Department for Environment Food and Rural Affairs

Environment Agency

Water for life and livelihoods

River Basin Management Plan
Thames River Basin District

Annex H: Adapting to climate change

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H.1 Introduction

The water environment is particularly vulnerable to the effects of climate change. We are already experiencing trends in climatic factors that are having impacts on the water environment.

The Intergovernmental Panel on Climate Change (IPCC) Climate Change and Water Technical Paper[1] concluded that "observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences on human societies and ecosystems".

Projections of future climate from the UK Climate Impacts Programme ('UK Climate UKCP09[2],[3]) identify that we can all expect climate changes to intensify, with the following key changes:

- All areas of the UK get warmer, and the warming is greater in summer than in winter;
- There is little change in the amount of precipitation (rain, hail, snow etc) that falls annually, but it is likely that more of it will fall in the winter, with drier summers, for much of the UK. There is likely to be an increasing incidence of very intense heavy rainfall (see section H3);
- Sea levels rise, with this rise being greater in the south of the UK than the north.

Climate change will inevitably affect the conditions and pressures that the Water Framework Directive seeks to manage in the water environment. Climate change impacts may not be strongly felt during the first river basin management cycle up to 2015 and may not be easily distinguishable from normal climatic variations. However, decisions and investments made during this period may have a lifetime that extends for many decades. In particular new infrastructure or modifications to existing infrastructure will last more than one cycle. Over this extended period, towards the end of cycle two (to 2021) and through cycle three (to 2027), it is predicted that the UK's climate is likely to change significantly. Therefore, if we all fail to take account of climate change now, this could result in poor investment decisions in terms of actions and limit the extent to which we can meet Water Framework Directive objectives and/or the efficiency with which we will achieve them. Further climate, change could affect the predicted effectiveness of current or new actions in meeting Water Framework Directive objectives (unless we all take this into account). This presents real risks for implementation and success.

The European Commission has identified water management as the priority area for action in taking into account the impact of climate change. In April 2009 an EU White Paper was produced, 'Adapting to climate change: Towards a European framework for action'. This describes the kind of action that can be best delivered at EU level to deal with the impacts of climate change. The White Paper sets out a framework to reduce the EU's vulnerability to the impact of climate change and specifically highlights the need to take climate change into account in developing the River Basin Management Plans and the role the river basin management process can play in delivering sustainable water management in a changing climate.

[1] Bates, B.C., Kundzewicz, Z.W. Wu, S. and Palutikof, J.P. (Eds.) 2008: Climate Change and Water. Technical Paper VI of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp. Available at: http://www.ipcc.ch/pdf/technical-papers/climate-change-water-en.pdf

[2] http://ukclimateprojections.defra.gov.uk//

[3] Note that UKCP09 was launched on the 18th June 2009. In developing the draft River Basin Management Plan we used the previous UK climate change projections (UKCIP02) that were available at that time. For this plan we have now considered the outputs of UKCP09 in carrying out an initial revision of our approach to climate change and particularly the likely performance of measures.

With respect to climate change impacts on the water environment the European Commission has made it clear that member states should take climate change into account when implementing the Water Framework Directive. A policy paper on the need for, and approach to, climate change adaptation through implementation of the Water Framework Directive has been endorsed by the EU Water Directors.[4] A Common Implementation Strategy activity on Climate Change and Water, started in 2007, is currently focusing on making the best use of existing EU water legislation and identifying adaptation measures at different scales to progress adaptation for water, and is currently producing guidance on integration of climate change into Water Framework Directive implementation. This guidance should be published by the end of 2009. The EU white paper identifies the development of guidance and supporting tools to 'climate-proof' River Basin Management Plans as a specific action. The UK (through Defra with the support of the Environment Agency) is supporting the development of this guidance including leading on the drafting of a chapter on the 'analysis' stages of Water Framework Directive implementation.

As a minimum, the European Commission expects our response to climate change to include, in the first cycle, screening of the likely effects of climate change on the pressures identified under the characterisation (Article 5) step of the river basin management process. The European Commission also recommends that member states carry out a climate impact sensitivity analysis or 'climate check' on the programme of actions to help in 'selecting actions that are effective, sustainable and cost efficient under changing conditions'. The European Commission also states that, 'In the second planning cycle, climate change impacts should be taken fully into account'. The European Commission recommendation is primarily in relation to climate change adaptation (rather than mitigation) which is the main thrust of this annex. This annex seeks to summarise how the Environment Agency has approached these assessments of the impacts of climate change in producing this first River Basin Management Plan.

H.2 Summary of approach in dealing with climate change

The Environment Agency priorities for dealing with climate change in the first cycle of implementing the Water Framework Directive in England and Wales will be to:

- consider the change in risk, due to climate change, of not achieving the Water Framework Directive default objectives (for example no-deterioration, good status) as a consequence of the identified Water Framework Directive pressures (for example abstraction);
- consider the impacts of climate change when identifying and appraising actions and propose appropriate adaptation of actions where necessary;
- look for opportunities in the monitoring programme to improve our understanding of climate change trend;
- consider the likely contribution of actions to future climate change through their impact on emissions of greenhouse gases, and propose appropriate mitigation where necessary.

In the first cycle the Environment Agency will not attempt to incorporate climate change into typologies, reference condition descriptions or default objective (including standards) and final water body objective setting. This is because we require some stability in our planning assumptions for subsequent work and because further work is required to understand what impact climate change will have on underlying conditions before we can do this. Further, on the basis of current scientific results, it is not expected that, within the timeframe of initial Water Framework Directive implementation (i.e. up to 2027) and within the metrics used for pressure assessment, a climate change signal will be observable above natural variability or adequately distinguishable from other human pressures at a level to cause major changes in

[4] Common implementation strategy for the Water Framework Directive, policy paper on climate change and water, June 2008

typology or major changes at reference sites. We are following the recommendations of the European Commission for the first cycle and are expecting a view from the commission as to common and consistent action to address issues identified above for future cycles. We will not reopen the agreed monitoring plan for similar reasons. However these aspects of the planning cycle will be addressed by future planning cycles.

We will do further research and scoping work in the first cycle of river basin management to determine if and how climate change should be factored into these considerations. There is already relevant ongoing or proposed research which will help inform our decision on these issues in the future. Examples include:

- A proposed assessment of the impact of climate change on river flows and groundwater levels across England and Wales, to improve the Environment Agency's capacity for taking this into account in management and regulatory decisions.
- Proposed development of guidance for water companies to prepare plans for future water supply that include effective adaptation to and mitigation of climate change.
- Project on 'Potential impacts of climate change on river water quality' (Environment Agency Science report: SC070043/SR).
- Project on 'climate change impacts and water temperature' (Environment Agency science report: SC060017/SR).
- Project on 'Preparing for climate change impacts on freshwater ecosystems (PRINCE)' (Environment Agency science report: SC030300).

Further work is also required to determine if and how controlling non-climate change pressures and maintaining ecosystems in good functional condition increases the resilience of ecosystems to the impacts of climate change. Robust evidence for this could influence adaptation strategies, appraisal outcomes and therefore alternative objective setting.

This annex addresses a number of the priorities identified in the bullets above:

- The impacts of climate change in England and Wales and the river basin district.
- The potential impacts of climate change on the identified Water Framework Directive pressures.
- How resilient the programme of actions are to the impacts of climate change.

Essentially this annex looks at climate change impacts on the pressures, actions and achievement of Water Framework Directive objectives in the first River Basin Management Plan. It does not report in detail the impact of the programmes of actions on greenhouse gas emissions and future climate change. These aspects are considered in the strategic environmental assessment reports which accompany the draft and this River Basin Management Plan and annex E which describes how the cost of carbon was included in the economic appraisal process. As such this annex E and the Strategic Environmental Assessment are complementary. The assessments in this annex are essentially qualitative. More quantitative information may have to be used in appraising existing measures or through other processes (e.g. PR09) and should be used in updating risk assessments prior to measures implementation.

H.3 Summary of climate change impacts

This section summarises climate change effects in England and Wales to date and scenarios for future climate change effects as reported in UKCP09[5]. You can find more detailed analyses and descriptions on historic trends and future projections, together with guidance on how to plan for climate change via either the UKCP09 or the UK Climate Impacts Programme[6] websites.

Climate change effects to date

The 'climate of the UK and recent trends' report from UKCP09 identifies the following climate change effects to date for the UK [7]

- Warming of the global climate system is unequivocal, with global average temperatures having risen by nearly 0.8 ºC since the late 19th century, and rising at about 0.2 ºC a decade over the past 25 years.
- It is very likely that man-made greenhouse gas emissions caused most of the observed temperature rise since the mid 20th century.
- Global sea-level rise has accelerated between mid-19th century and mid-20th century, and is now about 3mm per year. It is likely that human activities have contributed between a quarter and a half of the rise in the last half of the 20th century.
- Central England temperature has risen by about a 1.0 ^{o}C since the 1970s, with 2006 being the warmest on record. It is likely that there has been a significant influence from human activity on the recent warming.
- Annual mean precipitation (rain, hail, snow etc) over England and Wales has not changed significantly since records began in 1766. Seasonal rainfall is highly variable, but appears to have decreased in summer and increased in winter, although with little change in the latter over the last 50 years.
- All regions of the UK have experienced an increase over the past 45 years in the contribution to winter rainfall from heavy precipitation (rain, hail, snow etc) events; in summer all regions (except North-East England and Northern Scotland) show decreases.
- Severe windstorms around the UK have become more frequent in the past few decades, though not above that seen in the 1920s.
- Sea-surface temperatures around the UK coast have risen over the past three decades by about 0.7 ºC.
- Sea level around the UK rose by about 1mm a year in the 20th century, corrected for land movement. The rate for the 1990s and 2000s has been higher than this.

Scenarios for future climate change

Much of the change in climate over the next 30 to 40 years has already been determined by historic emissions and because of the inertia in the climate system. We are all likely, therefore, to have to adapt to some degree of climate change even if future emissions are reduced. The climate of the second half of the twenty-first century, and beyond, will be increasingly influenced, however, by the volume of greenhouse gases that human society emits over the coming decades.

Consideration of future climate change is based on scenarios of future global emissions of greenhouse gases. The scenarios reported by UK Climate Impact Programme 2009 describe three alternative emissions scenarios for the UK. These are 'low emissions', 'medium

[5] http//:ukclimateprojections.defra.gov.uk
[6] http://www.UKCIP.org.uk/
[7] Jenkins G.J., Perry M.C. and Prior M.J.O., 2009. The Climate of the United Kingdom and Recent Trends, Revised Edition, Jan 2009, Met Office Hadley Centre

emissions', and 'high emissions'. Due to space constraints we have largely presented results in this document for the medium emissions scenario. However in the Environment Agency assessment of climate impacts on pressures and the performance of measures we have looked across all three emission scenarios.

