined Government interventions, the share of renewables in the global energy mix will probably remain small. It considers that if Governments do not introduce "radical new policies", few renewables will be able to compete with fossil fuels in the near-term [21].

4.2.6 Across the economy it is estimated that we could reduce energy use by around 30 per cent in different sectors though energy efficiency measures. Environment Agency research[22] found that industry could cut its energy consumption by 20 per cent by 2020 if the right policies were put in place. The findings showed that without new policy objectives, energy use would only be cut by 10 per cent. Other research[23] explored the potential for energy savings from different industry sectors. It showed that savings could be made in chemicals, refineries, food and drink, and paper production – all from adoption of CHP in the near future. The Freight Best Practice Programme has shown techniques exist to increase fuel consumption between 7-15% but an advisory service has been little used as hauliers do not regard fuel economy as a priority. From 1990 to 2002, the UK cut CO_2 emissions by about 15 per cent whilst we experienced 30 per cent economic growth.

Further work

4.3.1 We would like to see more analysis of the impact of climate change on the capacity of the UK economy to continue developing. We would like to see how the UK infrastructure, in particular its environmental infrastructure (water resources and quality, flood defences, etc) will be affected, and how this will impact on human and environmental welfare.

---

[20] IP/05/1484 Brussesl 28 Nov 05 Emissions trading: companies want longer-term certainty and predictability
[21] IEA 2001 World Energy Outlook pp17-18.
[22] *Potential for Energy Efficiency in Industry*, Environment Agency, 2002
[23] *The Environment Agency Contribution Towards Achievement of Greenhouse Gas Reduction Targets*. R&D Technical Report P4-089/TR, Environment Agency 2001

4.3.2 We believe that we need more analysis of the costs and benefits of early action, which takes account of the option value of such no-regrets policies.

4.3.3 We support one recommendation of a recent workshop on adaptation that more analysis and information is needed on the economic costs and benefits of adaptation [24]. However we do not think that costs of adaptation and mitigation can be realistically compared to select one or other course of action.

4.3.4 It would be useful if the review could outline some guidance for appraisal and also identify priorities for further work.

5.0 Conclusion

5.1 We cannot afford to not take urgent action on climate change. The economic and social impacts of climate change could be extreme, especially if we set off irreversible changes, according to new research from the Tyndall Centre. It is not whether we pay for climate change, just a matter of when.

5.2 There is sufficient evidence to show that transferring to a low carbon economy can be achieved with very small loss to GDP growth, and there are many other benefits to action.

5.3 This review could usefully set out guidelines and standards for sound economic appraisal of policies on climate change mitigation and adaptation.

FURTHER INFORMATION

Further information or background to this response can be obtained from:

Primary contact:
Dr Merylyn Hedger, Climate Change Policy Manager
Environment Agency tel: 01454 624093
Merylyn.hedger@environment-agency.gov.uk

December 2005

[24] Conference summary: Adaptation what needs to happen next? UK Presidency Event Environment Agency and Defra.

ANNEX 1

Key Environment Agency Statutory Duties Relating To Climate Change Policy

Mitigation

- Regulation of electricity generation (fossil fuel and nuclear). The Environment Agency regulates certain pollutants from large power stations, mainly in line with pollution control legislation in EPA 1990.
- Compiling the pollution inventory. Greenhouse gas emissions and other energy pollutants are listed in the inventory.
- Regulation of oil refineries.
- Pollution prevention and control covers industrial energy efficiency. The new energy efficiency duty introduces the Environment Agency's direct interest in the efficient use of energy as a means of reducing environmental impact.
- Environment Agency waste regulation. Many aspects of waste policy are closed links to energy. For example, energy from waste and captured landfill gas. In addition to these specific areas of overlap, sustainable waste management policies, and more efficient resource use, represent an important aspect of increasing energy productivity in the longer-term.
- Gas pumping, fuel storage, COMAH. These specific duties illustrate the Environment Agency's regulation of energy- related impacts.
- Statutory duty to issue views on the state of the environment. The Environment Agency has a responsibility to produce assessments of the state of the environment, and energy use obviously plays a significant role in environmental impacts.
- Statutory duty to provide advice on Environmental Impact Assessment. Energy system infrastructure (including electricity generating sites and grid, and transport infrastructure) has substantial environmental impacts (including the new and renewable energy technologies).
- Environment Agency is a consultee on air quality plans. Energy use including transport is a key aspect of air pollution impacts.
- Acidification from SO_2 and NOx can affect river quality.

Environment Agency Duties Renewable Energy Use

- The Environment Agency regulates the air pollution aspects of biomass combustion for energy at the larger power stations.
- Environmental impacts associated with the construction of renewable energy infrastructure may affect some of the Environment Agency's duties, e.g. abstraction, impoundment, discharge and groundwater effects.

Adaptation

- We regulate water resources to ensure that the abstraction of water is sustainable, and provides the right amount of water for people, agriculture, commerce and industry and an improved water-related environment;
  - through water abstraction licensing and monitoring of groundwater levels.
  - via the planning consultation process requesting employment of SUDS, re-use of water etc
- We regulate water quality to protect, enhance and restore the environmental quality of inland and coastal surface water and groundwater, including implementation of the Water Framework Directive;
  - through discharge consents for treated water into watercourses for individuals (e.g. domestic sewage treatment), business, and the water industry (e.g. sewage treatment plants).

via the planning consultation process through requirement of accurate and suitable drainage systems.

