February 2010

The draft climate change adaptation strategy for London

Public Consultation Draft

MAYOR OF LONDON

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Greater London Authority
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Contents

Mayor's foreword

Our climate is changing, with London already experiencing warmer, wetter winters, hotter, drier summers and higher incidences of more extreme weather. To preserve and enhance our quality of life and maintain our status as a leading global city, we must adapt to manage these climatic shifts, which will result in increasing risk of floods, drought and heat waves.

Climate change is no distant threat. A prolonged period of soaring temperatures in the summer of 2003 led to 600 fatalities in London alone. The recent heavy snowfalls – while not attributable to climate change – show the huge challenges that extreme weather can pose to the smooth running of our city, and the potentially life-threatening risks it presents, not least to the most vulnerable in society.

Not only do we have an environmental duty to prepare London for these changes, but there is also an incontrovertible financial imperative to take action. Put bluntly, by increasing the resilience of our city to the changing climate now, will save hard cash for everyone: businesses, organisations and individuals alike.

I firmly believe we can approach this task with optimism rather than gloomy defeatism. There are a myriad of ways detailed in this strategy, many of them supremely straightforward, to ensure that we collectively work to prepare for extreme weather while creating a more pleasant city to boot. For example, becoming a greener, leafier city is more aesthetically pleasing, adds to a sense of wellbeing and reinforces London's

position as one of the best big cities in the world. At the same time, urban green space reduces flood risk and cools the city in hot weather. Alongside the eco-creativity required to weather proof our city also comes considerable untapped employment opportunities.

Weather conditions are seen as something outside our control. But there are many things we can do as a city to prepare for, and minimise the impact of, extreme weather events. Householders can check if they are in a flood zone and sign up to a free warning service, or get a water butt to reduce run off and collect rainwater for outdoor uses. Developers can install green roofs and design buildings to stay cool in hotter summers. Government bodies, including City Hall, have a responsibility to make these changes as easy as possible.

There are also two sides to the climate change coin. As well as adapting to inevitable changes, we must also take robust steps to ensure London moves swiftly to take advantage of the new energy economy. We are launching a complementary strategy in tandem with this document, on how we tackle this unparalleled task of becoming more energy efficient in order to cut carbon emissions to increase London's energy security and save millions on energy bills. Even from a purely economic standpoint no-one could fail to appreciate the value of insulating their home when, for example, the hefty fuel bills from this recent winter hit the doormat. That is why we are working with London's borough councils to give at least 200,000 of London's homes the chance to become more energy and water efficient by 2012.

This draft strategy proposes a broad range of measures on how we believe London can manage the challenges extreme weather conditions will bring, but Londoners have a crucial role to play in developing an effective, workable response. This vital issue requires an unprecedented conversation between City Hall and Londoners. We are calling on people to tell us what their solutions are. To help galvanise a formidable act of people power, the best of these will inform the final version of this strategy.

I urge all Londoners and those with an interest in the city's prosperity and wellbeing to tell us what they think.

Boris Johnson
Mayor of London

Executive summary

Introduction

Some climate change is now inevitable and there is increasing evidence that it is already happening. Unless urgent, concerted global action is taken to reduce greenhouse gas emissions, further more dramatic changes may become unavoidable. This means preparing for changes to our climate is not an alternative strategy to reducing greenhouse gas emissions, but a parallel and complementary one.

This strategy takes a risk-based approach to understanding the climate impacts today, and how these are expected to change through the century. The strategy provides a framework to identify and prioritise the key climate risks and then to identify who is best placed to work individually or collaboratively to deliver actions to reduce or manage these risks.

Scientists project that in the future the southeast of England will experience warmer, wetter winters and hotter, drier summers. These changes will mean that London will face an increasing risk of floods, droughts and overheating (high temperatures). Without action to manage these risks, the impacts from the changing climate will increasingly affect the prosperity of the city and the quality of life for all Londoners, but especially the most vulnerable in society.

As this is the first adaptation strategy for London, many of the proposed actions aim to increase our understanding of the challenges we face, to ensure that we do not increase the risks in the future and that we have emergency plans for when extreme weather events occur. Successive reviews of the strategy will develop an ever more detailed plan of actions.

In parallel to the consultation on the content and actions proposed in this strategy (see consultation questions on page 20), the Mayor would also like to hear from Londoners on what actions that they can take to prepare individually, or as communities, for the impacts of climate change. To add your ideas, or comment on other people's ideas, visit the Greater London Authority (GLA) website at www.london.gov.uk/climatechange.

Flooding

Context

London is vulnerable to flooding from the North Sea (tidal flooding), the freshwater Thames and the tributaries to the Thames (fluvial flooding) and from heavy rainfall (surface water flooding). Flood risk in London is managed by a system of flood defences (walls, gates and the Thames Barrier) and drainage networks.

Probability - Currently, there is a **LOW** likelihood of tidal flooding, a **MEDIUM** probability of river flooding and **HIGH** probability of surface water flooding. The risk is **INCREASING** as sea levels rise, tidal surges increase in height and winter rainfall increases in volume and intensity. Increasing impermeability of the urban landscape (loss of front gardens, for example) and limited drainage capacity also increase the likelihood of flooding.

Consequence - The consequences of a major flood in London would be HIGH because London is heavily urbanised and 15 per cent of London lies on the floodplains of London's rivers, an area that includes 1.25 million people, 481,180 properties, and a substantial proportion of the capital's schools, transport network, and emergency services. More than 680,000 properties lie at risk of surface water flooding. The consequences of flooding are **INCREASING** as London's population is set to grow by approximately 800,000 people over the next two decades.

Vulnerability - **HIGH** as there are a large number of flood-vulnerable communities and assets at risk. Warning times for fluvial and surface water flooding are short and public awareness and capacity to act are low.

Summary assessment

Despite the very low probability of a catastrophic tidal flood in London, the impact of a tidal flood would be significant. River and/or surface water flooding are much more likely and are difficult to predict and manage. The Mayor assesses that flood risk should be considered a **HIGH RISK** to London

Response

The Mayor believes that London should be resilient to all but the most extreme floods and should have robust emergency plans to respond to, and recover quickly from, flooding.

To reduce and manage current and future flood risk in London, the Mayor will work with partners to:

a improve the understanding of flood risk in London and how climate change will alter the risks, to improve our ability to manage flood risk

b reduce flood risk to the most critical assets and vulnerable communities, to target the greatest effort on London's most vulnerable assets

c raise public awareness of flooding and individual and community capacity to cope and recover from a flood, to improve London's resilience to flood events.

There is a good understanding of current tidal and fluvial flood risk in London, but a poor understanding of surface water flood risk. To improve our ability to predict and manage flood risk, further work is required to understand surface water flood risk and how climate change will increase all forms of flood risk.

Action 1 - The Mayor will work with the Environment Agency, boroughs and other partners to improve the mapping of who and what is at risk from all sources of flooding today, and to predict future flood risk for all flood sources.

Action 2 - The Drain London Forum, led by the GLA, will develop a surface water management plan for London which identifies and prioritises areas at risk and develops more detailed plans for the priority areas.

Action 3 - The Drain London Forum will create an online data portal to allow flood risk management partners to more effectively share information and data analysis.

Action 4 - The Drain London Forum will create a flood incident reporting system that is adopted throughout London to improve our understanding of flood risk today.

Action 5 - The Mayor will work with boroughs and the Local Resilience Forums to ensure that flood risk management is integrated across borough boundaries and within borough teams.

In order to prioritise flood risk management actions that target the most important and the most needy, we need to identify the most vulnerable communities and critical assets.

Action 6 - The Mayor will work with the Environment Agency, London Resilience and the London Climate Change Partnership to identify and prioritise critical infrastructure and vulnerable communities at flood risk.

Action 7 - To reduce the risk of local surface water flooding, the Mayor will work with Transport for London (TfL), the London boroughs and Thames Water to review their drain and gully maintenance programmes, particularly in high-risk areas.

In order to increase our capacity to cope and recover from a flood, we will seek to raise individual and community-level awareness of flooding.

Action 8 - The Mayor will work with the Environment Agency to increase the number of Londoners signing up to the Floodline Warning Direct scheme and to raise awareness of the measures that individuals and communities can undertake to reduce the risks and manage the consequences of flooding.

Action 9 – The Mayor will work towards a more community-based approach to managing flood risk for communities at high flood risk. The Drain London Forum will identify two communities at significant flood risk and work with them to develop bespoke community flood plans to build their capacity to manage flood risk.

Drought

Probability - The probability of a drought is currently **LOW** as in most years there is sufficient water to meet demand, but this balance is only met by withdrawing more water from the environment than the environment can sustain. The probability of a drought is **INCREASING** as summer rainfall and groundwater recharge reduces and evaporation and public water demand increases.

Consequence - The consequence of a prolonged drought is **MEDIUM** as drought conditions would impose significant restrictions on Londoners and for an extreme drought, there are currently few effective management options. The consequences are **INCREASING** as London's population is set to grow by approximately 1.3 million people over the next two decades.

Vulnerability - The vulnerability is considered to be **MEDIUM** as there are a significant number of businesses that are affected by drought management measures and droughts affect London's green spaces and biodiversity – particularly wetlands and watercourses.

Summary assessment

The Mayor assesses that the risk of prolonged and damaging drought is **MEDIUM** but **INCREASING** as London is already vulnerable to drought and climate change and the increasing population will combine to magnify this risk.

Responses

The Mayor believes that London should achieve a sustainable supply and demand balance for water in London by 2030 and should be more robust to drought.

The Mayor will work with partners to improve the sustainability of London's water supply and demand balance and make London more robust to drought by:

- taking a strategic view on London's water resources
- reducing the demand for water in London
- improving our response to drought.

The Mayor believes that as London is supplied water by four different water companies and that the aim of the water regulator is to reduce bills through long-term sustainability measures, that the Mayor should take an independent view of London's water resource management.

Action 10 - The Mayor will publish and regularly review a London Water Strategy that presents a London-specific view of managing water resources, with the goal of improved water management – both the water we want (such as drinking water) and the water we don't (such as sewage and floodwater in the wrong place).

Action 11 - The London Water Group will undertake a study to define 'water neutrality' in London and explore how strategic scale, water-efficiency measures could make London more resilient to drought and long-term changes in water resources.

Action 12 - The Mayor will lobby the water utility regulator (OfWat) to encourage and enable the water companies to deliver greater household water efficiency savings and greater investment in London's water infrastructure.

London must reduce the amount of water it consumes, both to reduce the impact on the environment of our demands for water and to improve our resilience to drought. Action 13. The Mayor will work with the boroughs (through the Home Energy Efficiency Programme) to improve the energy and water efficiency of up to 1.2 million homes across London by 2015, and with businesses and the GLA estate managers to improve the energy and water efficiency of public and commercial buildings in London.

There are national and water company responses to drought, but there is no London-specific emergency drought plan.

Action 14 - The Mayor recommends that the London Resilience Partnership should review the need for a London-specific Drought Plan.

Overheating

Probability - Currently considered to be a **HIGH** probability today as we have experienced two heatwaves this decade. The probability is **INCREASING** as average summers get hotter and heatwaves increase in intensity and frequency. In addition, London's microclimate amplifies summer night-time temperatures, meaning that people cannot cool off and recover for the heat of the next day.