As well as uncertainty surrounding future greenhouse gas emissions there are also other significant uncertainties (for example in the choice of climate model to use) that mean that it is not possible to give one correct value for future climate. UKCP09 addresses this through, for the first time, presenting climate change projections in probabilistic form. This has been made possible through advancements in the understanding and modelling of the climate system, advances in computing power, and the integration of the results of climate models from centres other than the Meteorological Office Hadley Centre. Within UKCP09 and in this annex, where probabilities are described, the Intergovernmental Panel on Climate Change definitions are used – for example very unlikely means that there is less than 10 per cent probability of occurrence of an event. Further, UKCP09 presents projections for three different emission scenarios: 'low', 'medium' and 'high'.

The following statistics, maps (Figure H1-H3) and cumulative distribution functions (Figure H4) are provided in order to give an indication of the scale, direction of change and uncertainty associated with annual average temperature, winter precipitation and summer precipitation in the 2050s. The 2050s are presented to allow consideration of the potential changes in climate over the lifespan of those measures that might be less flexible to changing conditions (i.e. fixed infrastructure such as housing, flood defences, reservoirs, wastewater treatment works and so on). UKCP09 projections are provided at seven 30-year time periods covering the period from 2010 to the end of this century – thus the '2050s' represents the average across the time period from 2040-2069. The changes are relevant to a 1961-1980 baseline. Further information including other significant variables (e.g. humidity, rainfall intensity, maximum and minimum temperatures), additional timescales and alternative probability levels are available from the UKCP09 website http://ukclimateprojections.defra.gov.uk.

The UKCP09 projections suggest that for the Thames River Basin District[8] in the 2050's:

- Under medium emissions, the central estimate of increase in **winter mean temperature** is 2.2ºC; it is very unlikely to be less than 1.2ºC and is very unlikely to be more than 3.5ºC.
- Under medium emissions, the central estimate of increase in **summer mean temperature** is 2.7ºC; it is very unlikely to be less than 1.2ºC and is very unlikely to be more than 4.6ºC.
- Under medium emissions, the central estimate of increase in **summer mean daily maximum temperature** is 2.7ºC; it is very unlikely to be less than 1.4ºC and is very unlikely to be more than 6.5ºC.
- Under medium emissions, the central estimate of increase in **summer mean daily minimum temperature** is 2.9ºC; it is very unlikely to be less than 1.3ºC and is very unlikely to be more than 5ºC.
- Under medium emissions, the central estimate of change in **annual mean precipitation** is 0 per cent chance; it is very unlikely to be less than –4 per cent and is very unlikely to be more than 5 per cent.
- Under medium emissions, the central estimate of change in **winter mean precipitation** is 15 per cent; it is very unlikely to be less than 2 per cent and is very unlikely to be more than 33 per cent.

[8] Based on the UKCP09 'London' administrative area

- Under medium emissions, the central estimate of change in **summer mean precipitation** is –18 per cent; it is very unlikely to be less than –39 per cent and is very unlikely to be more than 7 per cent.

Figure H.1 **Change in annual mean temperature (ºC) in the 2050s under the Medium emissions scenario for the Thames River Basin District for the a.) 10 per cent; b.) 50 per cent and c.) 90 per cent probability levels. Results from UKCP09.**

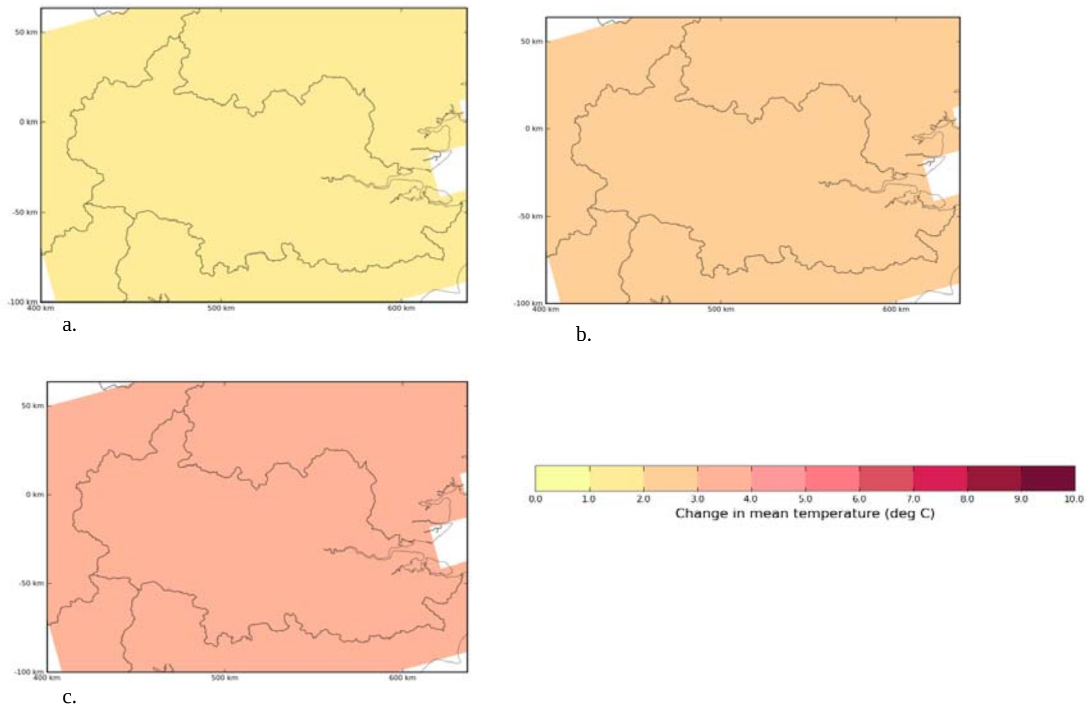
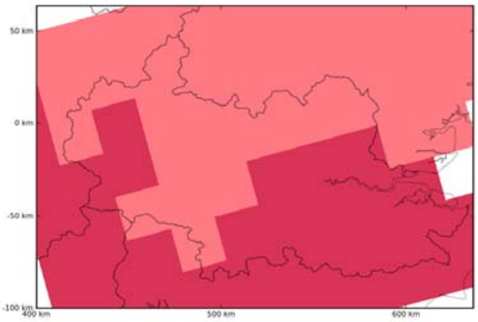
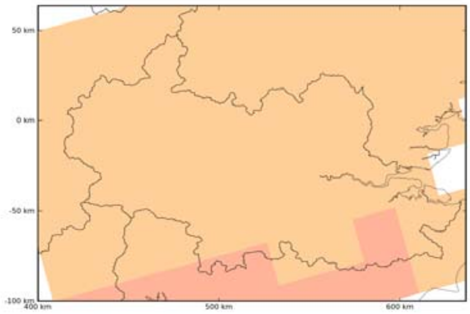


Figure H.2 - **Change in summer precipitation (per cent) in the 2050s under the Medium emissions scenario for the Thames River Basin District for the a.) 10 per cent b.) 50 per cent and c.) 90 per cent probability levels. Results from UKCP09.**



a.



b.

c.

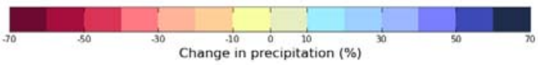
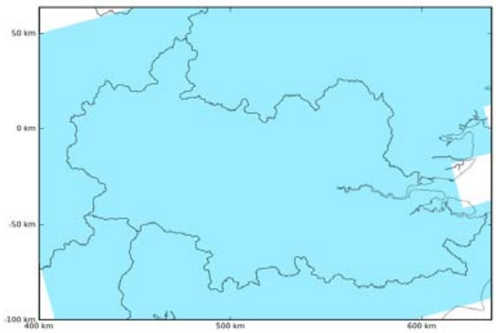
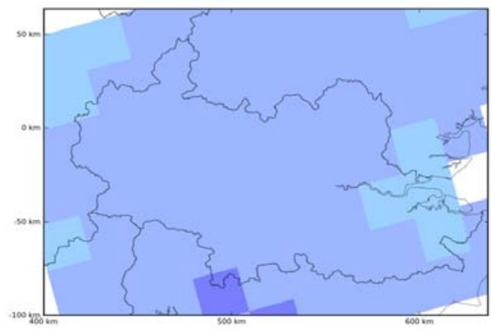


Figure H.3 **Change in winter precipitation (per cent) in the 2050s under the Medium emissions scenario for the Thames River Basin District for the a.) 10 per cent, b.) 50 per cent and c.) 90 per cent probability levels. Results from UKCP09*.***

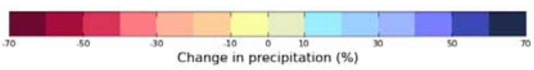
a.



b.



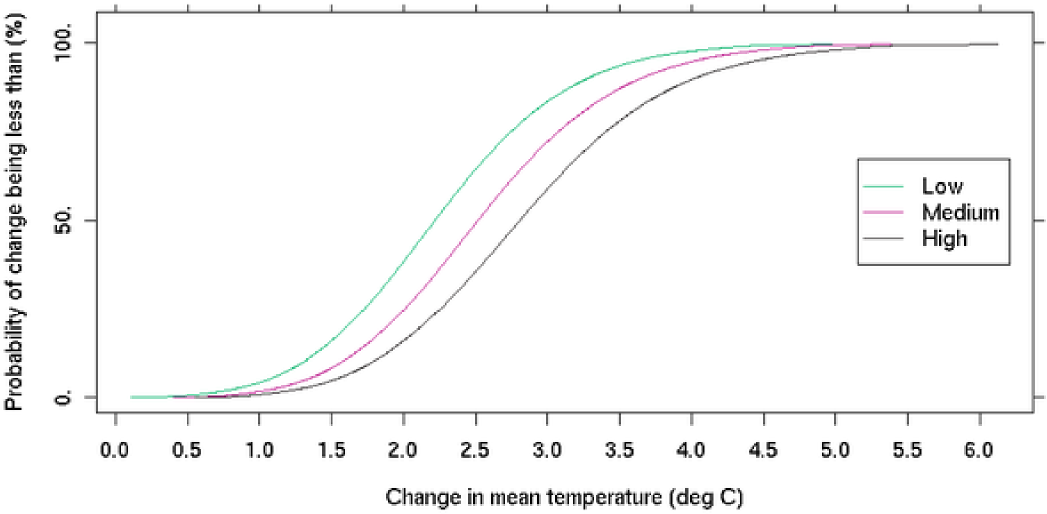
c.