- We have a duty to reduce the risks to people and to the developed and natural environment from flooding. We approach this through:
  - provision of adequate, economically, technically and environmentally sound and sustainable flood and coastal defences;
  - provision of adequate and cost-effective flood warning systems which contribute to a seamless and integrated service of flood forecasting, warning and response; and
  - discouraging inappropriate development in areas at risk from flooding, e.g. through the use of Flood Risk Consents.
  - spatial planning by advising Local Planning Authorities against the development in areas at risk of flooding e.g. encourage use of our flood risk maps
  - the risks of flooding be minimised via adaptation measures when development cannot be avoided
- We regulate the waste industry, ensuring that waste is recovered or disposed of in ways that protect the environment and human health, as well as providing comprehensive monitoring data.
- We are responsible for maintaining, improving and developing salmon and freshwater fisheries.

ANNEX 2

The social costs of climate change

1. Climate change will affect our health and well-being

1.1 The social consequences of climate change are considerable. In particular flooding has a wide range of social impacts on people's physical and psychological health, people's possessions and other economic assets, and households and communities.

1.2 The poorest and most vulnerable people tend to be hardest hit. Research by the Environment Agency has shown that deprived populations are more likely than less-deprived populations to be living in areas of indicative coastal flood risk in England and Wales[25]; and are likely to be particularly hard hit by the impacts of flooding.

2. The impacts of climate change result in loss of lives

2.1 Flood disasters worldwide since 1900 have resulted in at least 6.8 million reported deaths[26].

2.2 In addition people may be killed by 'hypothermia, electrocution, burns, carbon monoxide poisoning (associated with the use of petrol powered electric generators and pressure washers in poorly ventilated areas indoors)'[27].

2.3 More than 2000 people died in the UK because of the heat between 4 and 13 August 2003. Cold-related deaths are likely to decline substantially (by perhaps 20,000 cases), whereas heat-related deaths are likely to increase by a much smaller number (by about 2,000 cases pa)[28].

2.4 Poor air quality can lead to significant respiratory problems for sensitive people and was responsible for up to 38 per cent of the deaths caused by the August 2003 heat wave.

3. Impacts on physical health

3.1 From water shortages to flooding, from hotter summers to changes in the geographical distribution of vector-borne diseases, climate change will mean changes in the way the environment impacts on our health[29].

3.2 People who were flooded in Lewes in October 2000 were more likely than non-flooded individuals to report incidences of earache, gastro-enteritis and skin rash during the nine months after the event[30]. Women tend to carry the physical and emotional burden of

---

[25] Walker G, Fairburn J, Graham S and Mitchell G, 2003. Environmental quality and social deprivation. R&D technical report E2-067/1/TR, Environment Agency, Bristol; Walker, G., Burningham, K., Fielding, J., Smith, G., Thrush, D., Fay, H. (2005) Addressing environmental inequalities: Flood risk, Science report SC020061/SR1, Environment Agency, Bristol. To be published.

[26] Few, R., Ahern, M., Metthies, F. and Kovats, S. 2004 *Floods, health and climate change: a strategic review* Tyndall Centre for Climate Change Research: Working Paper 63.

[27] Ohl, C. and Tapsell, S., 2000, *Flooding and human health: the dangers posed are not always obvious* British Medical Journal, 321, 1167-8 11th Nov 2000.

[28] Department of Health, 2001. Health effects of climate change in the UK.

[29] Environment Agency, 2005. The climate is changing, time to get ready. Environment Agency, Bristol; Department of Health, 2001. Health effects of climate change in the UK.

[30] Reacher, M., McKenzie, K., Lane, C., Nichols, T., Kedge, I., Iversen, A., Hepple, P., Walter, T., Laxton, C. and Simpson, J. 2004 *Health impacts of flooding in Lewes: a comparison of reported gastrointestinal and other*

caring for sick household members[31], as well as experiencing particular physical and psychological flood-related health problems themselves[32].

3.3 An increase in the likelihood of accidents and injuries is associated with severe weather such as gales and with flooding.

3.4 As a result of hotter summers, food poisoning cases are estimated to increase by 10 000 each year by 2050[33], but may be largely preventable if effective measures are adopted.

3.5 There will be increase in exposure to high levels of ozone during hotter summers. Ozone pollution reached its highest peak for more than a decade in London in the summer of 2003[34]. Poor air quality can trigger asthma attacks, cardiovascular problems and cause deaths amongst vulnerable groups such as young children[35].

3.6 A combination of a changed climate and changed behaviour may lead to greater exposure to UV rays which in turn may lead to increased incidence of skin cancer[36].

4. Flooding can impact on people's psychological health and well-being

4.1 The risk of psychological distress can increase four-fold following flood events[37]. Victims of flooding often describe the event as traumatic, resulting in a range of psychological health effects that include panic attacks, agoraphobia, depression, tiredness, stresses and anxiety[38].