Consequence - The consequences of high temperatures are **HIGH**, as a large proportion of London's population are vulnerable to high temperatures and high temperatures increase water and energy demand in the capital, increasing the risk of blackouts and water shortages.

Vulnerability - The vulnerability of London to high temperatures is **HIGH**, as London has a large and increasing elderly population, and a high number of people living in poor quality and over-crowded homes. A significant proportion of London's development and infrastructure is not designed for hot weather.

Summary assessment

The Mayor believes that overheating is a **HIGH RISK** to London. London is already vulnerable to high temperatures and the urban heat island effect amplifies this in hot weather. Identifying and assisting vulnerable people is difficult to do and some of the responses to high temperatures (such as air-conditioning) will raise external temperatures in London.

Response

The Mayor's vision is to make London a more comfortable city to live, work and play in and to ensure that a robust emergency plan exists for heatwaves. The Mayor will seek to reduce and manage the impact of hot weather on Londoners by working with partners to:

- improve the understanding of overheating risk in London by identifying who and what is affected and where is most at risk
- manage rising temperatures in London by increasing the amount of green space and vegetation in the city
- reduce the risk of overheating and the need for mechanical cooling in new and existing development and infrastructure
- ensure London has a robust heatwave plan.

We currently have a poor understanding of how temperatures vary across London, how the city's microclimate will intensify the rising temperatures in the future and who and what is vulnerable to high temperatures. There is a need to improve the understanding of overheating risk and target priority areas.

Action 15 - The Mayor will work with partners to undertake a feasibility study into creating and maintaining a network of weather stations across London to improve our understanding of London's microclimate and the impact of urban greening measures on managing temperatures.

Action 16 - The Mayor will work with the Sustainable Cities: Options for Responding to Climate cHange Impacts and Outcomes (SCORCHIO) and The Development of a Local Urban Climate Model and its Application to the Intelligent Development of Cities (LUCID) projects to improve our understanding of how climate change will affect summer temperatures in the future and to identify and prioritise areas of overheating risk and risk management options.

We believe that by increasing green space and vegetation cover in the city we can manage and offset rising temperatures (and manage flood risk).

Action 17 - The Mayor will work with partners to enhance 1,000 ha of green space by 2012 to offset the urban heat island effect, manage flood risk and provide biodiversity corridors through the city.

Action 18 - The Mayor will work with partners to increase green cover in central London by five per cent by 2030 and a further five per cent by 2050, to manage temperatures in the hottest part of London.

Action 19 - The Mayor will work with partners to increase tree cover across London by five per cent (from 20 to 25 per cent) by 2025.

Action 20 - The Mayor will work with partners to enable the delivery of 100,000m2 of new green roofs by 2012 (from 2008/09 baseline).

There is a need to reduce the risk of overheating and the demand for mechanical cooling in new and existing development and infrastructure.

Action 21 - The Mayor and the Chartered Institution of Building Services Engineers will publish design guidance for architects and developers to reduce the risk of overheating, and encourage its use through the revised London Plan.

Action 22 - The Mayor has proposed a new 'cooling hierarchy' policy in the draft London Plan to require developers to reduce potential overheating and the need for mechanical cooling.

Action 23 - The London Development Agency (LDA) will work with the boroughs to map the opportunities for decentralised energy (power, heat and cooling) and engage business through a range of energy-efficiency programmes.

Action 24 - The London Climate Change Partnership will work with a social housing landlord to undertake a demonstration project to retrofit a social housing development to reduce risk of overheating using passive measures.

Action 25 - The Mayor will work with partners to assess and promote 'cool roof technology' (highly reflective, well-insulated roofs) in London to reduce demand for mechanical cooling.

We want to ensure that London has a robust heatwave plan and that Londoners know what to do during a heatwave to stay cool and save energy.

Action 26 - The Mayor recommends that the London Resilience Partnership should assess the benefits of having 'heatwave refuges' (publicly accessible cooled building) that can be used to provide temporary shelter during heatwaves.

Action 27 - The Mayor will review the lessons learned from developing the community flood plans (see Action 9) to determine how best to encourage and enable a community-level response to heatwaves.

Cross-cutting issues

The strategy also looks at the impacts of floods, droughts and heatwaves on the cross-cutting issues of health, environment, economy and infrastructure. The purpose of this analysis is to look at how climate change may affect a particular issue or sector, in some cases over the medium to long term. For some of these issues, the analysis of how climate change will impact upon them is at an early stage, and therefore further work is required to understand the challenges and relevant actions in more detail.

Action 28 - The London Climate Change Partnership will work with the London Regional Public Health Group to undertake a London-specific assessment of the impacts and opportunities of climate change on London's health services. The study will provide recommendations to the health sector on the priority risks and opportunities.

Action 29 - The Mayor will work with the Regional Public Health Group, NHS London and the London Primary Care Trusts to ensure that climate risks are addressed in their refurbishment programme and commissioning of health services.

Action 30 - The Mayor will work with the Environment Agency and other partners to restore 15 kms of London's rivers by 2015 through the London Rivers Action Plan.

Action 31 - The Mayor will engage with business organisations and other key stakeholders to consider how to raise awareness of the need to integrate climate risks and opportunities into their routine risk management and planning and whether there is further practical assistance that can be given to London's businesses, including its SMEs.

Action 32 - The Mayor will work with the insurance sector in calling for the government to amend building regulations to require buildings being rebuilt or renovated to be climate resilient.

Action 33 - TfL will undertake a climate risk assessment of their assets and operations and develop prioritised action plans for key climate risks.

Action 34 - The Mayor believes that London should have a resilient energy supply and will work with the Distribution Network Operator and the energy retailers to ensure that the distribution infrastructure is resilient to climate impacts and that energy suppliers can meet seasonal variations in demand.

Introduction

Some climate change is now inevitable and there is increasing evidence that it is already happening. With early, sustained and concerted global action to reduce our greenhouse gas (GHG) emissions we can limit the changes both to our climate, and to the natural systems that maintain our climate. Failure to significantly reduce our emissions may fundamentally alter the Earth's climate system and commit future generations to more dangerous changes.

We are already committed to some changes through the legacy of our past greenhouse gas emissions and how long they persist in the atmosphere. It will take time for actions we are currently taking to reduce emissions to have an effect. We therefore need to prepare for changes that are now inevitable and those that may happen. This process is called adaptation.

Climate change will mean that southeast England will experience progressively warmer, wetter winters, and hotter, drier summers. On top of these changes to our average climate will be an increase in the frequency and intensity of extreme weather events, such as heatwaves, tidal surges, storms and heavy rainfall. By the latter part of this century, an extreme weather event of a magnitude that might happen once every 100 years today, may occur every three or four years, and a new intensity will define the 'once in a 100 years' event. Sea levels will continue to rise for centuries.

The impacts of these changes on London will be to increase the risk of floods, droughts and uncomfortably hot weather. There will also be secondary and indirect impacts, including an increased risk of winter storm damage, ground instability and movement, and poor air quality periods in summer.

Climate change will therefore affect all Londoners and the quality of life in London will change both positively and negatively. On the positive side, rising temperatures may reduce winter deaths and warmer summers may benefit agriculture and tourism. However, many of the benefits of climate change will only be realised through proactive action. On balance the negative impacts are expected to exceed the benefits in London.

The GLA Act[1] charges the Mayor with a 'climate change duty', which requires him to assess the consequences of climate change for London and to prepare a Climate Change Adaptation Strategy for London that outlines how the Mayor will work with partners to manage the impacts on London. The Mayor must also prepare a Climate Change Mitigation and Energy Strategy to reduce GHG emissions in London. Under the Act, the Mayor must ensure that all GLA plans and strategies consider adapting to, and mitigating further, climate change. Appendix 2 provides a checklist of how this strategy fulfils the relevant statutory requirements from the GLA Acts and other government guidance.

Aim of the strategy

The aim of the London Climate Change Adaptation Strategy is to assess the consequences of climate change on London and to prepare for the impacts of climate change and extreme weather to protect and enhance the quality of life of Londoners.

The Mayor proposes that this aim will be met though achieving the following objectives:

1 to identify and prioritise the climate risks and opportunities facing London and understand how these will change through the century
2 to identify and prioritise the key actions required to prepare London, and to define where responsibility for delivering and facilitating these actions lies
3 to promote and facilitate new development and infrastructure that is located, designed and constructed for the climate it will experience over its design life
4 to improve the resilience of London's existing development and infrastructure to the impacts of climate change
5 to ensure that tried and tested emergency management plans exist for the key risks and that they are regularly reviewed
6 to encourage and help business, public sector organisations and other institutions prepare for the challenges and opportunities presented by climate change
7 to promote and facilitate the adaptation of the natural environment
8 to raise general awareness and understanding of climate change with Londoners and improve their capacity to respond to changing climate risks
9 to position London as an international leader in tackling climate change.

The strategy sits alongside other Mayoral and national strategies to prepare for climate risks and opportunities and to reduce greenhouse gas emissions, especially the London Climate Change Mitigation and Energy Strategy[2].

Scope of the strategy

The Climate Change Adaptation Strategy undertakes seven tasks:

1 It analyses how London is vulnerable to weather-related risks today (and so establishes a baseline to assess how these risks change).
2 It uses projections from climate models to identify how climate change accentuates existing risks and creates new risks, or opportunities in the future.
3 It prioritises the key climate risks and opportunities for London.
4 It provides a framework that:
   a identifies actions where the GLA is uniquely placed to act
   b identifies where other stakeholders need to act
   c facilitates action by highlighting where collaborative working will increase the efficiency and effectiveness of any action
   d identifies and prioritises where further work is required to understand the climate and its impacts before actions can be defined.
5 It establishes a strategic process by which London can put in place the measures necessary to adapt to future climate change.
6 It recommends how London should capitalise on the opportunities presented by climate change.

7 It demonstrates how London can become an international exemplar on adaptation.

The Mayor has only limited powers to implement the measures necessary to prepare London for the range of impacts and opportunities presented by climate change. Many of the actions needed are beyond the Mayor's direct control, but as they have strategic implications for London, this strategy calls on all relevant agencies to work together to help its delivery.

Structure of the strategy

The Draft Climate Change Adaptation Strategy is organised into four parts:

Considerations in preparing for a changing climate

Adaptation is a dynamic process. As the climate changes, so we must prepare for the risks and opportunities that will occur. Measures that address the impacts of our climate today may not provide an acceptable level of protection in the future, or enable us to make the most of the opportunities that arise, and so new measures will be needed. There is, therefore, no steady state of being 'adapted'. There is considerable evidence to suggest that we are not actually very well adapted to our current climate – as the impacts of extreme weather regularly highlight.

Part I - Context for adaptation in London	
Chapter 1	Understanding the climate of the future: a summary of the projected changes to the climate that London will face.
Chapter 2	Mapping adaptation: who is responsible for promoting and enabling adaptation and where are the critical gaps?
Part II - Understanding and managing the impacts	
Chapters 3-5	Covering the main impacts for London likely to result from the projected climate changes (flooding, drought and overheating). Each chapter starts with a vision and a number of key actions that cover issues raised in Chapters 6-9.
Part III - Analysing the impacts on cross-cutting issues	
Chapters 6-9	Summarising the cross-cutting issues of health, London's environment, London's economy (business and finance) and infrastructure (transport, energy and waste).
Part IV – Implementing the strategy	
Chapter 10	Providing a 'roadmap to resilience', with a summary of the key actions, and an action plan, including ways for the GLA Group to mainstream adaptation across its plans and strategies.