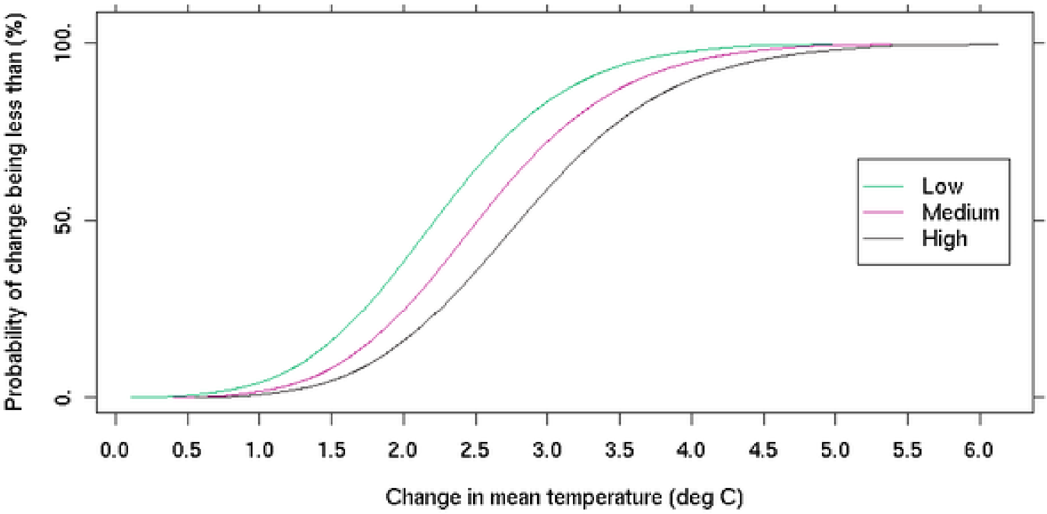
The maps above (figures H1-H3) present only a single possible future climate and do not properly represent the range of possible futures. In preparing for the impacts of climate change we need to consider the range of probabilities and take a risk based approach to our planning (in particular looking for solutions that are robust and cost effective over a wide range of conditions). Figure H4 gives an indication of the range of possibilities for future temperature, summer rainfall (June, July and August) and winter rainfall (December, January and February).

Figure H.4 **Change in a.) annual mean temperature (ºC), b.) summer precipitation (per cent) and c.) winter precipitation (per cent) in the 2050s for the Thames River Basin District plotted as cumulative distribution functions for the low, medium and high emissions scenarios. Results from UKCP09.**

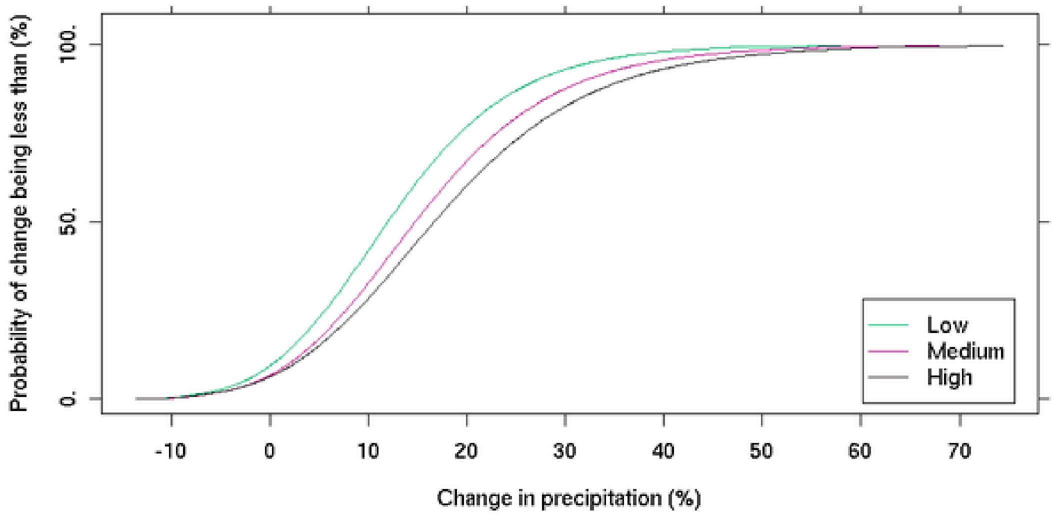
a.



b.



c.



H.4 The impact of climate change on the identified pressures and the ability of measures to perform under future climate conditions

Introduction

We all want to make sure that this River Basin Management Plan brings benefits now and into the future. We do not want the actions that are implemented, and the benefits they deliver in terms of Water Framework Directive objectives, to be undermined by changing climatic conditions.

This section looks at the likely consequences of climate change on the pressures that are being considered in the Thames River Basin District under the Water Framework Directive and then considers if the proposed actions will continue to perform under future climatic conditions.

Firstly, we include here an assessment of the potential impacts of climate change on the individual pressures. These are:

- Abstraction and other artificial flow pressures
- Biological pressures (fisheries management and invasive non-native species)
- Microbiological pressures (including faecal indicator organisms)
- Organic pollution (sanitary determinand) pressure
- Nutrients pressure (nitrogen and phosphate)
- Priority hazardous substance, priority substance and specific pollutant pressure
- Hazardous substances pressure
- Acidification pressure
- Salinity pressure
- Temperature pressure
- Physical modification pressure
- Sediment pressure

The assessments are only qualitative at this stage and give no indication of the severity and timescale over which changes may occur. UKCP has advised the Environment Agency that the new UKCP09 climate projections will not change the generalities of previous pressure trend analyses based on UKCP02. Although only qualitative, this assessment of pressures

will help us all prioritise both improving certainty in our risk assessments and our adaptation work. Whilst it is clear that human induced climate change is occurring, predicting the exact impacts on the water environment is difficult. There are a number of levels of uncertainty over, for example, what level of climate change to expect and over the combinations of processes controlling behaviour in water bodies. As we all continue to understand more about these uncertainties we will be able to improve these assessments and develop appropriate responses in future river basin management planning cycles.

Secondly, for each of the individual pressures, we include a summary of how the current or proposed actions are likely to be able to deal with the changes to the pressures due to climate change (that is, how well this River Basin Management Plan is adapted to climate change). The Environment Agency has carried out a systematic screening (or 'climate check') for most of the actions which make a contribution to achieving Water Framework Directive objectives to determine if and how they are likely to perform under future climate conditions – or where we need further adaptation, to seek alternatives or to develop additional actions. This screening has assessed both the 'mechanisms' in annex F and the 'actions' in annex C. This has been repeated since the draft River Basin Management Plan on the revised annex F and C with the new UKCP09 projections.

This screening is to help ensure any increased risk due to climate change does not compromise the benefit of the actions in terms of achieving Water Framework Directive objectives. In doing this we have tried to take a view on the lifespan and permanency of actions.

Because of the uncertainties concerning the impacts of climate change on the water environment we all need to, where possible, choose actions that can cope with a range of future climate conditions. There are a number of viable cost-effective adaptation approaches that we can apply. Applying these approaches will minimise risks associated with implementing actions whose cost-effectiveness at achieving Water Framework Directive objectives could be compromised by climate change even in the face of high uncertainties.

These adaptation options are normally referred to as win-win, no-regrets, low-regrets, and flexible/adaptive management. Actions may include more than one of these approaches. In addition the Environment Agency screening tried to make sure that we are not proposing any unfavourable or regrets options where the action is identified as unlikely to perform under future climate nor be able to be enhanced or modified to deal with future climate change. The way in which actions are likely to cope with climate change are described using the following descriptions:

- **Win-win options**– cost-effective adaptation actions that have the desired result in terms of minimising the climate risks or exploiting potential opportunities but also have other social, environmental or economic benefits. Within the climate change context, win-win options are often associated with those actions or activities that address climate impacts but which also contribute to climate change mitigation or meet other social and environmental objectives. For example, encouraging efficient use of water, and particularly hot water, in the home is a win-win option, reducing demand on water resources and also mitigating climate change by reducing carbon emissions from water heating.

- **No-regrets option** – cost-effective adaptation actions that are worthwhile (that is they bring net socio-economic benefits) whatever the extent of future climate change. These types of actions include those justified (cost-effective) under current climate conditions (including those addressing its variability and extremes) and are further justified when their introduction is consistent with addressing risks associated with projected climate

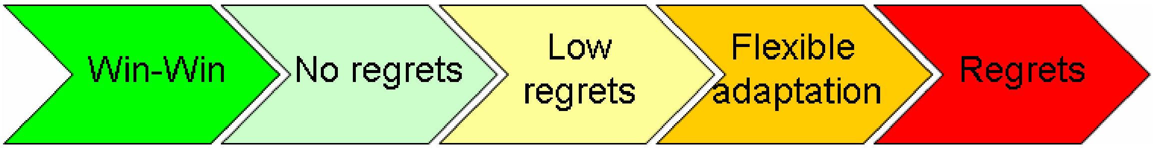
changes. For example promoting good practice in soil management to limit the risks of diffuse pollution is a no regrets option. This is a low risk option.

- **Low-regrets (or limited regrets) option** – adaptive actions where the associated costs are relatively low and where the benefits, although mainly met under projected future climate change, may be relatively large. For example allowing for climate change in assessing headroom in water company plans for managing water resources could be a low regrets option.

- **Flexible adaptation option**– these are actions which are designed to include a capacity to be modified at a future date as climate changes. Influencing the design of a reservoir so its capacity can be increased at a future date if necessary would be an example of flexible adaptation.

- **Regrets -** these are unfavourable options where the action is identified as unlikely to perform under future climate conditions and where it is likely that the action cannot be enhanced or modified to deal with future climate change. It should be noted that this term has been adopted for the purpose of this document and, unlike the other terms, is not commonly used.

Figure H.5 **Adaptation options**



The majority of the actions proposed within this River Basin Management Plan are identified as no regrets approaches. These are actions that are proposed and justified in the river basin management planning process due to current pressures. They will also bring benefits under future climatic conditions, and should, therefore, rightly be a favoured option. In several cases the actions proposed are highlighted as flexible adaptation – this means that as the climate changes the action can be adapted to cope with these changes. In terms of looking at future cycles of the river basin management process it is recommended that these actions in particular are revisited to assess whether adjustment is needed to cope with new climatic conditions. Few actions were identified as regrets actions. However one area of potential regrets is in the citing and performance of infrastructure within floodplains. Under climate change the frequency and severity of flooding is likely to increase, and it is important that any infrastructure (for example waste water treatment) is located or designed to provide business continuity with this in mind.

An example of our screening of actions is displayed below in Figure H.6 for abstraction and other flow pressures. In the following section we give a summary of the results of the screening, presented for the pressures the proposed actions are acting to address. In section H.6, where applicable we also give a summary of actions we are carrying out to address climate change in relation to some of these pressures.