4.2 Following the 2000 floods, Tapsell *et al.* (2002) found that people mentioned relationship problems in their households and in the community due to the stress of the flood and the recovery process[39]. Ketteridge and Fordham (1998, p127) also point to the fact that

---

illness and mental health in flooded and non-flooded households. Communicable Disease and Public Health, 7, No.1 1-8.

31 Tapsell, S.M, Tunstall, S.M, Penning-Rowsell, E.C and Handmer J.W. 1999 *The Health Effects of the 1998 Easter Flooding in Banbury and Kidlington* Flood Hazard Research Centre, Middlesex University

32 Tapsell, S.M. and Tunstall, S.M. 2001 *The Health and Social Effects of the June 2000 Flooding in the North East Region.* Report to the Environment Agency; Tapsell, S.M., Tunstall, S.M. and Wilson, T. 2003 *Banbury and Kidlington Four Years After the Flood: An Examination of the Long-Term Health Effects of Flooding.* Report to the Environment Agency, Thames Region; RPA/FHRC 2004 *The Appraisal of Human related Intangible Impacts of Flooding* Joint Defra/EA Flood and Coastal Erosion Risk Management R and D Programme. R and D Technical Report FD2005/TR

33 Department of Health, 2001. Health effects of climate change in the UK.

34 Environment Agency, 2005. The climate is changing, time to get ready. Environment Agency, Bristol

35 Stevenson, S. et al (1998). 'Examining the inequality and inequity of car ownership and the effects of pollution and health outcomes such as respiratory disease' Epidemiology, 9 (4).

36 DH, 2001; EA, 2005.

37 Reacher, M., McKenzie, K., Lane, C., Nichols, T., Kedge, I., Iversen, A., Hepple, P., Walter, T., Laxton, C. and Simpson, J. 2004 *Health impacts of flooding in Lewes: a comparison of reported gastrointestinal and other illness and mental health in flooded and non-flooded households*. Communicable Disease and Public Health, 7, No.1 1-8.

38 Tapsell, S.M, Tunstall, S.M, Penning-Rowsell, E.C and Handmer J.W. 1999 *The Health Effects of the 1998 Easter Flooding in Banbury and Kidlington* Flood Hazard Research Centre, Middlesex University; Hajat, S., Ebi, K.L., Kovats, S., Menne, B., Edwards, S. and Haines, A. 2003 *The human health consequences of flooding in Europe and the implications for public health: a review of the evidence* Applied Environmental Science and Public Health, 1, No.1. 13-21; Few, R., Ahern, M., Metthies, F. and Kovats, S. 2004 *Floods, health and climate change: a strategic review* Tyndall Centre for Climate Change Research: Working Paper 63; Thrush, D., Burningham, K. and Fielding, J. In Press 2005b *Exploring flood-related vulnerability: A qualitative study* Environment Agency R and D Report W5C-018/3 Bristol: Environment Agency.

39 Tapsell, S.M, Penning Rowsell, E.C, Tunstall, S.M and Wilson, T.L 2002 *Vulnerability to flooding: health and social dimensions* Phil. Trans. Royal Society London *A,* 360, 1511-1525.

‘flood events can put a significant strain on personal relationships and can even trigger separations’[40]. Research conducted after the 1997 Grand Forks flood in the USA found that community professionals observed an increase in domestic violence during the aftermath of the flood[41].

5. Economic and other losses

5.1 The Association of British Insurers (ABI) estimates that the increased cost to households due to extreme weather events will be up to 4 per cent extra every year. Households and individuals incur considerable expenditure, which may not be covered by insurance: the costs of temporary accommodation, meals out, increased electricity bills for drying out homes, prescription charges (should ill-health follow the flood).

5.2 Those on low incomes and without insurance are likely to find it more difficult to cover the incidental expenses associated with evacuation and temporary accommodation expenditure, which may not be covered by insurance.

5.3 People employed in unstable, low-income jobs are those most likely to lose their jobs should businesses close or move. Low paid ‘home work’ is particularly severely affected if the worker’s home is flooded[42].

5.4 Older people, who are more likely to be living in bungalows, ground floor flats and mobile homes, and households living in basement flats, single storey dwellings and caravans suffer greater economic losses as a result of flooding (Green and Penning-Rowsell 1989). They are also more likely to be affected by the loss of treasured items in floods that may not be recovered through household insurance policies’[43].

5.5 Members of some minority ethnic groups may be particularly likely to lack adequate insurance. For instance, Tapsell *et al.* (1999) found that the Asian community in Banbury had lower incomes and less insurance cover than their white neighbours and found it hard to understand the insurance system.

6. Community and neighbourhood changes

6.1 Flooding can result in changes to communities and neighbourhoods, with changes in population, closure of businesses, and alterations in levels and perceptions of social capital[44]. Those who have the ability to move (this may include absorbing a possible drop in property value as well as the associated costs of moving home) leaving behind those who are unable to do so, e.g. older or poorer residents and local authority or housing association tenants.

6.2 Floods disrupt local businesses, services and infrastructure, but the longer-term effects are less clear. Smaller businesses are likely to be hit harder than their counterparts, while some local businesses can profit from a flood event.