Adapting to climate change is not about drafting lots of new policies. It is about understanding how climate change may affect the world around us and then routinely integrating that understanding into our decision-making processes to make better decisions. Decisions about spatial planning, engineering and development, social justice, value for money and public safety will all be affected, positively or negatively, by climate change. Decisions with long-term implications will tend to be more affected by climate change, as their outcomes will experience more climate change. It is also essential that decisions taken today do not constrain adaptation options in the future. For this reason, the strategy considers the climate over the century, but particularly focuses on the period up to 2031.

'Climate' is a term used to describe the average weather and its variability over a long period of time (a minimum of thirty years is usually considered appropriate). There will therefore be years when summers are wetter, or winters are colder than the predicted trend. This does not mean that the climate change predictions are wrong, or that efforts to reduce emissions are working, but it underlines the complexity and natural variability of the climate. Adaptation actions must allow for this variability.

Climate change projections are only forecasts and therefore contain uncertainties. Because of the natural variability of the climate and the uncertainty inherent in forecasting the future, decision-makers must employ a risk-based approach. In order to assess risk, it is necessary to understand the components of risk. These are:

- the **probability** of an event (for example, a tidal surge) or change that exceeds our ability to cope with it and therefore has an impact
- the **consequence** of the event or change - who and what is affected and how severely affected they are. Consequence is in turn determined by **exposure** (for example, being located on the ground floor of a building in a flood zone), and **vulnerability** (for example, how sensitive those affected are to an impact, what ability they have to respond and how much time they have to react).

As our climate changes and the frequency and intensity of extreme events increases, it is important to understand the sensitivity to these changes. It is essential to determine the threshold above which a trend, or an extreme event has a significant effect. This sensitivity analysis should consider not just the extremes of the changes, but also the frequency, duration, and the joint probability of two or more variables. For example, a single extremely hot day may not present a risk to public health, but a week of sustained high temperatures might. An extreme event once every ten years may be manageable within an existing budget, but one every year may not.

In order to avoid unsustainable adaptation (known as 'mal-adaptation'), when considering possible adaptation options, the wider implications of the action should be assessed over the lifetime of the action. For example, air conditioning is not generally considered to be a sustainable adaptation action (because of the large energy demands), whereas developing flood resilient buildings on a floodplain may be sustainable. As the impacts may be felt across many sectors, the ways in which we adapt may also have to be multi-sectoral. As highlighted in the Stern Review[3], anticipatory adaptation is usually more effective and less costly than retrospective or emergency action.

This strategy uses the 'Prevent, Prepare, Respond, Recover' framework developed by emergency planners to categorise actions.

- *Prevent*: Actions taken to reduce the probability and/or consequences of an impact. For example, raising flood defences to prevent flooding, or removing flood sensitive development from the flood plain. The key preventative action is reducing greenhouse gas emissions to limit further climate change.
- *Prepare:* Actions taken to better understand the risks and opportunities ahead of the change occurring and to proactively enable an effective response and recovery. For example, undertaking a flood risk assessment, developing a contingency plan, insuring sensitive assets, and raising public awareness.
- *Respond:* Actions taken in response to an event to limit the impact of the event, for example, restricting non-essential water use during a drought, or providing emergency accommodation for people displaced by an extreme weather event.
- *Recover:* Actions taken after an event to enable a rapid and cost-effective return to normal, or a more sustainable state. For example, enhancing the flood resilience of a property when undertaking flood damage repairs, or providing counselling for flood-affected residents.

Determining where in the above framework of actions a decision-maker should prioritise efforts depends upon:

- the scale of the risk/opportunity (considering probability and consequence)
- the level of uncertainty around the prediction of the event, or degree of change
- the risk attitude of the decision maker (how risk averse he or she is)
- the lifetime of the outcome of the decision being made.

This strategy aims to provide the rationale for why the proposed actions are required and where they fit in the above framework. It should be noted that as this is the first such strategy for London, many of the proposed actions fall under the 'prepare' heading. As we build our understanding and capacity to deliver, subsequent versions of the strategy will seek to deliver more actions on the ground.

The Mayor and partners can take action to improve the resilience of London's buildings, services and infrastructure to climate risks. Londoners can also take action to improve the resilience of their homes and communities. The Mayor is very interested to hear what Londoners believe they could and would do to respond to the risks of floods, droughts and heatwaves. To capture peoples' ideas and stimulate debate, the Mayor has created a website to facilitate this discussion – http://www.london.gov.uk/climatechange/. Information gathered from this website will be used to inform the final strategy.

Review of the strategy

This strategy will be kept under review and any one of the following issues may trigger the update of the strategy:

- publication of new climate projections, or sea-level rise scenarios
- a significant climate-related impact on London
- the appointment of a new Mayor
- the requirement for the GLA to report to the Secretary of State on adaptation in London under the Adaptation Reporting Power[4] every five years.

Next steps

The publication of this draft starts a three-month period of consultation with the public and other stakeholders, during which the Mayor would like to receive your views about the issues raised in the strategy and particularly on the questions below.

1 Have we correctly identified the climate risks to London?
2 Does the draft strategy provide a framework for identifying and prioritising the key climate risks to London and prioritising the key actions? If not, how can it be improved?
3 Do you agree that the proposed actions are the right ones? What alternatives and additions do you suggest and how can you or your organisation help implement them?
4 How can we measure how well London is adapting to climate change? What do you think are the key indicators and who should measure them?

Consultation ends on 9 May 2010. Please send your comments by email to adaptation@london.gov.uk or by FREEPOST to :

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Part I - Context for adaptation in London

Chapter 1 London's future climate

Carbon dioxide is one of a number of greenhouse gases (GHGs), so called because they keep our planet warm by absorbing and re-emitting energy from the sun that would otherwise escape into space. This is called the 'greenhouse effect' and keeps the Earth 20-30ºC warmer than if there were no GHGs.

The amount of carbon dioxide in the atmosphere has been maintained at between 200-300 parts per million (ppm) over the last 400,000 years by the carbon cycle. At the end of the last ice age it stabilised at around 278 ppm, but following the industrial revolution, land use changes and intensive use of fossil fuels, carbon dioxide levels are now at their highest point for 800,000 years, rising to a new level of over 380ppm, and still climbing.

The increased carbon dioxide levels in the atmosphere have intensified the greenhouse effect and caused a 0.74ºC[5] increase in the average global temperature over the last century. Carbon dioxide emitted in the last century is still present in today's atmosphere and will not be absorbed back into the oceans and forests until the middle of the 21st century. This inertia in the carbon cycle means that even if all emissions stopped today, carbon dioxide levels would take hundreds of years to stabilise, during which time we would continue to experience climate change. As emissions are likely to rise for some time before global efforts to reduce them may be successful, these emissions will further increase the amount of climate change we will experience.

If GHG emissions do not drastically reduce, then the world may face a significant temperature change and potentially irreversible damage to the Earth's ability to buffer extreme changes to our climate, leading to dangerous climate change. We face a period of changing climate as a result of historic and current emissions and further changes in response to future emissions. Climate change cannot be prevented for the current generations, but it can be limited for future generations.

Catastrophic climate change

Climate scientists are particularly concerned that unless we drastically reduce global GHG emissions, the continued warming may instigate a number of changes where we pass a 'tipping point'. Beyond that point, the climate system is unable to correct itself and a number of self-reinforcing 'runaway' processes are initiated (such as the loss of the Amazon rainforest, or the rapid melting of the polar icesheets).

There is general consensus that in order to prevent catastrophic climate change, the rise in global annual average temperatures should not exceed 2°C, which means that global carbon dioxide levels must be stabilised at or below 450 ppm. With the continued growth in greenhouse gas emissions around the world, and a dramatic acceleration of emissions in some countries, and some sectors, *many climate scientists now believe that stabilisation at 450ppm is now impossible, and that even 550ppm may be unattainable*. This further emphasises the need to adapt, as potentially a far greater degree of climate change will be experienced.

The Mayor is committed to reducing London's carbon dioxide emissions by 60 per cent by 2025 through action involving all levels of government, as well as individuals and the private sector. In his London Climate Change Mitigation and Energy Strategy, he will review this target and set out the steps on how this will be achieved.

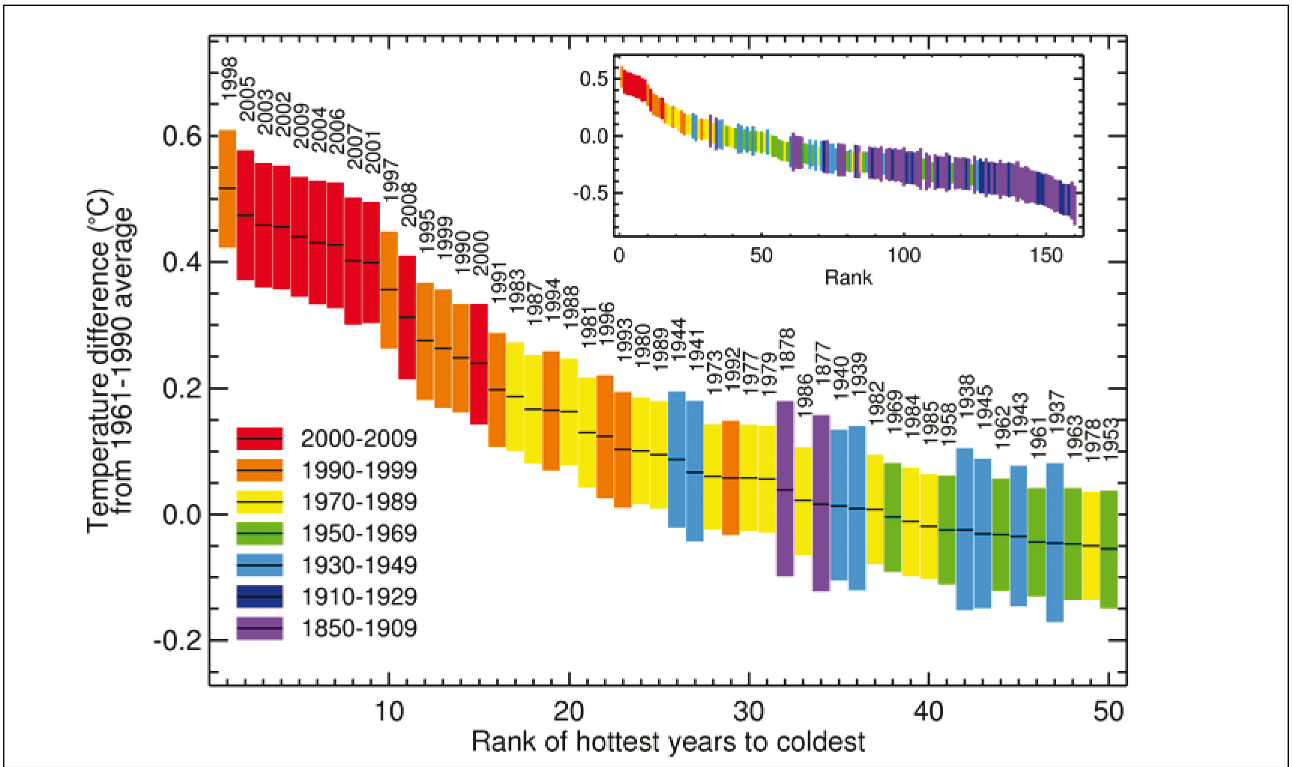
Our climate is already changing

An analysis of global annual average temperatures shows that global temperatures have been progressively rising over the last 150 years. Figure 1.1 ranks global annual average temperatures, with different colours used to highlight different decades. It can be seen that every year from the last decade falls within the 15 hottest years on record.