Figure H.6 - **Summary of ability of actions to perform under future climate for abstraction and other artificial flow** (an example of the screening is only displayed for this pressure)

Name of action	Mechanism	How is action able to cope with climate change?
Preventing damage to the environment from new development, which helps to achieve good status for surface and groundwater and reduce the effects of flooding.	The Environmental Impact Assessment Directive (85/337/EEC) Town and Country Planning (Environmental Impact Assessment) Regulations 1999 (SI 1999 No. 293) Environmental Impact Assessment (Land Drainage Improvement Works) Regulations 1999	Regrets – potentially development may add to risks of flooding and drought under climate change if not adequately adapted. Currently there is low confidence that all new developments will be properly adapted to future climate. No regrets options (for example sustainable drainage systems or high levels of water efficiency should be sought.
Prevent unauthorised abstraction.	Abstraction of water prohibited without a licence with certain exemptions[1] under Water Resources Act 1991 s24.	No regrets – preventing unauthorised abstraction helps us manage water resources now and under future climate.
Managing abstraction such that it is sustainable, efficient and within environmental limits.	Conditional licences for water abstraction and conditional licences for impoundment under Water Resources Act 1991, Chapter II of Part II (as amended by Water Act 2003) Time limited abstraction licences	No regrets – managing abstraction improves our ability to manage water resources now and under future climate. Flexible adaptation – a flexible licensing system means that abstraction can be modified as necessary as the climate changes through review of licenses.
Reduce unacceptable abstraction impact.	Amend or revoke abstraction licences often requiring compensation.	No regrets – reducing abstraction improves our ability to manage water resources now and under future climate. Flexible adaptation – a flexible licensing system means that abstraction can be modified as necessary as the climate changes through review of licences.
Reduce unacceptable abstraction impact through operational arrangements for example for river support schemes.	Agreements under Water Resources Act 1991 s20, 20A and 158.	No regrets – reducing abstraction improves our ability to manage water resources now and under future climate. Flexible adaptation – operational arrangements can be amended further as necessary as the climate changes.
Tighten controls in times of drought.	Drought orders and permits under Water Resources Act 1991, Chapter III of Part II.	No regrets – controls help us manage droughts now and under future climate Low regrets – action may also be needed to highlight increased risk of drought under climate change (and the higher natural probability of drought than that which we currently plan for) and prepare abstractors.
Mitigation work.	Direct action to maintain, improve/ increase flows. Will depend on natural flow conditions.	Flexible adaptation – approach may not be able to withstand future climatic conditions and will therefore need to be reviewed from time to

Name of action	Mechanism	How is action able to cope with climate change?
		time. Issues of sustainability and carbon emissions relating to water transfers will need to be taken into account. (could be 'Regrets' if not adjusted to future climate).
Demand management actions.	Voluntary agreements, permits, economic incentives (water pricing) water-saving campaigns etc.	Win-win – demand management improves our ability to manage water resources now and under future climate and reduces the carbon footprint of water use. Low regrets – climate change as a driver of the need for demand management should be brought into water-saving campaigns now.
Preservation, maintenance and re-establishment of biotopes and habitats for wild birds.	The Council Directive on the conservation of wild birds (Birds Directive (79/409/EC). Direct action by Natural England or service of management notices or implementation of management agreements under Wildlife and Countryside Act 1981. In some coastal sites, this may be directed by Coastal Habitat Management Plans	No regrets – protection of habitats now likely to give greater robustness to climate change. See for example conserving biodiversity in a changing climate guidance for practitioners[9]
Restricted operations within the Special Protected Areas	The Council Directive on the conservation of wild birds (Birds Directive (79/409/EC). This may be directed by Coastal Habitat Management Plans in some coastal sites.	No regrets – protection of habitats now likely to give greater robustness to climate change.
Designation of Special Protected Areas.	The Council Directive on the conservation of wild birds (Birds Directive (79/409/EC). Conservation (Natural Habitats &c.) Regulations 1994.	No regrets – protection of habitats now likely to give greater robustness to climate change.
On land designated as a Special Area of Conservation or Special Protection Areas designated under the Wild Birds Directive you must comply with requirements to take appropriate steps to avoid deterioration or disturbance of species and habitats and to assess plans and projects likely to have a significant effect on the Special Area of Conservation.	European Community Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora 'Habitats Directive'. Conservation (Natural Habitats &c.) Regulations 1994 – Regulation 3(3) & 3(4) and Regulations 48 & 50.	Variable – dependent on pressure on Special Protected Areas or Special Areas of Conservation. Where pressures from abstraction or diffuse pollution may be high. No regrets and low regrets actions should be sought.

[9] Conserving biodiversity in a changing climate: guidance on building capacity to adapt, Published by Defra on behalf of the UK Biodiversity Partnership, DEFRA 2007

Name of action	Mechanism	How is action able to cope with climate change?
General duties for protecting, managing the quality and sufficiency of supplies and promotion of water efficiency	Section 6(2) Environment Act 1995	Win-Win – demand management improves our ability to manage water resources now and under future climate and reduces the carbon footprint of water supply R- Potential carbon increases from some measures (particularly water quality related infrastructure)
Provisions to encourage water conservation, through installation of water efficient appliances	Water Industry Act 1991	Win-Win – demand management improves our ability to manage water resources now and under future climate and reduces the carbon footprint of water supply
Standards for water efficiency	Government code for sustainable homes. Initiated through Development Plans etc	Win-Win – demand management improves our ability to manage water resources now and under future climate and reduces the carbon footprint of water supply Flexible Adaptation – standards may need to be tightened as climate change progresses (potential for R if standards insufficient in large portion of housing stock).
Review and improve environmental flow indicators (EFI)	Catchment abstraction management strategies	No regrets – Abstraction can be reduced further as necessary with climate change through review of EFIs
Improve flow estimates for surface water bodies	Catchment abstraction management strategies	No regrets – Action should help us manage water resource pressures now and in the future
Programme of investigation of ecological impacts of managed flows in Heavily Modified Water Bodies with water supply use	Catchment abstraction management strategies	No regrets – Action should help us manage water resource pressures now and in the future
Extension of abstraction control to include previously exempt uses.	Water Resources Act 1991	No regrets – Control helps us manage water resource pressures now and in the future
Registration for previously exempt activity: 'water meadows'	Water Resources Act 1991	No regrets – Control helps us manage water resource pressures now and in the future

As well as the consideration of adaptation for individual pressures we all need to consider how pressures link together. We also need to factor in other changes that will change the risk from the pressures such as population change and housing development into risk assessments. For instance Governments in England and Wales are still committed to increase house building to meet demand through new growth points and eco-towns. The greatest demand is often in areas that are already water stressed. It is projected that some of these areas, such as the South-East of England, are likely to experience significant reductions in summer rainfall increasing the risk that water stress will increase. In England the Government's water strategy for England 'Future Water[10]' and in Wales the Environment Strategy for Wales[11] identifies water demand and water supply actions and approaches to reduce potential climate effects to reduce this risk. Water companies are expected to

[10] Future Water- The Governments Water Strategy for England. DEFRA. HM Government Feb 2008
[11] Environment Strategy for Wales. Welsh Assembly Government. 2006

incorporate estimations of increased demand from new development within their water resources planning, and this feeds into this River Basin Management Plan (see Annex J).

Partnership working and better integration of different aspects of water management will increase our chances of successfully adapting to climate change. In particular flood risk management, urban planning, and water resource management will need to integrate better with river basin management planning.

Abstraction and other artificial flow pressures

Climate change impact on abstraction and other artificial flow pressures

Water is abstracted from groundwater and surface waters for a variety of purposes such as drinking water, irrigation and industrial uses. This should be managed in a sustainable way so that other uses and the environment are not compromised.

Demand for water is likely to increase for domestic, leisure industry, agricultural and industrial uses as a result of rising temperatures. Studies such as Climate Change and the Demand for Water[12] suggest that agricultural irrigation use, for example, will increase by around 20 per cent by the 2020s and around 30 per cent by the 2050s. Demand in tourist areas may increase as tourism increases due to more predictable warmer and longer summers. There is also likely to be a need for increased abstraction for cooling waters as industrial processes operate at higher ambient air temperatures and as the temperature of abstracted cooling water itself increases at certain times of the year. The proposed house-building programme will also put further pressures on current water resources, particularly in areas which are already water stressed. Water resources are likely to decrease at the same time due to higher temperatures, reduced and changing rainfall and, increased saltwater intrusion into drinking water supplies. Studies have assessed flow change across a wide range of catchments, under different climate model projections[13]. By the 2020s flows in winter could increase by between four and nine per cent and summer flows will decrease on average by 11 per cent but this could range from one to 32 per cent depending on the catchment location, land use, soils, geology and model uncertainty. A number of organisations, including the Environment Agency, plan to carry out further research to understand, and integrate in water resource planning, the likely impacts of climate change on river flows following the publication of UK Climate Projections (previously named UK Climate Impact Programme 2008).

Household water use in the Thames Region is particularly high compared with other parts of the UK with water companies in this region reporting figures ranging from 157-175 litres per head per day in 2008. By 2020 public water supply could rise by 3 per cent in the Region if no action is taken. This could mean an extra 116 million litres of water will be need every day.[14]

Reduced available water resources to maintain compensation flows and overall reduction in flows at certain times of the year may reduce the opportunities for fish migration within systems and particularly around or across barriers such as weirs. This will be in relation to protected area objectives, status, no deterioration and groundwater level objectives

[12] Downing, T.E., Butterfield, R.E., Edmonds, B., Knox, J.W., Moss, S., Piper, B.S. and Weatherhead, E.K. (and the CCDeW project team) (2003). Climate Change and the Demand for Water, Research Report, Stockholm Environment Institute Oxford Office, Oxford.
[13] Romanowicz *et al*., 2007
[14] Draft Water Resources Management Plan- Baseline Distribution Input

The recent Environment Agency study examining how potential changes in rainfall could affect average river flows demonstrates a 5 per cent increase to 5 per cent decrease in flows during the summer months and a 10-30per cent decrease during the winter months by 2050.

Relative severity of impact of climate change on abstraction and other artificial flow pressures **Very high**

Ability of actions for abstraction and other flow pressure to perform under climate change

The Environment Agency and other bodies already do a lot to plan for climate change in managing water resources. For example, water companies are considering the impact of climate change on supply-demand balance, make estimates of their carbon footprint and use the shadow cost of carbon in their comparison of options. The Environment Agency has a role to ensure that all water companies make these assessments. The system for licensing water resources is now flexible and includes time limited licences, meaning that as climate changes adjustments can be made to ensure continued protection of the environment. A further example is the Environment Agency's developing water resources strategy which looks to 2050. Several modules of this strategy are considering how climate change will impact on available water resources and how our management of them might adjust to cope with future pressures.

Within the screening of actions identified in this River Basin Management Plan it is clear that existing and proposed actions are likely to need to change to make sure they deliver Water Framework Directive objectives with changing climatic conditions for this pressure. It is considered that all the actions, related to managing abstraction and flow pressures, help us tackle these pressures now and in a future climate (see Figure H.6). The Environment Agency cannot identify any current or proposed actions in the programme of actions where it would be a significant mistake in terms of managing the pressure now or under a future climate to continue to apply or introduce these actions (this assessment does not consider in detail the impact on carbon emissions. This should be considered in economic assessments of the actions. Also the effects of actions to reduce abstraction pressures on climate change (that is impact on carbon emissions) are presented in the strategic environmental assessment reports which accompany the draft and this River Basin Management Plan).

Furthermore most of these actions can be adapted in the future so that they will be capable of managing any increased risk from climate change. For example, abstraction licences can be modified in relation to volume and abstraction period to adjust to seasonal water availability. Flows in rivers can be augmented by changing management procedures. This depends on individual rivers as their natural flow patterns vary. Flexible adaptation will require a good understanding of how changing conditions increase or decrease the risk that the pressures will prevent us achieving Water Framework Directive objectives. The possibility of the option to adapt the action is purely a technical possibility. Future socio-economic considerations may change this view. For example land take costs could increase such that adaptation of a particular action that involves land take is no longer the cost-effective approach.