---

[40] Ketteridge, A. and Fordham, M. 1998 *Flood Evacuation in two communities in Scotland: Lessons from European Research* Int. J. of Mass Emergencies and Disasters August 1998, 16 (2), 119-143

[41] Clemens, P., and Hietala, J.R. 1999 *Risk of domestic violence after flood impact: Effects of social support, age and history of domestic violence* Applied Behavioral Science Review, 7, No. 2 199-206

[42] Morrow, B.H. 1999 *Identifying and Mapping Community Vulnerability.* Disasters, 23 (1), 1-18.

[43] Penning Rowsell E.C. and Green, C.H. 2000 *New Insights into the appraisal of flood alleviation benefits. I. Flood damage and flood loss information*. Journal of the Institute of Water Environmental Management, 14, 347-353 cited in Tapsell *et al*. 2002, p.1511).

[44] Tapsell and Tunstall 2001

6.3 Flood events can also contribute to an initial sense of community spirit, cohesiveness and solidarity[45], but also the emergence of new divisions and conflicts, which often revolve around the issue of perceived differences in the treatment of flood victims.

[45] Ketteridge and Fordham 1998, Tapsell *et al*. 1999, Tapsell *et al*. 2002, Thrush *et al*. 2005

ANNEX 3

Portfolio of Science Case Studies for the Stern Review

[1] Foresight may have understated the cost of future flood risk

Despite the immediate divergence of future emissions in the underpinning Special Report on Emission Scenarios (SRES), uncertainty in future emissions has very little influence on uncertainty in climate change until the second half of the 21st century. In comparison, differences between climate model projections are large. For example, changes in winter precipitation over the British Isles as whole by the 2080s under the SRES Medium-High emissions scenario ranges between +1% and +61% depending on the choice of global climate model[46].

Inter-model uncertainty may be even greater at regional scales due to different treatments of important processes (such as cloud properties) by different climate models. This is particularly true for changes in the climate extremes that lead to fluvial flooding[47]. Such changes might include more frequent short-duration, high-intensity rainfall or more frequent periods of long-duration, frontal rainfall of the type responsible for the autumn 2000 flooding.

Recent assessments of flood risk such as the Foresight study and review of Defra guidance on future peak river flows[48] were based on the 2002 UK Climate Impacts Programme (UKCIP02) scenarios[49]. These scenarios were based on four emission scenarios and a single Global Climate Model (GCM). A key feature of the UKCIP02 scenarios is that winters will become wetter and summers drier, with increased likelihood of heavy winter precipitation. Overall, the GCM used to produce UKCIP02 yields changes in winter rainfall that are in the middle of the range for different GCMs, but summer drying that is near the extreme of models[13]. Changes in flood risk estimated from UKCIP02 by continuous simulation river flow models can yield *reductions* in future floods[12] because large soil moisture deficits accumulated by the summer drying depress flows in winter, despite higher rainfall during the latter season.

The following Fig illustrates the uncertainty of flood frequencies for the River Rea at Calthorpe Park by the 2050s due to choice of GCM (source: Reynard *pers. comm.*). If this result is representative of UK catchments, then the UKCIP02 scenario (blue line) that underpinned Foresight could have underestimated the true cost of future flood risk. Of course, there are big questions surrounding the relative credibility of different climate models (i.e., how much weight should be placed on the Japanese or

---

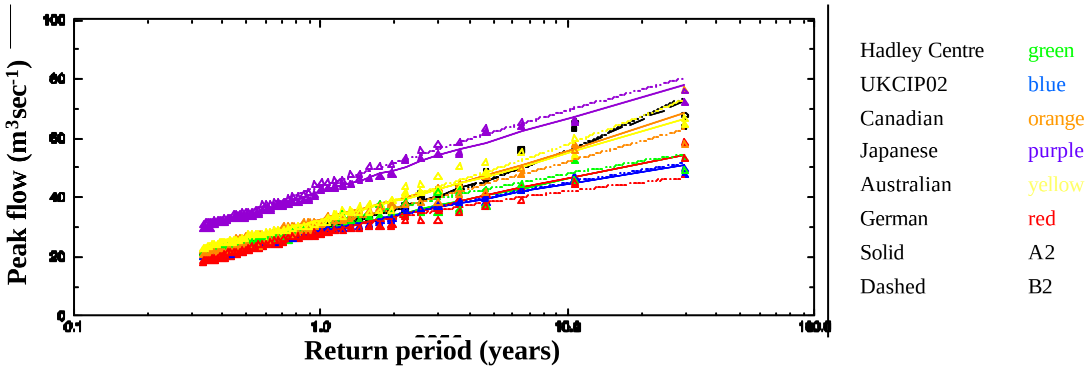
[46] Lowe, J., Smith, F., Jenkins, G. and Pope, V. 2004. *Uncertainty, risk and dangerous climate change*. Hadley Centre, Exeter, pp12.

[47] Fowler, H.J. and Kilsby, C.G. 2003. A regional frequency analysis of UK extreme rainfall from 1961 to 2000. *International Journal of Climatology*, **23**, 1313-1334

[48] Reynard, N., Crooks, S., Wilby, R.L. and Kay, A. 2004. Climate change and flood frequency in the UK. *Defra National Conference,* University of York, UK.