These changes are also seen at a local level. All regions of the UK have experienced an increase in average temperatures between 1961 and 2006 annually and for all seasons. Increases in annual average temperature are typically between 1.0 and 1.7 °C, tending to be largest in the south and east of England and smallest in Scotland.

Figure 1.2 plots the average summer temperatures (June, July and August) in London for the period 1950-2006. It can be seen that

Figure 1.1 Global annual average temperatures, ranked hottest to coldest (source: The Meteorological (Met) Office, Hadley Centre)



despite considerable variation from year to year, that summers have got progressively warmer and that this rate of warming has increased over the past 30 years (dotted line), compared to the last 50 years (solid line). Average summer temperatures in London have warmed by over 2˚C over the period 1977 – 2006.

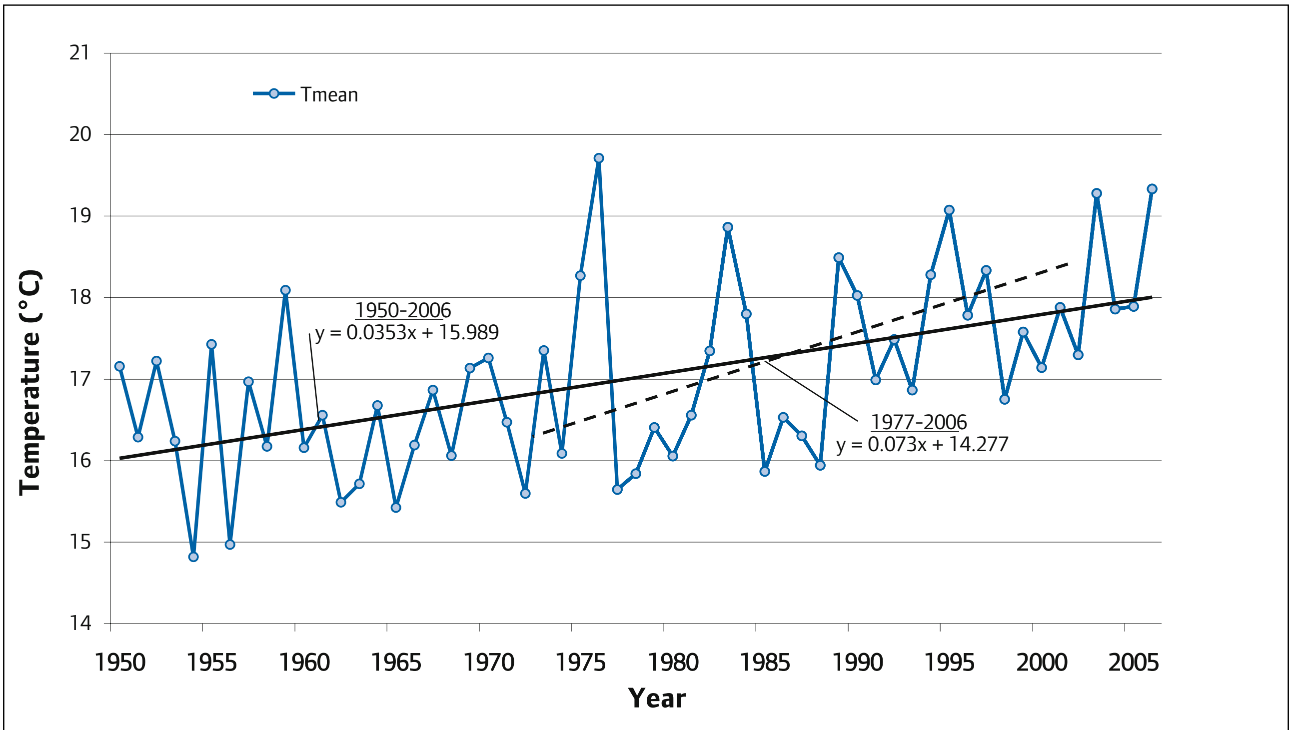
Projections of London's future climate

Climate models are used to project future climate changes. They represent the energy exchanges between the sun, the atmosphere, the oceans and the land to calculate the changes to the climate against a baseline period (1961-1990). Their outputs are validated by their ability to recreate our recorded climate.

In June 2009, the government published the latest generation of climate projections, known as the UK Climate Projections 2009 (UKCP09). These projections update the UK Climate Impacts Programme 2002 (UKCIP02) scenarios and represent the best climate projections in the world. The UKCP09 are available online[6] and provide probabilistic projections for a number of atmospheric variables (such as temperature, rainfall and humidity) covering:

- three different temporal averages (month, season, year)
- two spatial resolutions (25km square, or administrative regions, for example, London)
- seven future overlapping 30-year timeslices, starting with 2010-2039

Figure 1.2 Average summer temperatures in London 1950-2006 (source: Met Office)



- three future greenhouse gas emissions scenarios (high, medium, low).

The changes projected in UKCP09 are generally consistent with the UKCIP02 projections. Temperatures are projected to rise all over the UK, but most of all in the south and more so in summer than in winter[7]. Both sets of projections allow for a slight weakening of the Gulf Stream, so are cooler than would otherwise be projected[8].

The key difference between UKCIP02 and UKCP09 is that UKCP09 use multiple runs of the Met Office's climate model, plus a number of other international weather centre models to generate a spread of projections. The distribution of the projections is then assessed to provide 'probabilistic projections'[9], which, rather than providing a single figure for a future variable and emissions scenario (such as temperature in the 2050s under a medium emissions scenario), provide a range of projected figures, together with their associated likelihood[10].

Climate versus weather

'Weather' is what we experience over a short period of time – over an hour or a day. 'Climate' is the average weather and its variability over a long period of time (at least 30 years). It is important not to confuse short-term weather events (for example the cold winter of 2010), with long-term trends (for example, winters warming by over 2°C by the mid century).

For example, the winter of 2010 was one of the coldest for 20 years. In most winters, south-westerly winds from the Atlantic mean that the UK benefits from comparatively warm, but wet winters. In mid-January 2010, the Atlantic air was 'blocked' by a high-pressure weather system, and cold air from the Arctic drove temperatures down. Meanwhile, a low-pressure system from the northeast brought moisture that fell as snow. The Met Office's seasonal forecast predicted the potential for an unusually cold spell11.

This spell of cold weather in the UK and parts of Europe does not mean that climate change has stopped. In the UK, 2009 was in fact the 15th warmest year on record and taking the globe as a whole, 2009 was the fifth warmest year on record. Cold weather events will continue to occur in the future, but will become increasingly less common.

The following section shows information from the UKCPO9 projections for London in three different formats. Table 1.1 summarises changes to the key atmospheric variables for the middle of the century under a medium emissions scenario (compared to the baseline period 1961-1990) and the sea level and tidal surge changes for the end of the century.

Figures 1.3 – 1.6 show the average projected changes for London for summer and winter temperatures and rainfall for three successive 30-year time slices through the century. While Figures 1.3 and 1.4 show the progressive increase in summer and winter temperatures, Figures 1.5 and 1.6 highlight the increasing seasonality of rainfall.

Figures 1.7 and 1.8 show how London is projected to warm in summertime and experience more seasonal rainfall through the century, in comparison to the 1961-1991 baseline period. These graphs show the average monthly maximum figures rather than the seasonal averages shown in figures 1.3 - 1.6. The grey bars represent the past climate (1961-1990) and the coloured lines represent the projected future climate (average monthly maximum changes projected for three 30-year timeslices).

Table 1.1 UK Climate Projections 2009 for London (2050s medium emissions scenario)

Rising temperatures	Summers will be warmer, with the average summer day[12] being 2.7°C warmer and very hot days 6.5°C warmer than the baseline average. By the end of the century the hottest day of the year could be 10°C hotter than the hottest day today. Winters will be warmer, with the average winter day being 2.2°C warmer and a very warm winter day 3.5°C above the baseline.
More seasonal rainfall	Summers will be drier, with the average summer 19 per cent drier and the driest summer 39 per cent drier than the baseline average. Winters will be wetter, with the average winter 14 per cent wetter and the wettest winter 33 per cent wetter than the baseline average.
Tidal surges	Tidal surges (see Chapter 3 for description) are not projected to increase in frequency, though the height of a one-in-fifty-year tidal surge is projected to increase by up to 70cms by the end of the century.
Sea level rise	Sea levels are projected to rise by up to 90cms by the end of the century. An extreme projection of a 2-metre increase has been generated using the latest ice-sheet modelling published after the IPCC (Intergovernmental Panel on Climate Change) Fourth Assessment report.

Figure 1.3. Changes in average summer temperature (˚C) for London over the century compared to 1961-1990 baseline (central estimate, medium emissions scenario)

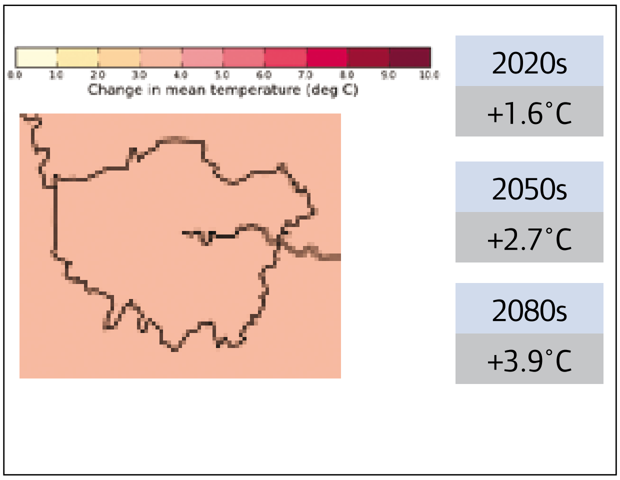


Figure 1.4 Changes in average winter temperature (˚C) for London over the century compared to 1961-1990 baseline (central estimate, medium emissions scenario)

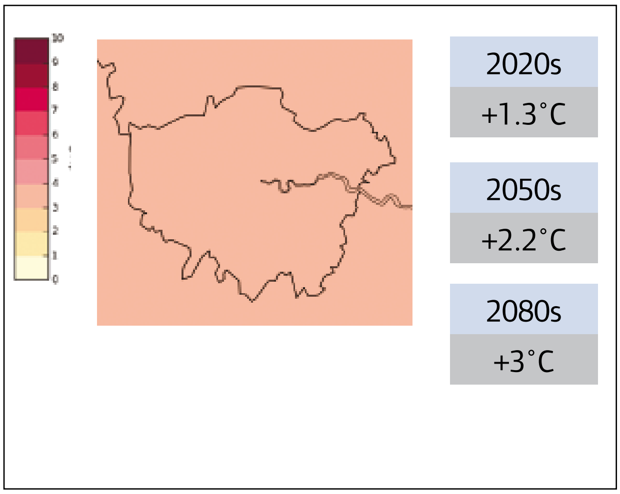


Figure 1.5 Changes in average summer rainfall (percentage change against baseline) for London over the century compared to 1961-1990 baseline (central estimate, medium emissions scenario)