Some of the actions have risks in terms of successful application unless we change policies and operational relationships/ requirements. For instance, abstractors will need to be prepared for a higher probability for the application of drought orders or permits under the Water Resources Act 1991.

Certain actions represent a win-win. For instance, demand management actions will improve our ability to manage water resources now and in the future as well as reduce the carbon

footprint from water supply and treatment (see Strategic Environmental Assessment reports which accompany the draft and this River Basin Management Plan).

It is clear, however, that further actions will be required in areas of proposed housing development, particularly in areas which are already water-stressed and where climate change is projected to have greatest impact on water resources (e.g. in the South-East).

Biological pressures (Fisheries management and invasive non-native species)

Climate change impact on biological pressures

Fisheries management can represent a risk in terms of direct fish/shellfish removal, impact of competition/predation from managed fisheries on native biology, impact of supplied feeds on nutrient conditions and impacts of removing migratory fish.

Climate change could result in increased disease levels in managed fisheries which could spread to native plant and animal life. There could be an increased consequence of nutrient impacts from supplied food. Changing water temperatures may bring about changes to stocked species. Reduced flows may increase stocking pressures on native fish. Longer term temperature increases may mean that certain water courses may not be able to support the species for which they are required to achieve a designated water quality standard. In these cases we will take the view, in line with the requirements of the Water Framework Directive that the lack of particular indicator species is no reason to let the quality of the water course deteriorate.

Relative severity of impact of climate change on fisheries management pressure	**Low/Medium**

Invasive non-native species can be introduced intentionally or non-intentionally as a result of their use as ornamentals, ‘hitch-hiking’ on ornamentals, washout from ship ballast water and from farming and fishing practices. Species can spread rapidly as a result of these activities, water transfers and transfer between catchments caused by animals and people moving.

A recent study on the effects of climate change on the Thames river ecosystem concludes that warmer winters and milder springs will favour riverine birds and increase the recruitment of many coarse fish species.

However, warm, slow-flowing, shallower water would increase the incidence of fish diseases. This is because bacterial and viral infections of fish that currently have a higher temperature threshold (for disease expression or infection) may be able to establish and proliferate more readily. In addition, some exotic pathogens with high temperate thresholds (e.g. *Lactococcus garviae)* are more likely to establish, if introduced. Predicted increases in temperature, residence times and nutrient concentrations, together with decreases in water flow, will impact on all hosts directly, altering fish distribution, immuno-competence and susceptibility. These changing conditions would make southern UK rivers in general a less favourable habitat for some species of fish, such as the Atlantic salmon (*Salmo salar*). Accidental or deliberate, introductions of alien macrophytes and fish may change the range of species in the rivers. The study also notes that higher incidences of endocrine disruption, as well as other disruptive effects caused by pharmaceuticals, will be an increasing threat to fish populations in the future in regions like the Thame In some areas, it is possible that a concurrence of different pressures may give rise to the temporary loss of ecosystem services, such as providing acceptable quality water for humans and industry.

Climate change will alter the geographical location of the climatic conditions that define many UK habitats, with knock-on effects for the species they support. It is already having a significant impact upon the timing of the developmental cycles of species such as early emergence of certain plant and animal species in spring and early breeding of birds. This includes the survival, variety and extent of non-native species, increasing the risk of their becoming invasive. The range of invasive non-native species may have to be constantly updated as new species are introduced and become established as the climate changes. Further concepts about what constitutes a 'non-natural' species may have to change as our climate and underlying conditions change. Research such as the 'Modelling Natural Resource Responses to Climate Change' (MONARCH) programme, the Marine Biological Association led project 'Marine Biodiversity and Climate Change' and the Environment Agency led project 'Preparing for climate change impacts on freshwater ecosystems' (PRINCE) are helping to predict how the composition of plant and animal communities in the UK will change. Increasing air temperatures in a future climate may increase the survival and transport of invasive non-native species. Increasing water temperatures and lower flows may increase their survival, proliferation and spread. The variety and use of invasive non-native ornamental species could increase as more species survive in a future UK climate and as people use their gardens more in warmer summers particularly in terms of water features such as ponds.

The predicted increase in aquaculture across the UK coupled with increased storminess may increase the risk of release of invasive non-native species.

It has been suggested that invasive non-native aquatic macrophytes (for example *Crassula helmsii*) may spread more rapidly if winters become warmer and frost events are less frequent. Invasive non-native animals, such as bullfrogs, may also benefit from warmer weather, with possible serious implications for native amphibians. A large number of marine and estuarine species are already well established. Examples include cord grass, slipper limpet, wire weed and the Chinese mitten crab. New and established marine non native invasives are likely to increase rapidly in number and range as sea temperature increases. These invasives are already having significant impacts on coastal and estuarine native species and/or morphology.

Relative severity of impact of climate change on invasive non-native species pressure	**Medium**

Ability of actions for invasive non-native species pressure to perform under climate change

It is likely that existing and proposed actions for invasive non-native species will need to be adapted to make sure they meet Water Framework Directive objectives climatic conditions change. It is possible that new actions may be needed due to the increasing risk resulting from climate change. It is considered that all the actions, related to managing invasive non-native species help us tackle this pressure now and in a future climate. The Environment Agency cannot identify any current or proposed actions in the programme of actions where it would be a significant mistake in terms of managing invasive non-native species, now or under a future climate, to continue to apply or introduce these actions. This assessment does not consider the impact on carbon emissions which is considered elsewhere in the Strategic Environmental Assessment reports which accompany the draft and this River Basin Management Plan. In this respect they are 'no regrets' actions. For instance controls on importation and releases will continue to be an essential way to manage invasive non-native species.

Most of these actions can be adapted in the future so that they will be able (in a technical sense) to manage any increased risk from climate change (wider socio-economic considerations may change this view). For example, the range of species restricted for importation could be broadened. Flexible adaptation will require a good understanding of how changing conditions increase or decrease the risk of the pressures of not achieving Water Framework Directive objectives.

Some of the actions have risks in terms of successful application unless we change policies and operational relationships/ requirements. For instance in order to maintain biodiversity, which species we consider as 'invasive non-native species' will have to be updated as new species arrive and become established in the UK as the climate warms.

Microbiology (including faecal indicator organisms)

Climate change impact on microbiology pressure

Livestock farming, wastewater treatment and urban runoff (e.g. dog fouling) can all lead to microbial contamination of waterways.

The 2005 Thames Tideway study collected microbiological water quality data for the upper Thames tideway. The study established the following:

- evidence that background concentrations of microbiological indicator organisms exceed the World Health Organisation (WHO) recommended levels for recreational use at Kew Barnes and Putney.
- that water quality improves as you move downstream from Kew to Barnes and Putney.
- using the WHO guidelines, less than 1 per cent of days when samples were taken from the Thames' tideway were acceptable by the WHO guideline standard. i.e. the limit below which there would be no observable adverse effect on human health (NOAEL) i.e. of ≤ 40 colony forming units (cfu) enterococci /100 ml.of water.
- ninety-one percent of sampling occasions resulted in *Escherichia coli* (*E.coli*) counts, that would be viewed as 'poor water quality' in terms of EC Bathing Water quality (more than 1000 cfu/100ml level)[15].
- evidence of an elevated risk to the health of recreational users of the upper tideway for 2 - 4 days after CSO discharge events.
- there is evidence of frequent contamination with potential human pathogens including *Campylobacter* spp, *Salmonella* spp and Enteroviruses present in samples from at least one of the three sampling locations on 99 per cent of sampling occasions, (Kew 90 per cent, Barnes 90 per cent, Putney 86 per cent) and at all three locations on 65 per cent of sampling occasions.
- there is evidence to suggest that plugs of discharged waste-water moving with the ebb and flood of the tide remain relatively concentrated for as long up to 4 days.
- that samples collected up to 5 days after CSO discharge may still reflect raised levels of indicator organisms depending on the location of the last discharged plug of waste-water.

Climate change predictions suggest that there is likely to be increased contamination from farmland and urban runoff due to compacted soils and/or less frequent but intense summer rainfall events. These events may also cause an increased frequency of combined sewer overflows overflow and sewage treatment plant flooding. These events can kill fish and other water life, and threaten human health. Although there may be an increase in the number of

[15] E. coli is an indicator of faecal contamination of human and /or animal origin

events that lead to high levels of microbial pathogens in water bodies increased water temperature and ultra-violet light exposure may improve the survivorship of bacterial pathogens.

Relative severity of impact of climate change on microbiology pressure	Medium

Ability of actions for microbiology pressure to perform under climate change

It is likely that existing and proposed actions for this pressure will need to be adapted to make sure they meet Water Framework Directive objectives with changing climatic change. It is possible that new actions may be needed due to the increasing risk resulting from climate change, particularly from the increased risk from diffuse sources. Most of the actions, related to managing microbiological pressures, help us tackle these pressures now and in a future climate. For instance effluent treatment at sewage works will continue to be an essential way to manage this pressure. However, the Pitt review and Environment Agency reviews of the summer 2007 floods identified that a lot of water sector critical infrastructure is in the floodplain. Investing considerable funds in ‘climate vulnerable’ sewerage treatment and water treatment plants could represent a significant risk to not achieving Water Framework Directive objectives. Therefore although most actions are ‘no regrets’ actions there are some possible ‘regrets’ actions.

Most of these actions can be adapted in the future so that they will be capable (in a technical sense) to manage any increased risk from climate change (wider socio-economic considerations may change this view). For example there is the possibility of improving effluent treatment at sewage treatment works, changing standards and fitting improved storm tank capacity. However this will only be possible where there is capacity or space to do this. Therefore any investment in new works or managing current sites should allow for the opportunity for flexible adaptation. Unless this is done this is a case of possible ‘regret’. This will have to be bought to any operator’s attention. It is recommended that water companies use the guidance provided by Water UK ‘A Climate Change Adaptation Approach for Asset Management Planning’. Flexible adaptation will require a good understanding of how changing conditions increase or decrease the risk of the pressures of not achieving Water Framework Directive objectives.

Organic (sanitary determinand) pressure

Climate change impact on organic (sanitary determinand) pressure

Organic pollution such as ammonia and substances resulting in high biological oxygen demand come from sources such as sewage and industrial effluent discharges, urban runoff and runoff from farmland and farm premises.

Nutrients released from agriculture or from sewage treatment works could be less diluted due to the reduced flows in summer. Whitehead et al. (2006, ‘Impacts of climate change on nitrogen in lowland chalk streams: adaptation strategies to minimise impacts’ Sci. Total Environ. 365, 260–273.) simulated these combined effects on the River Kennet in terms of projected nitrate and ammonia concentrations. Nitrate concentration were shown to increase over time as higher temperatures increased soil mineralisation. This is particularly significant under high flow conditions following a drought.

Whilst this was a theoretical modelling exercise, similar responses have been observed in the field. For example at the termination of the 1976 drought (Whitehead & Williams, 1982). Nitrate-N concentrations rose from 4 to 18 mg/L as nitrates were flushed from the Thames catchment. Increased frequency of flushing events is expected under some climate change

scenarios, and this extra nitrogen could enhance eutrophication in receiving water bodies. This may be more important for nutrient-poor upland rivers and lakes, and could be significant for estuary and coastal systems that ultimately receive the extra nutrients.