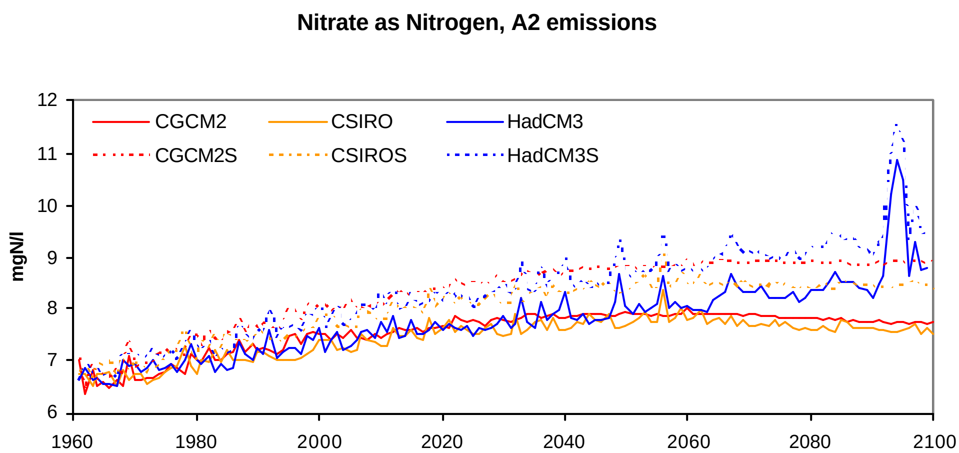
[49] Hulme, M., Jenkins, G.J., Lu, X., Turnpenny, J.R., Mitchell, T.D., Jones, R.G., Lowe, J., Murphy, J.M., Hassell, D., Boorman, P., McDonald, R. and & Hill, S. 2002. *Climate Change Scenarios for the UK: The UKCIP02 Scientific Report*, Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich, UK. 120pp.

Canadian models compared with the Hadley Centre model). Furthermore, it should be noted that representation of key processes affecting local surface/groundwater partitioning is often simplistic in the continuous simulation models used to produce these kind of flood plots.



Existing guidance recommends that planned flood defence works apply a sensitivity test of 20% increase in peak river flows by the 2050s. This figure is based on a very broad interpretation of research on a small number of catchments under a limited range of scenarios. Therefore, Defra and Agency have just begun a 2-year project to consider evidence for refining the precautionary allowance, taking into account likely changes in peak flood flows between different regions, catchments and time periods (e.g. over the next 25, 50, 75 and 100 years), under different climate scenarios.

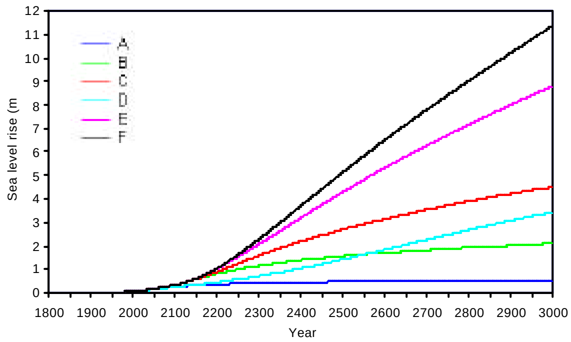
[2] <u>Costs associated with clean up of diffuse water quality problems may increase</u>
The following Fig shows the impact of climate change on peak nitrate-N concentrations in the River Kennet with (dotted lines) and without (solid lines) enhanced nitrification[50]. The CSIRO and CGCM2 models generate rising levels of nitrate and ammonium until the 2050s and a gradual decline thereafter. However, HadCM3 generates rising nitrate and ammonium with large extremes occurring towards the end of the century. The final peak in Nitrate-N is of the order of 11 mg/l and even higher when the effects of the enhanced nitrification are taken into account. Increased nitrate concentrations are caused by sequences of dry summers leading to the build up of nitrogen in the soil that is subsequently flushed from the land into the surface water network when a drought breaks.



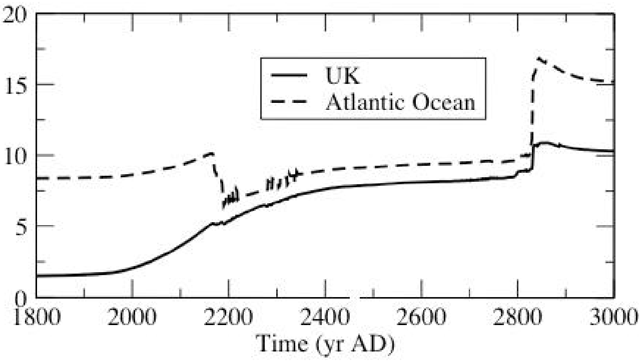
50 m ... 2006. Integrated ... River Kennet, UK *Journal of Hydrology*, in press.

[3] Time is running out to combat irreversible/costly changes in Earth systems

The following Fig shows the rise in sea level for different long-term fossil fuel CO2 emission scenarios ranging from (A) linear decline to zero by 2200 (~IS92c) through to (F) consumption of all conventional and exotic fossil fuel reserves[51]. The plots show the total contributions of thermal expansion and Greenland ice sheet melt, but do not include potential changes in the mass balance of the Antarctic ice sheets. The report arrived at the stark conclusion that dangerous climate change (taken as a global sea level rise of 2m) can only be avoided by allowing a modest increase in global CO2 emissions to 8.8 GtC/yr in 2025, followed by a roughly linear decline to zero emissions by 2200.