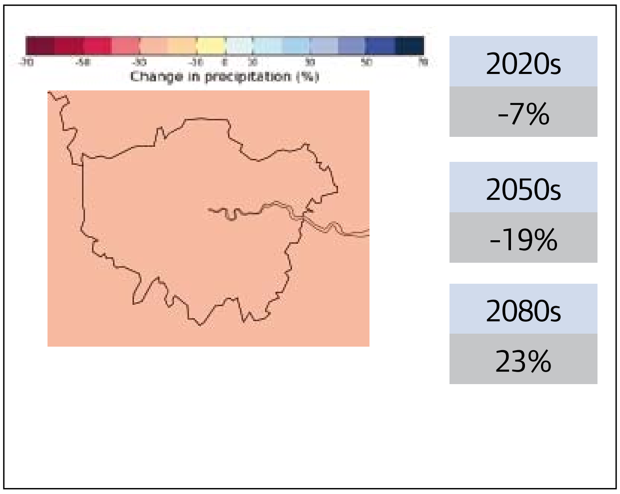


Figure 1.6 Changes to winter rainfall (percentage change against baseline) for London over the century compared to 1961-1990 baseline (central estimate, medium emissions scenario)

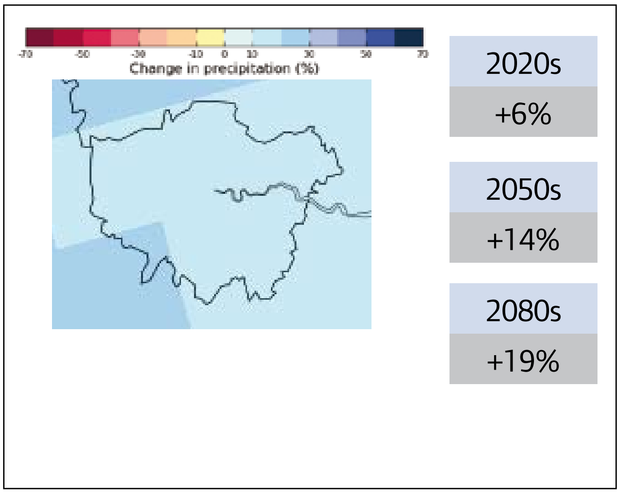


Figure 1.7 Average monthly maximum temperatures (°C) in London over the century, under a medium emissions scenario, compared to baseline period.

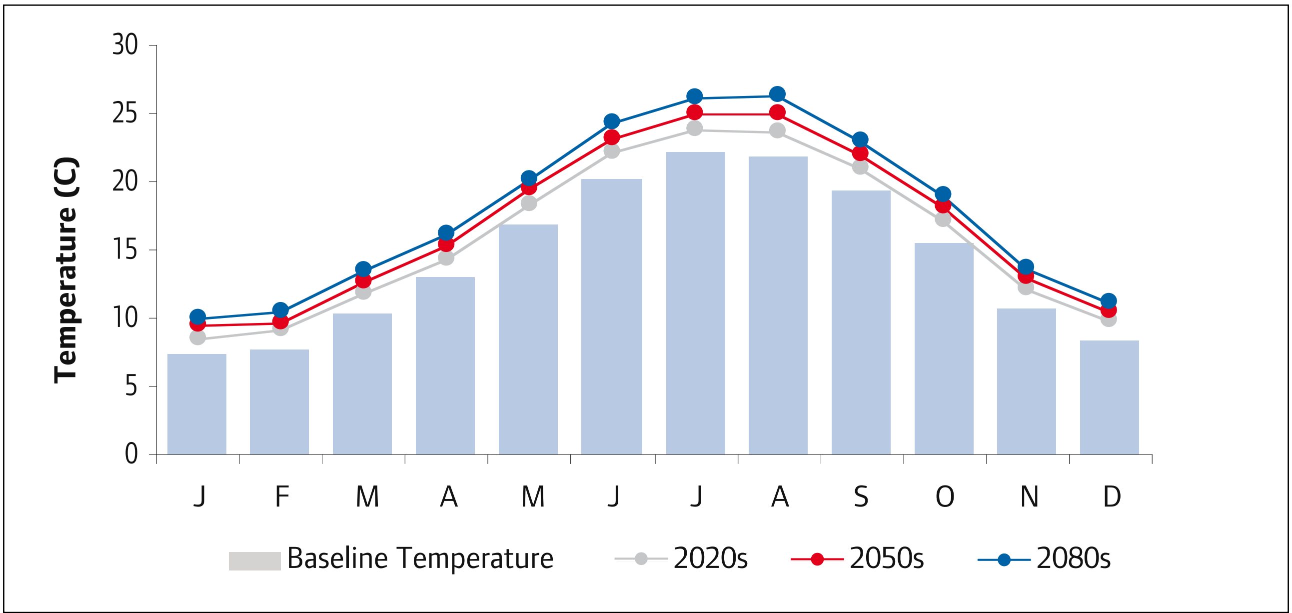


Figure 1.8 Average monthly rainfall (mm of rainfall per month) in London over the century, under a medium emissions scenario, compared to baseline period.

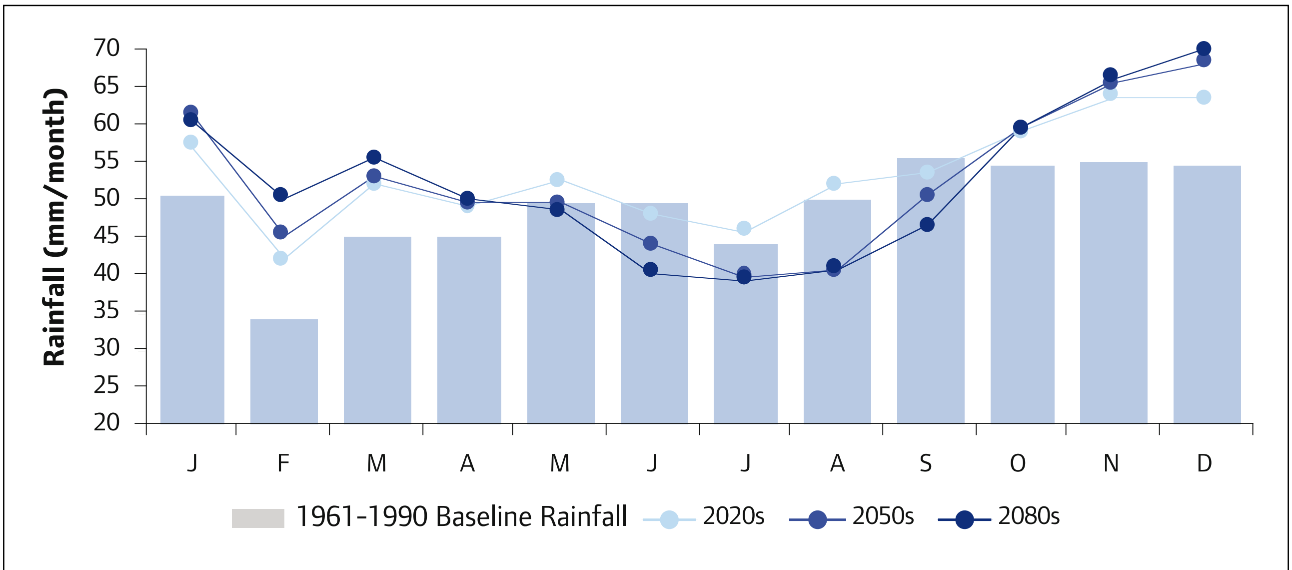


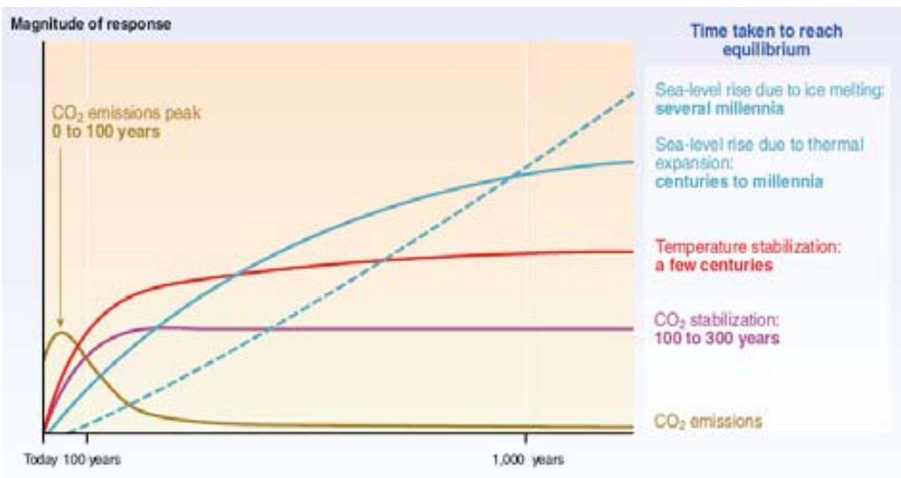
Figure 1.9, from the IPCC Third Assessment Report, shows the response of the world's oceans to rising temperatures. The graph illustrates that even if global carbon dioxide levels are dramatically reduced within this century, it will take several hundred years for the carbon dioxide levels to stabilise within the atmosphere, and several centuries more for global temperatures to stabilise, but thousands of years for sea levels to reach equilibrium.

Windstorms

It is difficult to discern a trend from the windstorm record due to the low numbers of such storms, but evidence suggests that severe windstorms around the UK have become more frequent in the past few decades. The increasing number and cost of windstorm damage claims to Association of British Insurers members supports this.

Due to uncertainty in the projections of windstorms in UKCP09, and the fact that southeast England has the highest building standards for wind resistance in England, this draft of the strategy does not consider in depth the impacts of windstorms. This will be kept under review for inclusion in future revisions of the strategy. It should be noted that the climate models cannot currently predict intense local windstorms, such as the tornado that affected north London in December 2006.

Figure 1.9. Climate system responses to reducing carbon dioxide (CO2) emissions (source: IPCC Third Assessment Report)



As highlighted in the introduction, there is no steady state of being 'adapted' (because the climate, and hence the risk, will keep changing), therefore adaptation should be seen as a 'journey' rather than a 'destination'. This chapter, using the 'Prevent, Prepare, Respond, Recover' series of actions, 'maps' out who is responsible for enabling adaptation. It also highlights where there are critical gaps and signposts the relevant actions in the strategy.

Risk assessment is a key part of managing risks. All local authorities have to report to government on a number of performance indicators, two of which cover adaptation issues – national indicator 188 on adaptation generally and national indicator 189 on flood risk management. All boroughs are therefore undertaking some level of climate risk assessment, with progress against national indicator 188 requiring the production of a comprehensive adaptation action plan. The Mayor believes that in developing their adaptation strategies, all boroughs and their strategic partners should use the process to draw together the many other policy requirements (including flood risk appraisals, community risk registers and sustainability appraisals) into a single document. The Mayor encourages boroughs to focus not only on their own area, but to take a more strategic perspective on issues such a river catchments and mutual aid.