Climate change predictions suggest that there is likely to be increased contamination from organic pollutants from farmland and farm premises. This is due to washout during intense rainfall events from compacted soils and from urban environments at first-flush during intense rainfall events. It is possible that increased disease outbreaks amongst livestock as a consequence of climate change may lead to higher levels of organic pollution from high stock densities where movement and/or slaughter is restricted and where disease control culls are undertaken. The risk of this is not known at the moment. Intense rainfall events and increased flooding may also cause an increased frequency of combined sewer overflow. On the other hand the performance of sewage treatment works could increase under higher temperature reducing the biological oxygen demand burden. Ammonia concentrations in rivers will also potentially reduce due to greater nitrification.

Relative severity of impact of climate change on organic pressure	**Medium**

Ability of actions to for organic (sanitary determinand) pressures to perform under climate change

The approach to consenting of discharges to water courses, together with the Periodic Review system for the investments of water companies, allow us to adapt, to some degree, to climate change as it progresses. However it is particularly important that climate change is adequately factored into decisions for investments that will have a long lifetime to avoid regrets in the future.

For the organic pollutant pressure it is likely that existing and proposed actions will need to be adapted to make sure they meet Water Framework Directive objectives with changing climatic conditions for this pressure. It is possible that new actions may be needed due to the increasing risk resulting from climate change, in particular from the increased risk from diffuse sources. It is considered that most of the actions, related to managing organic pollution help us tackle these pressures now and in a future climate. For instance discharge licensing of point source discharges will continue to be an essential to manage this pressure. However, investing considerable funds in sewage treatment and water treatment plants built on floodplains could represent a significant risk to not achieving Water Framework Directive objectives as these will be vulnerable to flooding as a result of the consequences of climate change. Therefore although most actions are ‘no regrets’ actions there are some possible ‘regrets’ actions.

Most of the actions can be adapted in the future so that they will be capable (in a technical sense) to manage any increased risk from climate change. Wider socio-economic considerations may change this view. For example discharge consents can be modified in relation to biological oxygen demand. However, this will only be possible where there is capacity or space to do this within waste water treatment works. Carbon implications of tightening standards in this way would also need to be considered and options other than end-of-pipe (for example the phasing out of phosphate in detergents) may be preferable. The Environment Agency is currently assessing the carbon costs of wastewater management options, and will be looking to include some of the ‘quick wins’ from this work in the Periodic Review 2009. Therefore, any investment in new works or the management of current sites should allow for flexible adaptation. Unless this is done, this is a case of possible ‘regret’. This will have to be bought to operators attention. Flexible adaptation will require a good understanding of how changing conditions increase or decrease the risk of the pressures of not achieving Water Framework Directive objectives.

Some of the actions have risks in terms of successful application unless we change policies and operational relationships/ requirements. For instance, dischargers may require improved codes of practice to account for changing climatic conditions. The same is true for farmers in terms of slurry and soil management for instance.

Nutrients pressure (nitrogen and phosphate)

Climate change impact on nutrient pressure

Diffuse nutrients such as nitrogen and phosphate compounds can come from sources such as unsatisfactory combined sewer overflow, leakage from sewerage systems, urban runoff (for example animal and bird faeces) and runoff of fertilisers and animal sludge from agricultural land and premises.

The Environment Agency have recently been working with Reading University using the 'Integrated catchment' suite of water quality models (Integrated Nutrient in Catchment model) to assess the potential impacts of water quality on river systems in the UK. The models have been used to simulate flow, total and soluble phosphorus, nitrate (as N), ammonia, sediments, and ecology (macrophytes and epiphytes). Results show that a number of factors controlling nutrient concentration will be affected by climate change. Under all climate change scenarios water quality will be affected by changes in flow regime with lower minimum flows giving less volume for dilution and hence higher concentrations downstream of point discharges. Increased storm events, especially in summer, could give more frequent incidences of combined sewer overflows discharging highly polluted waters into receiving water bodies. The potential impacts on urban water quality will be largely driven by these changes in short duration rainfall intensity overwhelming drainage systems, as well as rising sea levels affecting combined sewage outfalls. For diffuse inputs there is likely to be increased contamination from organic pollutants from farmland and farm premises. This is due to washout during intense rainfall events particularly in winter.

Whitehead et al have developed the INCA model which attempts to simulate the many processes that affect nitrogen levels in river ecosystems, including daily temperature, soil moisture conditions, rainfall and flow. As temperature increases, microbial populations controlling Nitrate mineralisation and nitrification processes in soils will increase. This will raise the process rate co-efficient resulting in increased nitrate and ammonia exports. There is some evidence of this happening already in Tillingbourne a tributary of the Thames. Extending the model to simulate nitrate-nitrogen Whitehead et al (2006) show that the droughts trigger a release of nitrate from the soils and this nitrate would be exported into the river as a diffuse source. The model suggests that nitrate-nitrogen will increase to levels close to EU water drinking limits. The study concludes that these falling flow rates and rising nitrate levels could affect water supply but will also put in doubt plans to improve water quality and ecology of such a sensitive chalk stream as the Kennet.

A recent study on the possible effects of changing climate on the Thames River used the CLASSIC hydrological model, driven by output from the Hadley Centre climate model (HadCM3), based on IPCC low and high CO_2 emission scenarios for 2080 as the basis for the analysis. Compared to current conditions, the CLASSIC model predicted lower flows in the river, in all seasons except winter. Such an outcome would lead to longer residence times (by up to a month in the Thames), with nutrient, organic and biological contaminant concentrations elevated by 70–100 per cent pro-rata, assuming sewage treatment effectiveness remains unchanged. The study concludes that an increasing demand for water in southern England due to an expanding population, a possibly reduced flow due to climate change, together with the Water Framework Directive obligation to maintain water quality, will put extreme pressure on river ecosystems, such as the Thames.

Climate change predictions suggest that there is likely to be increased contamination from nutrients from farmland due to compacted soils and less frequent but intense rainfall events. These intense rainfall events are also likely to cause high-levels of 'first-flush' pollution from urban areas. Intense rainfall events and increased flooding may also cause an increased frequency of combined sewer overflows, overflow, sewage plant flooding, flooding of industrial and commercial premises and wash-in from silage pits. The seasonality of changes in nutrient inputs is likely to vary between rivers dependent on the balance between urban and rural inputs, but overall nutrient loads are expected to increase.

Prolonged growing seasons may result in increased use of fertilisers. However this should be compensated by increased uptake by plants. The impact of nutrients from eutrophication may be worsened due to enhanced algal growth as a result of increased sunlight and water temperatures. This may be offset to some extent by improved breakdown of nutrient compounds in sewage treatment works due to higher temperatures and increased functioning of microbes and increased denitrification within rivers.

Loss of baseflow during summer months could lead to a reduction in dilution of effluent from sewage treatment works increasing in-stream concentrations. This is a particular concern where a large proportion of streams are fed by groundwater from chalk aquifers. Lower flows, reduced velocities and, therefore, higher water residence times will increase the potential for algal blooms. Some blooms cause toxicity issues and/or water deoxygenation killing other native species.

For chalk streams further work, using a version of the Integrated Nutrient in Catchment-Nitrogen model modified to account for the transport of nitrate through the unsaturated zone of the underlying chalk rock, predicts that reducing fertiliser inputs today will have a short-term impact on in-stream nitrate concentrations but a clear long-term reduction will not occur until between 2060 and 2080. This is because of nitrate that has already accumulated in the chalk aquifer (Jackson et al, 2007[16]). Thus, some in-stream intervention, such as constructing water meadows, may be the best option to reduce in-stream nitrate concentrations within the timescale of the Water Framework Directive.

This is particularly in relation to bathing water and drinking water protected areas objectives. Decreasing quality of abstracted water will increase the risk of not achieving Article 7 objectives (avoid deterioration in their quality [water bodies] in order to reduce the level of purification treatment required in producing drinking water). There is already a rise in the need for groundwater blending and treatment to achieve drinking water standards for nitrate.

Relative severity of impact of climate change on nutrient pressure	**High**

Ability of actions for nutrient pressures to perform under climate change

Similar to organic pressures it is likely that existing and proposed actions for nutrient pressures will need to be adapted to make sure they meet Water Framework Directive objectives with changing climate. It is possible that new actions may be needed due to the increasing risk resulting from climate change, in particular from the increased risk from diffuse sources. It is considered that all the actions, related to managing nutrient pollution help us tackle these pressures now and in a future climate. The Environment Agency cannot identify any current or proposed actions in the Programme of Actions where it would be a significant mistake in terms of managing the pressure now or under a future climate to continue to apply or introduce these actions (this assessment does not consider in detail the

[16] Jackson B.M. et al. 2007. Ecological Modelling, vol. 209, 41-52

impact on carbon emissions). This should be considered in economic assessments of the actions. In this respect they are 'no regrets' actions. For instance discharge licensing of point source discharges will continue to be an essential way of continuing to manage this pressure.

Furthermore, most of these actions can be adapted in the future so that they will be capable (in a technical sense) to manage any increased risk from climate change. Wider socio-economic considerations may change this view. For example discharge consents can be modified in relation to the loads and concentrations of nutrients. However, this will only be possible where there is capacity or space to do this. Implications for greenhouse gases of tightening standards in this way would also need to be considered and options other than end-of-pipe (for example the phasing out of phosphate in detergents) may be preferable.

Some of the actions have risks in terms of successful application unless we change policies and operational relationships/ requirements. For instance, dischargers may require improved codes of practice to account for changing climatic conditions. The same is true for farmers in terms of fertiliser use, slurry management and soil management for instance.

Priority hazardous substances, priority substances and specific pollutants

Climate change impact on priority hazardous substance, priority substance and specific pollutant pressure

At the England and Wales scale the main source of priority hazardous substances, priority substances and specific pollutants is from the chemical, pharmaceutical and manufacturing sectors. They also come from sewage discharges, contaminated land runoff and urban runoff.

Any change in risk as a result of climate change will be substance/ groups of substance specific and depend on issues such as sources and uses. It is unlikely that climate change will significantly increase the risk from industrial point sources. It is also unlikely that the risk for substances such as Tributyl Tin will significantly change from either point or diffuse sources. However more frequent and intense rainfall events may cause significant first-flush spikes in some chemicals such as oils from urban and land runoff and inputs resulting from flooding of combined sewer overflows and industrial and commercial premises.

Available dilution may decrease as a result of reduced precipitation and reduced summer flows, again meaning chemical spikes occur which could exceed set limits. This could be the case for substances including pesticides and polycyclic aromatic hydrocarbons.

Cropping patterns may change as a result of climate change. This may influence the types of pesticides used and therefore the levels detected in water. For example, pesticides used on oil seed rape are now being found more frequently and at higher levels as the market for biofuel crops increases.