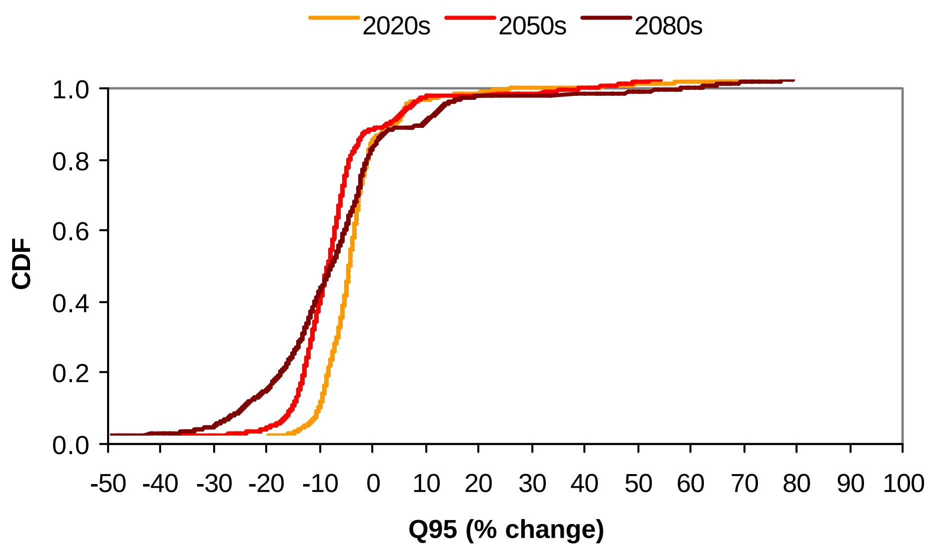
Furthermore the report notes that abrupt changes can be triggered many decades before they actually occur, and even after emissions have completely ceased, there is still a legacy from decades past (a "sleeping giant" in the climate system). This is evidenced by rapid global and regional warming events (see below) that occur in MoBidiC around 2700 (scenario F) or 2800 (scenario E). In both cases, the timing of the event coincides with zero emissions, atmospheric CO_2 is actually declining, yet temperature is still increasing very gradually due to thermal inertia in the climate system. The Fig below shows abrupt changes in regional temperatures in °C as seen in the North Atlantic region in MoBidiC under scenario E ('UK' refers to continent at UK latitude).



[4] Next generation probabilistic scenarios could yield valuable information for economic appraisal of water resource (supply) options

[51] Tyndall Centre, 2005. *Climate change impacts in the UK on a millennial timescale*. Final Report of Tyndall Project T3.18, under review.

The following example shows cumulative probabilities (CDFs) of low flows (Q95) in the River Thames reflecting uncertainties due to choice of emissions (A2, B2), GCM (CGCM2, CSIRO, ECHAM4, HadCM3), downscaling method (CF, SDSM), water resource model structure (CATCHMOD, regression), and water resource model parameter set (100 best)[52]. This type of information could be used to assign levels of risk for specific outcomes and time horizons. For example, in this case study, the risk that low flows will decrease in the Thames by 10% *or more* is 10% in the 2020s, 40% by the 2050s, and 41% by the 2080s. However, the risk that flows will decrease by 20% or more is <0.1% in the 2020s, 2% by the 2050s and 14% by the 2080s. Probabilistic information showing different levels of risk could be used to trigger the timing and/or shape of major investment decisions.