Flooding

Prevent

There are three key ways to prevent or reduce the impact of flooding:

Spatial planning – This involves avoiding the creation of flood-vulnerable land uses in high flood-risk areas and identifying where current developments should be removed or exchanged for less flood-sensitive land uses. However, the pressure for development in urban areas means that is it sometimes necessary to develop in flood-risk areas. The GLA and London boroughs are responsible for using the planning process to reduce flood risk.

Flood defences and drainage systems - A significant amount of London is already located in areas of flood risk. Although London has flood defences in place, it is not always possible to prevent flooding. For example, an extreme event may overcome the defences or the defences may fail. The Environment Agency has responsibility for maintaining most of the flood defences, but some riverside landowners also have responsibility for the flood defences on their land and these have to be maintained to the Environment Agency's standards by the landowners. The Environment Agency has a long-term investment strategy for maintaining and improving flood defences, and is also responsible for reviewing the standard of protection provided, in consultation with other flood defence owners.

The drainage network is owned and managed by a number of organisations. Thames Water owns and manages much of the network, but the London boroughs, TfL and private landowners also have responsibility for the drains. There is no set standard for drainage and maintenance is often poor, so the standard of service provided by parts of the network is often well below the original design standards.

Flood Storage areas – This involves designing some areas to deliberately flood (such as parkland or sports fields) so that other more vulnerable land uses can be spared flooding. At present, this option is under-utilised in London and many areas of open space could be designed to flood to reduce the risk to built-up areas.

Prepare

A lot of work has been undertaken in compiling the information to understand and prepare for flood risk at a strategic level. This now needs to be interpreted at the local level by infrastructure managers and communities to protect their own areas and facilities.

The GLA has undertaken a Regional Flood Risk Appraisal (RFRA). This identifies many of the regionally important assets at flood risk and makes 19 recommendations to improve resilience to flood risk. Further work is required to develop and maintain a more comprehensive list of regionally important assets at flood risk.

The Environment Agency has produced Catchment Flood Management Plans for London's rivers, while its Thames Estuary 2100 Project examines the tidal flood risk. These plans operate at a strategic scale and identify areas of flood risk today, as well as using climate projections to assess how risk will change in these areas. Local authorities are required to work with the Environment Agency on managing flood risk through their spatial plans and emergency plans, and to report on actions under national indicator 189.

The London boroughs are well advanced in producing their Strategic Flood Risk Assessments (SFRAs). These provide a good starting point. In future, the SFRAs should be more integrated, with boroughs which share flood risk taking a wider view on areas where there is the potential for an exchange of risks, as well as promoting closer links between land use planning and emergency planning.

Local authorities also have a responsibility to assess surface water flood risk and produce Surface Water Management Plans (SWMPs). Richmond and Kingston are one of the first six areas in the country to have produced a SWMP. Through the Drain London Forum, the GLA is working with the boroughs to support them in producing their SWMPs and encouraging boroughs facing a shared risk to work together.

Utility companies have made a commitment to identify strategically important assets (such as water treatment works, or electricity sub-stations) and ensure that they are protected from flooding to a 1-in-1,000-year flood level. However, the utility regulators (Ofwat and Ofgem) have not allowed the utility companies to invest in improving the flood resilience of these assets, so there is concern that they are not being protected. The utility companies are also required to report to government on their climate risks under the Adaptation reporting power contained within the Climate Change Act 2008.

Communities and individuals in areas of known risk can prepare themselves by taking out appropriate insurance cover, keeping irreplaceable or valuable possessions in a safe place, signing up to the Environment Agency's flood warning system, Floodline Warnings Direct, and having a flood plan and emergency kit. Currently there is a low uptake of the Floodline Warnings Direct scheme and many Londoners are uninsured or under-insured.

Respond

The London Resilience Partnership (LRP) has published a Regional Risk Register that identifies the key risks to London. Tidal and fluvial flooding are recognised as priority risks, and the LRP is revising the London Strategic Flood Response Framework to set out how a regionally significant flood would be managed, and to define the mechanism for escalating a local scale flood response to a regional scale response. The revised framework will be adopted early in 2010. A mutual aid agreement is also being developed for all emergencies and all boroughs, which will set out how boroughs will assist each other at times of need.

Each London borough either has a generic emergency plan that can be used to manage the response to a flood, or has a bespoke flood emergency plan. All London boroughs are also in the process of producing Multi-Agency Flood Plans, which will set how the borough will work with the emergency services and other partners to manage a local-scale flood. These plans must be completed by March 2010. These plans should be developed in consultation with neighbouring boroughs facing the shared flood risk. There are no bespoke community flood plans.

Homeowners and landlords can fit flood resilient or resistant measures to their homes and buildings. The government has published advice on these and also has a grant scheme[13] to help toward the costs. Currently, insurance providers do not incentivise these practices through reduced premiums or even require them when a flood-damaged property is repaired.

Recover

The London Recovery Management Protocol sets out the roles and responsibilities of agencies in London to facilitate recovery following a regional emergency. The protocol has been used by some local authorities as a basis for their local recovery plans. Local authority recovery plans should set out how the authority will provide humanitarian assistance, house displaced residents, facilitate the insurance claims process, help affected businesses get back on their feet, clear flood debris and damaged home contents, manage the longer term social impacts and co-ordinate support from the voluntary agencies.

Communities and individuals who have followed their flood plan will be in a better position to recover following a flood. It may also be possible to implement some of the measures to limit the impact of the flood as part of the recovery stage, for example by repairing a building with flood resilient design and materials. Currently, few insurance companies offer to replace flood-damaged buildings

Current gaps in adapting to flood risk	Action
Borough SFRAs should be better integrated across boroughs	5
A lack of integration between borough spatial planners and emergency planners on flood risk management measures	5
Utility managers have not completed flood risk assessments of infrastructure	6
Lack of community flood plans in high risk areas	9
Poor sign-up to Floodline Warnings Direct and lack of individual preparedness for flooding	8
Like-for-like insurance replacement fails to improve the resilience of property at risk from flooding	32

fixtures and fittings with more flood resilient designs, thereby continuing instead of reducing future risks.

Drought

Prevent

A drought is caused by the prolonged shortage of rainfall. It is therefore not possible to prevent a drought, but there are many ways of reducing the impact of a drought through reducing the amount of water that we use, or exploiting new water resources.

Prepare

Water companies have a duty to provide water and are required to develop Water Resource Management Plans (WRMPs), detailing how they plan to provide sufficient water to meet demands and manage environmental impacts. These plans cover a 25-year period and are reviewed every five years, together with a parallel business plan on how the water companies will fund the delivery of their plans and how much they will charge customers. Water companies have to identify changes to the demand for and supply of water, and propose actions to manage any shortfalls.

The Environment Agency is responsible for advising DEFRA on the WRMPs, and OfWat, the water regulator, assesses the water companies' business plans. OfWat's recent price review (PR09) did not allow water companies to invest in adapting their infrastructure to risks based on the UKCIP02 projections. The water industry has just started using the latest generation of climate projections (UKCP09) to model the changes to supply, so it is likely that the water companies will invest in adaptation in the next round of planning. The Mayor thinks that OfWat should place more emphasis on ensuring that customers' supplies are more secure in the long term and reducing environmental damage by improving the water infrastructure and encouraging water efficiency.

Communities and individuals can help reduce the need for drought restrictions by reducing overall water demand. Some simple measures, which can also reduce bills and impacts on the environment, include using water-efficient fittings or installing water butts for watering the garden or washing the car.

Respond

As a drought becomes more likely or prolonged, water companies have a staged process of implementing water restrictions in order to save water for the most essential needs. Water companies need to apply to government for permission to implement their drought plans, which start with asking customers to reduce the amount of water they consume and progresses to enforced cuts and ultimately restricting the supply of water on a rota basis. While the initial steps proved to be effective in the 2005-6 drought, there is some doubt as to how effective rota cuts would be within London.

Communities and individuals can respond by further reducing their water consumption all year round, but especially at the earliest signs of a potential drought.

Desalination plants offer one potential source of additional water which is still available during a drought. A desalination plant is due to be completed in London in 2010. However, desalination is an energy-intensive method of producing water and its use should be limited. It does nothing to help reduce the current unsustainable levels of water use.

Recover

Once a drought is over there is little need for a recovery programme as rainfall tends to quickly replenish the water resources. There is no requirement for any government body or agency to produce a drought recovery plans.

Heatwaves

Prevent

Heatwaves are weather-related and therefore it is not possible to prevent them. It is possible, however, to reduce the impact of a heatwave and how much the city intensifies the impact of hot weather.

Buildings can be designed, or retrofitted to stay cool during hot weather. Building managers can decide to only cool critical parts of a building. Spatial planners can plan to locate heat-vulnerable land uses away from warmer areas in the city (see Chapter 6) and design green spaces and breeze pathways to cool the city.

The risk of overheating has only recently been recognised and is therefore poorly understood and managed. Building regulations do not currently require developers to consider the risk of overheating, and even where best practice recommends that overheating should be considered, the usual response is to install air conditioning. Air conditioning is energy

Current gaps in adapting to drought risk	Action
OfWat should support investment in long-term drought resilience	12
The need to reduce our demand for water Londonwide	11, 13
London Resilience should review the need for a London-specific drought plan	14

intensive and produces waste heat, which can further increase the risk of overheating. This means that a large proportion of new development, and the refurbishment of existing sites (such as schools and hospitals) do not take the forthcoming climate into account in their design or construction, and may overheat. This strategy is one of the first to tackle the issue at a strategic scale.

Prepare

Following the 2003 heatwave, the Health Protection Agency has developed and annually revised a national Heatwave Plan (see Chapter 6). Each UK region is required to adapt the national Heatwave Plan for their regional circumstances. The Heatwave Plan relies upon GPs and borough social services identifying vulnerable people and ensuring that they are aware of what to do during a heatwave, and making sure that they are contacted during a heatwave to check on them. There are concerns on how effective this is in practice, as a person's vulnerability may vary from day-to-day based upon their health and their care arrangements, and many 'vulnerable' people do not consider themselves to be vulnerable and so ignore the advice. It is especially difficult to reach and maintain contact with vulnerable people in London as the health and social services are already stretched.

Good design, such as minimising solar gain, fitting shutters or shading and increasing green cover can reduce the effect of overheating and particularly the urban heat island effect. In turn, these will reduce the need for air conditioning.

Respond

As previously stated, borough social services and GPs have a responsibility to respond to their vulnerable communities and individuals during a heatwave, but there are questions regarding how effective this works at present. In addition hospitals and care homes are required to have heatwave plans, which look at how they would provide a satisfactory service and maintain a room which does not exceed 26°C.

Communities and individuals can respond by ensuring that they take measures necessary to cope with heatwaves without resorting to fitting air conditioning, or at least minimising its use.

Recover

Once a heatwave is over, there is little need to recover as there are few lasting effects. There is currently no requirement for any government body or agency to produce drought or heatwave recovery plans, so the generic London Recovery Plan would be used. Following a heatwave, an assessment of the implementation of the Heatwave Plan and any other responses should be undertaken to determine how effective they were.