Relative severity of impact of climate change on priority substances pressure	**Low**

Ability of actions for priority hazardous substance, priority substance and specific pollutant pressures to perform under climate change

It is possible that existing and proposed actions for this pressure may need to be adapted for controls on certain substances to make sure they meet Water Framework Directive objectives with climate change. It is possible that new actions may be needed due to the increasing risk resulting from climate change, in particular to address the increased risk from

diffuse sources. It is considered that all the actions, related to managing priority substances help us tackle these pressures now and in a future climate. The Environment Agency cannot identify any current or proposed actions in the programme of actions where it would be a significant mistake to continue to apply or introduce these actions (this assessment does not consider in detail the impact on carbon emissions. This should be considered in economic assessments of the actions. Also the effects of actions to reduce hazardous substances pressures on climate change (that is impact on carbon emissions) are presented in the strategic environmental assessment reports which accompany the draft and this River Basin Management Plan). In this respect they are ‘no regrets’ actions. For instance, discharge licensing of point source discharges will continue to be an essential way to manage this pressure.

There are potential win-win actions. For instance better storage and handling of toxic substances in industrial and commercial premises reduce the risk of wash-in during high rainfall or flooding events while also potentially improving health and safety and/or resource use issues in relation to industrial raw materials and wastes.

Furthermore, most of these actions can be adapted in the future so that they will be able (in a technical sense) to manage any increased risk from climate change. For example, standards can be modified (wider socio-economic considerations may change this view so other more cost-effective actions may be needed). Flexible adaptation will require a good understanding of how changing conditions increase or decrease the risk of the pressures of not achieving Water Framework Directive objectives.

Some of the actions have risks in terms of successful application unless we change policies and operational relationships/ requirements. For instance, we may need to change codes of practice for the using and disposing of materials containing hazardous substances.

Acidification

Climate change impact on acidification pressure

Possible sources of acidification are emissions of sulphur and nitrous oxides from power stations and road transport and ammonia emissions from agriculture.

Reductions in sulphur emissions since the 1980s have lead to a decrease in acid deposition across the country, but some studies warned of future problems associated with increased N deposition and climate change (Wilby R.L., 1993[17]). Climate variables that could affect acidification include higher temperatures, increased summer drought, wetter winters, reduced snow pack, simultaneous changes in hydrological pathways, and more frequent sea-salt deposition events. Intense rainfall and wetter winter conditions favour acidic episodes (Wright R.F., 2007[18]).

Droughts can make acidification even worse by lowering water tables, creating aerobic conditions and enhancing the oxidation of sulphur to sulphate (Dillon P.K. et al, 1997[19]; Wilby R.L., 1994[20]). Acid anions are exported during subsequent storm events along with heavy metals (Tipping E. et al, 2003[21]).

[17] Wilby, R.L. 1993. The influence of variable weather patterns on river water quantity and quality regimes. International Journal of Climatology, **13**, 447-459.
[18] Wright R.F. 2007. Hydrology and Earth System Sciences Discussions, vol., 4, 2945-2973.
[19] Dillon P.K. et al. 1997. Environmental Monitoring and Assessment., vol 46, 105-111
[20] Wilby, R.L. 1994. Exceptional weather in the Midlands, UK during 1988-1990 results in the rapid acidification of an upland stream. Environmental Pollution, **86**, 15-19.
[21] Tipping E. et al. 2003. Environ. Pollution. Vol., 123, 239-253.

Seawater has been shown to be a significant sink for carbon absorbing 27-34 per cent of the CO_2 emitted into the atmosphere since the industrial revolution[22]. This has already had a significant impact on ocean chemistry, with estimates of mean surface ocean pH decrease of approximately 0.1 (equivalent to an approximately 30 per cent increase in hydrogen ion (H^+) concentration), from a value of approximately 8.18 around the time of the industrial revolution. This pH drop is significantly larger than the seasonal pH variability of 0.03 to 0.04 due to changes in temperature and photosynthesis. This is making seawater more acidic threatening marine life. By 2100, atmospheric CO_2 concentrations could reach more than 800 parts per million without any mitigation of emissions causing an additional surface water pH decrease of ~0.4 pH units.

Monitoring will be able to identify if this situation changes, and, if necessary, update the pressure in future river basin management planning cycles accordingly.

Relative severity of impact of climate change on acidification pressure	**Low for freshwater. Medium/High for marine waters**

Ability of actions for acidification pressure to perform under climate change

Actions, related to acidification help us tackle these pressures now and in a future climate. Furthermore, most of these actions can be adapted in the future so that they will be capable (in a technical sense) of managing any increased risk from climate change.

Salinity

Climate change impact on salinity pressure

The main sources of saline inputs to water courses included runoff of de-icing salts from roads and urban surfaces and industrial sources.

Freshwater surface water can become more saline as a result of incursion (high tide and surge impacts) and intrusion (inland migration of saline front) from marine waters. Likewise groundwater can be impacted by intrusion. Furthermore reduced rainfall in summer may reduce freshwater flows to estuaries increasing their salinity.

Climate change predictions suggest that there are likely to be higher peaks of salinity as a result of first-flush high rainfall events from roads and urban areas after extended dry periods. However, the use of de-icing salts is likely to decrease due to milder winters and fewer snowfall events. Industrial sources will probably not change significantly.

Increasing sea levels and storm surges are likely to cause increased saline intrusion into surface freshwaters, but more importantly into groundwater systems. Although some freshwater habitat may be lost, the most significant impact will be on groundwater resources.

Relative severity of impact of climate change on salinity pressure	**Medium**

[22] Turley, C, Findlay, HS, Mangi, S, Ridgwell, A and Schimdt, DN. (2009) CO2 and ocean acidification in Marine Climate Change Ecosystem Linkages Report Card 2009. (Eds. Baxter JM, Buckley PJ and Frost MT), Online science reviews, 25pp. www.mccip.org.uk/elr/acidification

Ability of actions for salinity pressure to perform under climate change

It is likely that existing and proposed actions will need to be adapted to make sure they meet Water Framework Directive objectives for this pressure as the climate changes. It is possible that new actions may be needed due to the increasing risk resulting from climate change. It is considered that all the actions, related to managing salinity pressure help us tackle this pressure now and in a future climate. The Environment Agency cannot identify any current or proposed actions in the programme of actions where it would be a significant mistake in terms of managing the pressure now or under a future climate to continue to apply or introduce these actions (this assessment does not consider in detail the impact on carbon emissions. This should be considered in economic assessments of the actions. Also the effects of actions to reduce abstraction pressures on climate change (that is impact on carbon emissions) are presented in the strategic environmental assessment reports which accompany the draft and this River Basin Management Plan). In this respect they are ‘no regrets’ actions. For instance discharge licensing will continue to be an essential way of continuing to manage this pressure.

Most of the actions can be adapted in the future so that they will be able (in a technical sense) to manage any increased risk from climate change. There may be exceptions. For instance environmental controls on new developments and infrastructure (for example roads) may not have adequate requirements for applying sustainable urban drainage systems and road runoff treatment and maintaining this treatment to cope with future conditions.

In the longer term, there is little we will be able to do to avoid sea level rise having an impact on coastal aquifers. In future cycles of river basin management planning it may be necessary, therefore, to redefine reference conditions. The implications of salinisation of coastal aquifers on increasing demands on alternative water resources will need to be considered.

Temperature

Climate change impact on direct temperature pressures

It should be noted that in this section ‘temperature pressure’ refers to the release of point source effluents which are of a higher temperature than the receiving water as opposed to the direct effects of climate change on water temperature. ‘Heated’ point source effluents can originate from power station and industrial cooling waters and sewage discharges. However it is believed that nature of higher temperature discharges will not change to a large extent as the result of climate change

Climate change will cause a rise in water temperatures regardless of these direct sources of higher temperature waters. The potential impact in areas that receive heated discharges may be increased due to the increased temperature of the receiving water resulting directly from climate change

Relative severity of impact of climate change on direct temperature pressures	**Low**

Ability of actions to perform under climate change for temperature pressure

Most, if not all, actions for this pressure can be adapted in the future so that they will be capable (in a technical sense) to manage any increased risk from climate change. This is mainly controlled through discharge licensing.

The most immediate reaction to climate change is expected to be in river and lake water temperatures. There is little we can do now to avoid at least some increase in temperatures. In future cycles of river basin management planning it may therefore be necessary to redefine reference conditions.

Physical modification

Climate change impact on physical modification pressure

Climate change could change patterns of development and the physical pressures this imposes on water bodies. For instance coastal areas may develop because of increased tourism due to warmer drier summers.

The increased chance of extreme events leading to flooding, rising sea levels and storm surges is likely to mean flood defences and surface water drainage will need upgrading. This could threaten achieving not only good status but also good potential in water bodies designated as heavily modified water bodies. However, all new flood defences would be required to satisfy Article 4.7 of the Water Framework Directive, which will ensure that the best environmental option is considered for the flood risks posed.

Alternative strategies to deal with high flows, described in documents such as Defra's 'Making space for water' and the Welsh Assembly Government Environment Strategy may reduce the need for hard engineered modifications whilst having additional benefits in terms of water management in catchments.

Reduced availability of water to maintain compensation flows and overall reduction in flows may result in fewer opportunities for fish migration within systems particularly around or across barriers such as weirs. This increases the significance of this pressure.

There is a possible increased risk from dredging as more marine aggregate material is required for flood defences to protect against increased flood risk as a result of climate change. However, currently most marine aggregate regions are well offshore from the closest coastal water body such that any changes in marine aggregate production may not affect Water Framework Directive compliance.

Relative severity of impact of climate change on physical modification pressure	**Medium**

Ability of actions to perform under climate change for physical modification pressure

It is likely that existing and proposed actions will need to be adapted to make sure they meet Water Framework Directive objectives with changing climatic conditions for this pressure. It is possible that new actions may be needed due to the increasing risk resulting from climate change. It is considered that all the actions, related to managing physical modifications help us tackle these pressures now and in a future climate. For instance codes of practice and impact assessment will continue to be an essential way to manage this pressure. However these actions may have negative impacts for other pressures (see section 5.5.) which are increased as a consequence of climate change. Therefore careful consideration is needed to assess if there are any potential negative consequences in relation to achieving Water Framework Directive objectives of implementing these actions.

Most of these actions can be adapted in the future so that they will be able (in a technical sense) to manage any increased risk from climate change (wider socio-economic considerations may change this view).

There are a number of possible situations where climate change represents a significant risk to any investment in actions (that is a ‘regrets’ situation). For instance investment in fish passes or lifts could be wasted and bring no benefits in relation to meeting Water Framework Directive objectives if reduced flows in a future climate prevent them from operating properly. Climate change effects would have to be factored into their effectiveness, design and operation.

Certain actions represent a win-win situation. For instance, ‘Green infrastructure’ (the managed interconnected network of open spaces and natural areas, such as greenways, wetlands, parks, woodland and native plant vegetation, that naturally manages stormwater, reduces flooding risk and improves water quality), river restoration and regeneration could reduce the impact of physical modification pressures whilst bringing about other significant benefits such as reducing the carbon footprint from ‘old infrastructure’ and improved quality of life in urban environments (see strategic environmental assessment reports which accompany the draft and this River Basin Management Plan). Similarly these actions could improve habitat conditions such that the biology is better able to cope and migrate with changing climatic conditions.