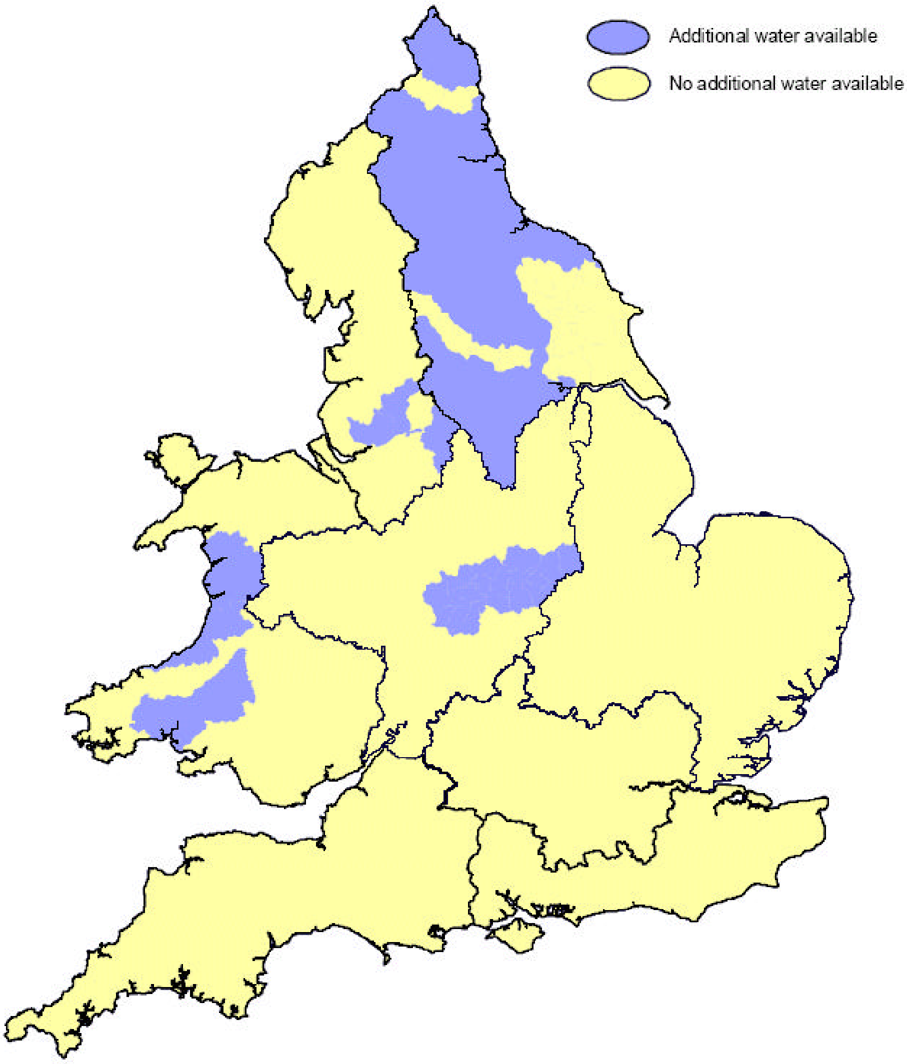
The Agency has joined with Oxford University and the Tyndall Centre to evaluate different frameworks for handling probabilistic scenarios. The three-year project will undertake impact assessments using very large ensembles of climate model experiments (held by the NERC-supported ClimatePrediction.Net project) applied to water resource and biodiversity case studies. This work will enable the Agency and partner organisations to develop risk-based approaches and guidance for handling probabilistic information ahead of the release of the Hadley Centre's UKCIPnext scenarios in 2008.

52 Wilby, R.L.and Harris, I. 2005. A framework for assessing uncertainties in climate change impacts: low flow scenarios for the River Thames, UK. *Water Resources Research*, in press.