Current gaps in adapting to heatwave risk	Action
There is a need to publish and promote design guidance on reducing overheating in buildings	21
The Heatwave Plan recommends that GPs and social services should identify heat vulnerable individuals but there is no mechanism for this	27

Part II – Understanding and managing the impacts

Chapter 3 Flooding

Vision

London is resilient to all but the most extreme floods and has robust emergency plans to respond to, and recover from, flooding.

From vision to policy

Policy 1. The Mayor will work with partners to reduce and manage current and future flood risk in London by:

- improving the understanding of flood risk in London and how climate change will alter the risks, to improve our ability to manage flood risk
- reducing flood risk to the most critical assets and vulnerable communities, to target the greatest effort on London's most vulnerable assets.
- raising public awareness of flooding and individual and community capacity to cope and recover from a flood, to improve London's resilience to flood events.

From policy to action

There is a good understanding of current tidal and fluvial flood risk in London, but a poor understanding of surface water flood risk. To improve our ability to predict and manage flood risk, further work is required to understand surface water flood risk and how climate change will increase all forms of flood risk.

Action 1. The Mayor will work with the Environment Agency, boroughs and other partners to improve the mapping of who and what is at flood risk from all sources of flooding today, and to predict future flood risk for all flood sources.

Action 2. The Drain London Forum, led by the GLA, will develop a surface water management plan for London which identifies and prioritises areas at risk and develops more detailed plans for the priority areas.

Action 3. The Drain London Forum will create an online data portal to allow flood risk management partners to more effectively share information and data analysis.

Action 4. The Drain London Forum will create a flood incident reporting system that is adopted throughout London to improve our understanding of flood risk today.

Action 5. The Mayor will work with boroughs through the Association of London Borough Planning Officers and the Local Resilience Forums to ensure that flood risk management is integrated across borough boundaries and within borough teams.

In order to prioritise flood risk management actions we need to identify the most vulnerable communities and critical assets.

Action 6. The Mayor will work with the Environment Agency, London Resilience and the London Climate Change Partnership to identify and prioritise critical infrastructure and vulnerable communities at flood risk.

Action 7. To reduce the risk of local surface water flooding, the Mayor will work with TfL, the London boroughs and Thames Water to review their drain and gully maintenance programme, particularly in high-risk areas.

In order to increase our capacity to cope and recover from a flood, we will seek to raise individual and community-level awareness of flooding.

Action 8. The Mayor will work with the Environment Agency to increase the number of Londoners signing up to the Floodline Warning Direct scheme and to raise awareness of the measures that individuals and communities can undertake to reduce the risks and manage the consequences of flooding.

Action 9. The Drain London Forum will identify two communities at significant flood risk and work with them to develop bespoke community flood plans to build their capacity to manage flood risk.

See also Actions 17-20 in Chapter 5 and Action 32 in Chapter 8.

Background

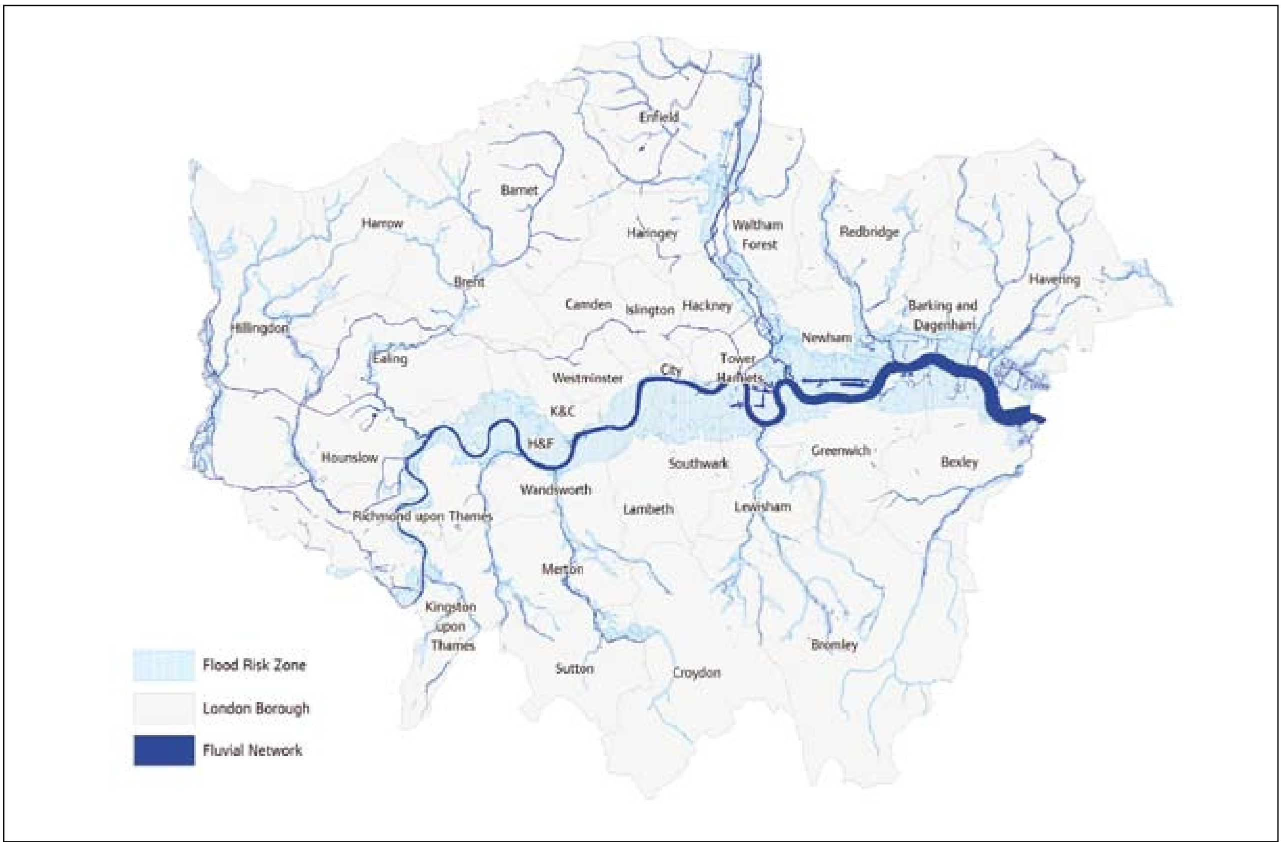
London is prone to flooding from five sources of floodwater:

- from the sea (tidal flooding)
- from the Thames and tributaries to the Thames (fluvial flooding)
- from heavy rainfall overcoming the drainage system (surface water flooding)
- from the sewers (sewer flooding)
- from rising groundwater (groundwater flooding).

It is possible for flooding from a combination of these flood sources to occur simultaneously.

Nearly 15 per cent of London lies on the former flood plains of London's rivers. Figure 3.1 shows the extent of the area of London that would be flooded by an 'extreme' flood if there were no flood defences. It is standard to show the area that would be flooded without the presence of defences, as this highlights the people and assets provided some protection by those defences. London has some of the highest standards of tidal flood defence in the world, with only the Dutch having higher standards of flood protection.

Figure 3.1 Area of London at tidal and fluvial flood risk.



The flow in the Thames is affected by the tide as far as Teddington Weir in west London. Most of London lies within the Thames tidal floodplain and without the protection afforded by the tidal flood defences, much of London would flood twice a day, every day on each high tide (the amount of flooding depending on the height of the tide and the amount of freshwater flow in the Thames).

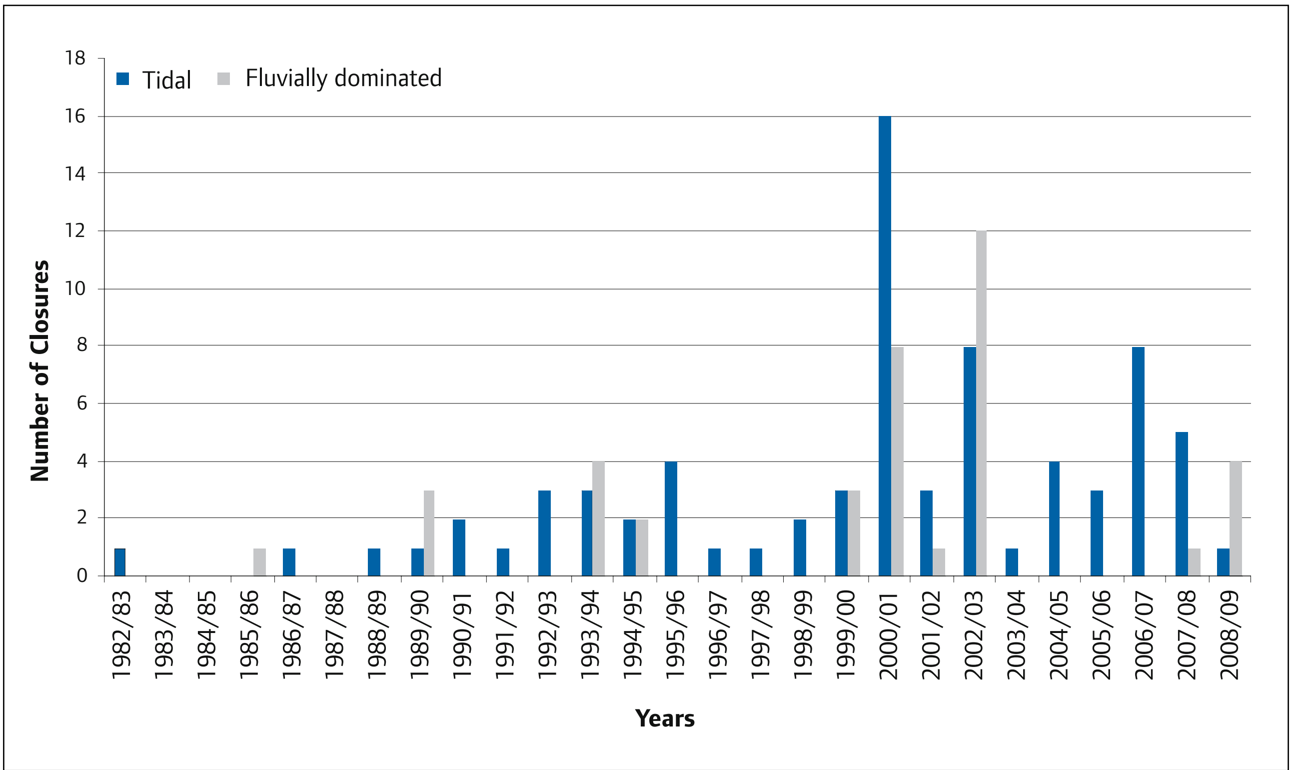
London has always faced flood risk from the sea. Today's tidal flood defences are the legacy of the response to previous floods, with each flood resulting in the flood defences being increased in height. The last tidal flood in London was in 1928, when 14 people drowned in Pimlico. In 1953, a tidal surge inundated large parts of Kent and Essex, killing over 300 people, though this did not reach London. This resulted in the construction of the current Thames tidal defences, an integrated system comprising the Thames Barrier, 185 miles of floodwalls, 35 major gates and over 400 minor gates.