Sediments

Climate change impact on sediment pressure

Excessive levels of sediments in water bodies can result from runoff from agricultural and urban areas, sewage discharges and combined sewer outputs, industrial waste management procedures, construction and forestry activity.

Climate change predictions suggest that there is likely to be increased contamination from sediments from farmland and farm premises and from urban environments. This will be due to washout during intense rainfall events from compacted soils and from urban environments after first-flush releases during intense rainfall events. Changing crop types and seasonal patterns of agriculture and forestry may also change sediment runoff. Increased winter cropping is already having an effect on sediment runoff. Promotion of tree planting (for shading of rivers from UV and for carbon storage for instance) may have positive effects in reducing sediment runoff. Localised runoff from construction sites could also increase in intense rainfall events. There will also be changes in stream power during storm events and hence enhanced sediment loads due to channel erosion and enhanced resuspension. The Integrated Nutrient in Catchment model framework mentioned in the nutrients section above has been used to predict phosphorous and sediment movements and loads. In this model sediment release was described as a function of previous climate conditions and the rate of change of flow conditions. Climate change is likely to increase the rate of change of flow conditions and therefore sediment movement and loads. This will lead to higher sediment loads to lakes. Stream power between events may be reduced, causing higher rates of sediment deposition higher up the stream systems. Intense rainfall events and increased flooding may also increase the frequency of combined sewer overflow. The Defra soil strategy and the Welsh Assembly Government draft soil action plan are acting to help reduce this risk.

Relative severity of impact of climate change on sediment pressure	**High**

Ability of actions for sediment pressure to perform under climate change

Existing and proposed actions will need to be adapted for controls to make sure they meet Water Framework Directive objectives with changing climatic conditions for this pressure. It is possible that new actions may be needed due to the increasing risk resulting from climate change, in particular from the increased risk from diffuse sources. It is considered that all the actions, related to managing sediments help us tackle these pressures now and in a future climate. However the effectiveness of some actions may be compromised if climate change is not considered in their design and implementation. For instance any proposed sediment traps or sustainable urban development systems may need to be designed and operated to cope with increased sediment loads to prevent blocking and to maintain their effectiveness at achieving Water Framework Directive objectives. If this is not done this would represent a 'regrets' situation.

Furthermore, most of these actions can be adapted in the future so that they will be capable (in a technical sense) of managing any increased risk from climate change.

Sediment and soils store carbon. Managing soils and sediments better will ensure soil carbon is not released to the atmosphere increasing climate change. Also soil and the minerals and nutrients it contains are retained for agriculture. This represents a win-win situation (see Defra soil strategy).

H.5 Interaction of management action for pressures

Management action to address one pressure may increase the risk of not achieving Water Framework Directive objectives for another pressure. Climate change may increase this risk further. For example, removing weirs to remove obstacles to the movement of native flora and fauna may increase the risk of allowing the spread of invasive species where the suitable habitat of these invasives is broadened because of climate change.

Further, climate change adaptation action for one issue and/or in one location may in itself cause problems elsewhere. For instance managed retreat may reduce the risk from morphological pressures but increase the risk of saline intrusion, particularly where lower groundwater and surface water levels and flows are reduced as a consequence of climate change.

Because many of these risks are higher because of climate change the interaction of climate change and management action for different pressures need to be considered. There is unlikely to be an ideal set of actions. 'Trade-offs' between different management actions for different pressures and drivers need to be considered. This highlights the need for integrated catchment thinking when managing different pressures under the Water Framework Directive. This point was made by several consultees in the various Water Framework Directive consultations.

There will also have to be significant trade-offs in relation to particular outcomes in catchments such as those for conservation, agriculture and water supply. Trade-offs will also need to be considered in relation to adaptation actions and the outcomes these deliver. This is nothing new. These trade-offs have to be considered in sustainability appraisals. Political priorities, however, may affect the methodology that is used and decisions made. Transparency, in relation to appraisal methodologies and decision-making, are therefore important to ensure a consensus on the balance that is struck between competing outcomes and priorities.

H.6 Adaptation strategies

A number of organisations will play a part in delivering the objectives of the Water Framework Directive. This annex considers the implications of climate impacts on the effectiveness of the actions to deliver these objectives. It is important that everyone is involved in developing and implementing effective adaptation action for actions in order that we are all able to meet Water Framework Directive objectives.

Several organisations involved in the River Basin Management process are developing and acting on strategies for adapting their activities to address climate change. Generally these are targeted at a wide range of responsibilities including those under the 'umbrella' of the Water Framework Directive. Much of the activity will be to better understand risks and appropriate responses in the first instance. This work should rapidly develop into effective adaptation action to ensure we all meet Water Framework Directive objectives as planned. The Environment Agency would expect that organisations that have not taken on board planning for adaptation for areas of the Water Framework Directive for which they are responsible, should start to do this as part of river basin management planning and implementation of plans. The Environment Agency as competent authority for Water Framework Directive implementation will review if this is happening.

The Environment Agency, for example has developed an organisational climate change adaptation and mitigation strategy. The different parts of the Environment Agency are now developing action plans to enact this strategy and to embed adaptation into the environmental management of sectoral activities. These will be published at a later date but include the following:

- Identifying good practice in terms of adaptation and making sure this is communicated.
- Updating our risk information using new 2009 UK Climate Projections (previously named UK Climate Impact Programme 2008).
- Ensuring water companies consider the impact of climate change on the supply-demand balance.
- Developing a map of the impact of climate change on river flows across England and Wales and examining the impact of climate change on demand for water in the 2020s, 2030s and 2050s.
- Looking at the carbon cost of different water supply actions, including the carbon footprint of operating the water supply system.
- Looking at how people value water, and alternative ways of allocating resources that will help us respond to increasing water scarcity as a result of climate change.
- Progressing research to look at, for example, the use of probabilistic climate scenarios on water supply and ecology, changes in water quality and failures of water quality standards, discharges, effluent treatment and chemical processes; the spatial coherence of European droughts in the past and in the future and the impact of future droughts on water supply management.
- Considering how to take on board climate change in our 'Time limiting of abstraction licence' policy and improving water efficiency requirements in our abstraction licences.
- Improving the resilience of water supplies to climate change through involvement in the Water Saving Group.
- Ensuring climate change adaptation is embedded into fisheries practices and invasive species strategies.
- Looking for opportunities in joint working to manage and adapt for a range of pressures.
- Reflecting the long term costs of climate change in the way decisions are made to maintain or improve water quality. Make sure options are assessed by Net Present Cost, taking account of operating costs to perpetuity and, in this, the estimates that have been advised for the social costs of carbon.

As part of river basin management planning it will be important to co-ordinate activity on adaptation as part of the Water Framework Directive. Therefore the Environment Agency would like to hear of any developed or developing strategies, plans or activities which are occurring for adaptation across the Thames River Basin District, particularly where these have relevance to planning and implementing actions under the Water Framework Directive and/or achieving Water Framework Directive objectives. As identified in section H1 the Environment Agency and other UK representatives are working within the EC common implementation strategy to help deliver guidance and tools for how climate change should be considered in the steps of the River Basin Management process. This will help ensure we all take a consistent approach in the way we address climate change risks and adaptation across water management activities.

H.7 Adaptation in relation to underlying conditions and biology

Work is needed to understand how changes in underlying 'natural' environmental conditions and the impacts of man-made pressures as a consequence of climate change will impact on the biology in the water environment. This is needed to ensure we all implement the most cost-effective actions to meet Water Framework Directive objectives, particularly those for biology. Those organisations involved in the river basin management process that have direct responsibilities for managing the natural environment need to consider the consequences of climate change and the need for adaptation in the context of delivering biological outcomes. The Environment Agency, for instance, is starting to set out its adaptation action plan for ecology and conservation. This includes the following actions:

- Develop the 'landscape ecology approach' to identify and protect key habitats, open up new habitats and develop and maintain wildlife corridors. Reduce habitat fragmentation and protect and restore areas of floodplains and wetlands.
- Work with Natural England and Countryside Council for Wales on their review of protected area designation criteria and on managing changing conservation objectives for designated sites.
- Work with others to develop better understanding of climate space. Map current and future climate spaces and the vulnerability and impacts for priority species and environments. Develop robust case on the future ranges of key species and how reducing current risks and adaptation actions may affect their viability.
- Target action to build environmental resilience in relation to both existing and climate change pressures.
- Work with partners to identify those species and environments at greatest risk, prioritise policies and strategies for action and identify and make changes in management practices and policies that may help freshwater ecosystems and habitats to adapt to climate change.
- Ensure we all build environmental resilience and restore damaged habitats to ensure salmon and trout species are to remain in existing localities. We will also seek to protect the habitat conditions for glacial relict fish species such as Char and White Fish which have little opportunity to adjust or move from their rare and isolated lake habitats and are therefore at significant risk of local extinction.

Further the Environment Agency intend to commission research to understand if, and over what timescales, the variables on which the characteristics of water bodies are determined will change, how this could change such things as water body type or category and whether or how best to modify tools, analyses, and management as a consequence.

H.8 Summary

It is likely that the risk to not achieving Water Framework Directive objectives from a number of man-made pressures will increase as a result of climate change. The Thames is particularly vulnerable to the effects of climate change. It is already under pressure from abstraction for public supply. At times of drought approximately 80 per cent of the river flow is abstracted; climate change is likely to reduce summer flows so the need to manage abstraction will increase. Research shows that peak flood flows could increase by about 40 per cent by 2080; this could alter the current sediment regime and influence habitat and fish populations. Whilst extensive engineering solutions to flood risk are not envisaged any schemes will need to take account of the effect on ecological status.

Increases in temperature and the flow regime of the Thames will mean that the natural flora and fauna will change with time. As described in this Annex we will need to factor this into future revisions of the River Basin Management Plan. The provision of the new UKCP09 projections will facilitate this.

Therefore we will all be at more risk of failing Water Framework Directive objectives in the future unless we use adapted actions that continue to bring benefits (in terms of Water Framework Directive objectives) in a future climate. In our screening analysis of actions the Environment Agency consider that the vast majority of actions will help us tackle pressures now and in a future climate (there are few current or proposed actions in the programme of actions where it would be a significant mistake to continue to apply or introduce them). Most actions can be adapted as the climate changes. Therefore most represent a 'no regrets' and/or 'flexible adaptation' option. Any investment in new works or managing current sites should include adaptation or allow for the opportunity for flexible adaptation. Unless this is done this is a case of significant possible 'regret'. Of particular significance here is infrastructure where the effectiveness could be compromised by flooding.

We should all be looking for win-win type actions. It is clear that a number of these exist. It is also clear that actions for different pressures can be counterproductive particularly in a context of a changing climate. This highlights the need to think and plan in a more integrated and catchment based way.

The issues raised in this annex need to be progressed in terms of improving understanding and certainty through to management action. Organisations involved in River Basin Management are starting to identify positive action to do this. However this work must be accelerated if we are all to ensure delivery of Water Framework Directive objectives to the Water Framework Directive timescale.