ANNEX 4

MAP 1

CURRENT INDICATIVE AVAILABILITY: SUMMER SURFACE WATER



MAP 2
SITES WHERE CURRENT LICENSED ABSTRACTION IS BELIEVED TO BE UNSUSTAINABLE

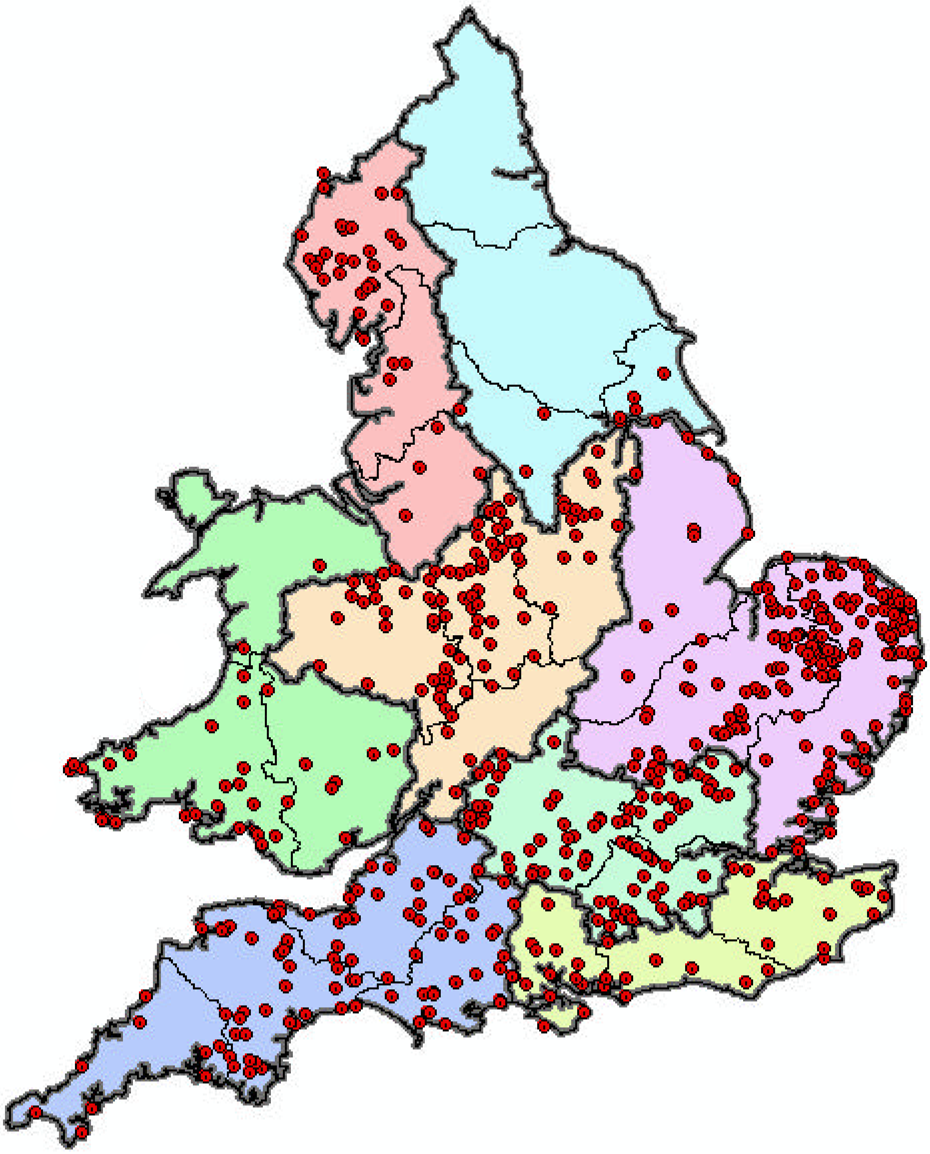
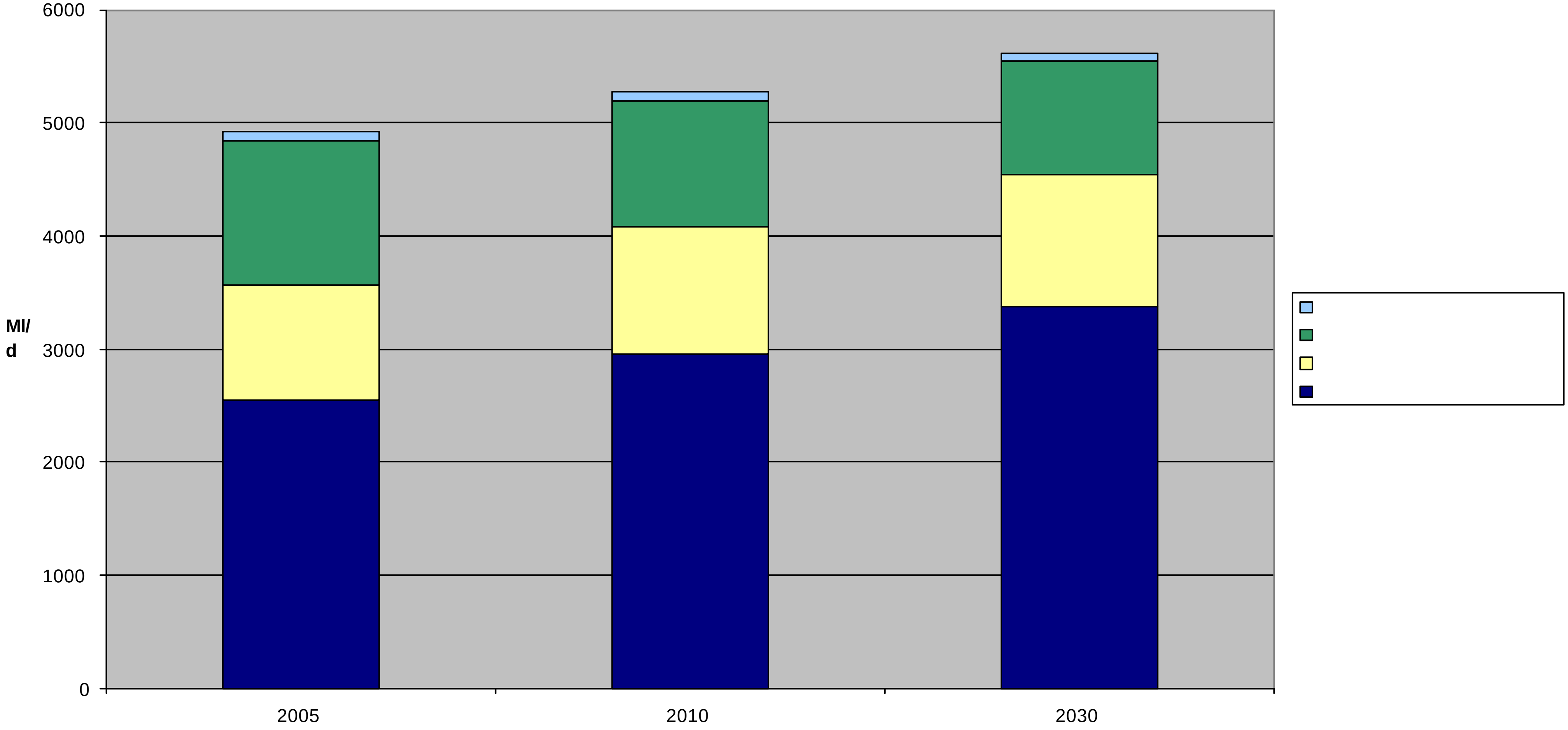


FIGURE 3
WATER COMPANY REPORTED (2005) AND FORECAST (TO 2030) OF TOTAL DEMAND IN SOUTH EAST ENGLAND



MAP 4
PERIODIC REVIEW 2004 SUPPLY DEMAND BALANCE – WATER COMPANY ZONES WITH A DEFICIT BETWEEN NOW AND 2015