The Thames tidal defences protect London and the Thames estuary from an uncommon meteorological phenomenon known as a tidal surge. Tidal surges occur when an intense low-pressure weather system (depression) forms over the Atlantic and literally sucks water towards its centre, raising sea levels below it. As the winds drive the depression eastwards towards Europe it carries this extra water with it. If the depression moves down the North Sea towards the Channel, the water is funnelled in a bottleneck between the east coast of the UK and mainland Europe, creating a surge. Onshore winds can drive the surge up the Thames estuary and if the surge coincides with an incoming spring tide, water levels can be in excess of three metres higher than normal water levels.

The Thames Barrier has been operational since 1982 and has been closed over 100 times to protect London from flooding. Figure 3.2 shows the number of Thames Barrier closures between 1982/83 and 2008/09. In addition to being closed to stop tidal surges from entering central London, the barrier can also be closed to 'keep out the tide' and provide additional space for high freshwater flows after heavy rainfall. These closures protect riverside development in west London from fluvial flooding and are known as 'fluvially dominated' closures.

Because the Thames tidal defences work as an integrated system, each closure of the Thames Barrier also results in the closure of the other gates and barriers along the Thames to prevent a tidal surge (outside the barrier) or high

Figure 3.2 Thames Barrier closures 1982/83 to 2008/09 (source: Environment Agency)



river levels in the Thames (inside the barrier) from moving up the less protected tributaries. Preventing these tributaries from flowing into the Thames when the barrier is closed can also increase the flood risk along the tributaries.

The Thames tidal defences were designed to provide protection against a tidal surge that might statistically occur only once in every 2,000 years. The sort of tidal flood event that could seriously affect central London is expected to occur less than once in 10,000 years. This is because the floodwater would spill over the top of walls and banks downstream of the barrier and the tidal surge would dissipate before arriving at the barrier. Even if some of the surge did go over the top of the barrier, the space provided by the defences upstream would act as a reservoir and protect London.

Baseline

In order to assess the current flood risk it is necessary to look at the probability of a flood occurring, the consequence of a flood and the vulnerability of the people and assets that may be affected by a flood. The following section makes an assessment of each of these factors.

Probability

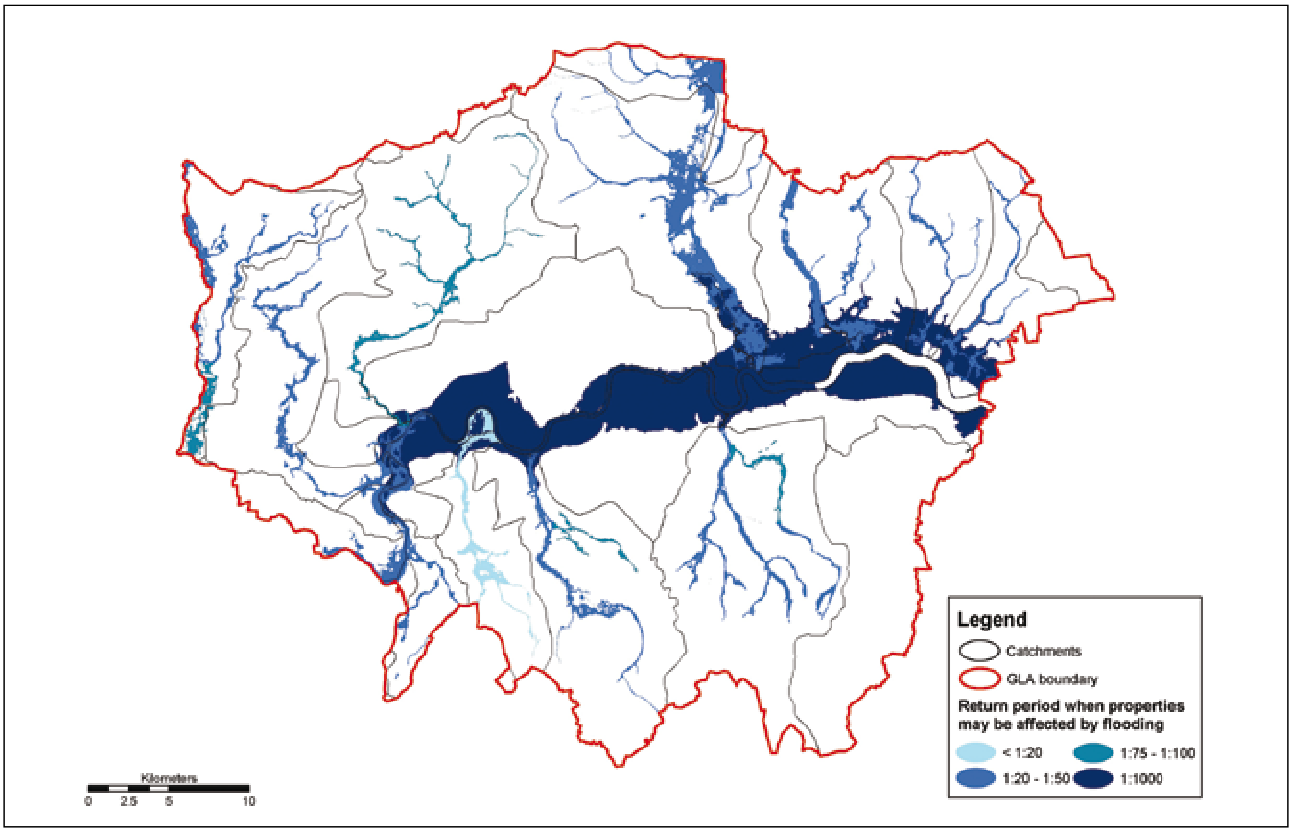
The standard of protection provided by London's flood defences, and hence the likelihood of being flooded can be mapped for tidal and fluvial flooding. The probability is usually expressed as a 'return period', or as an annual percentage[14]. It should be remembered that climate change will increase the frequency and intensity of extreme weather, so that what is a 1 in 100 year event today may be a 1 in 70 year event in the future and a greater intensity will define the new 1 in 100 year event. Table 3.1 sets out the risk categories used to describe the standards of protection.

Figure 3.3 shows the current probability, expressed as a return period, of flooding for areas at flood risk from the Thames and tributaries to the Thames in London. On some stretches of the tributaries to the Thames, the standard of protection is below the level at which insurers are committed to providing flood insurance as part of usual insurance cover[15]. The Environment Agency 'What's in my backyard?' website[16] provides an online Flood Map that shows the areas that could be flooded.

Table 3.1

Risk category	Probability of being flooded
Significant	Greater than 1.3 per cent (1 in 75 chance)
Moderate	1.3 per cent (1 in 75 chance) or less, but greater than 0.5 per cent
Low	0.5 per cent (1 in 200 chance) or less

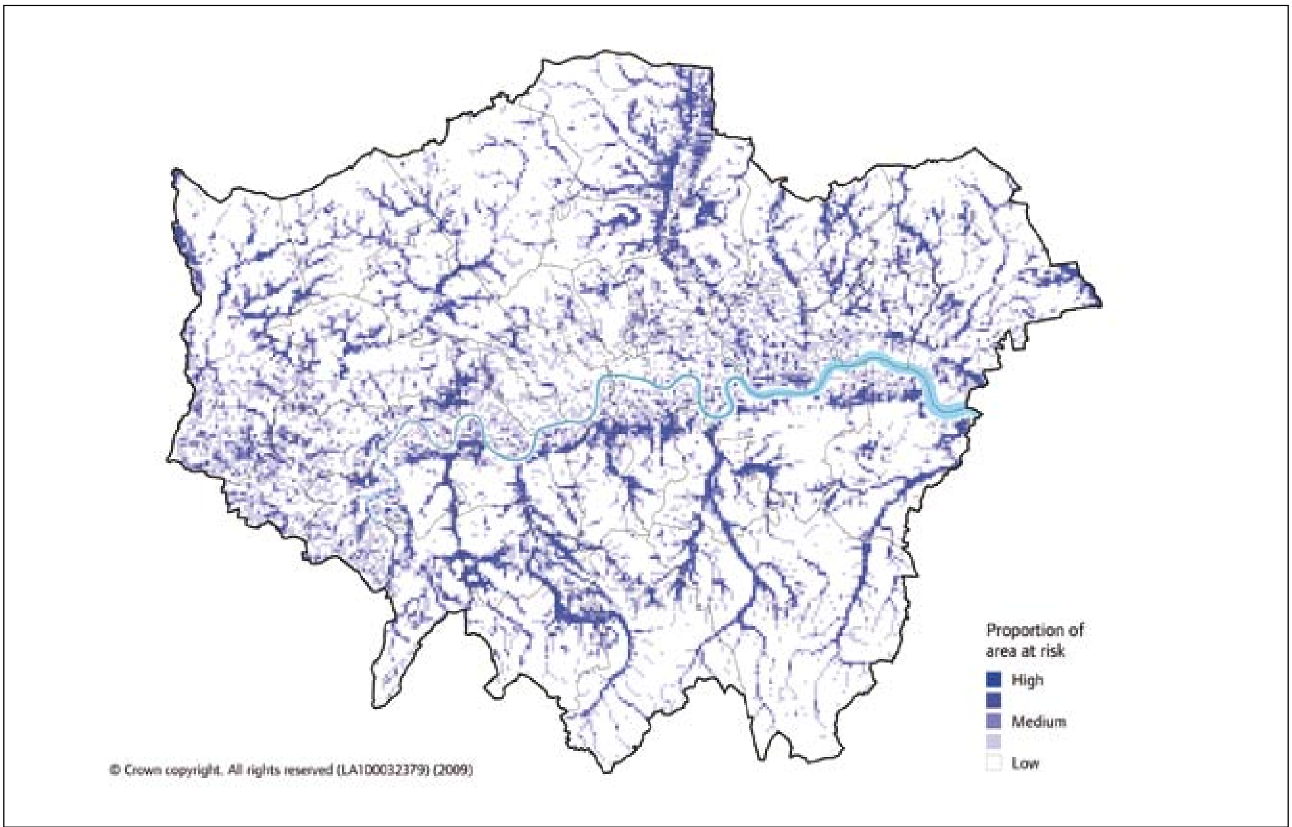
Figure 3.3 Area of London at risk of flooding, showing the different levels of probability, expressed as a return period (source: Environment Agency)



It is more difficult to predict areas at risk of surface water flooding than tidal or fluvial flooding, as surface water flooding usually results from the drainage network being overwhelmed by heavy rainfall. This is because the storms that are usually responsible for heavy rainfall (for example, summer convective storms) tend to be very localised and extremely unpredictable, combined with the fact that the drainage system is designed for high frequency, low volume rainfall, and therefore its ability to prevent flooding depends upon its state of maintenance, how much water is in it before the storm and the intensity of the rainfall.

Figure 3.4 shows the areas susceptible to surface water flooding in London from a 1 in 200 year rainfall event[17]. As most drainage networks are designed for a maximum intensity of 1 in 30 year rainfall event, it is assumed that the drainage network has stopped performing and that rainwater is running to and collecting in low-lying areas. Because many of London's storm water drains discharge into London's rivers, there is extensive flooding along some of the rivers (shown in dark blue).

Figure 3.4 Areas at risk of surface water flooding from a 1 in 200 yr rainfall event. Source. Environment Agency



Consequence

- The impacts of flooding include:
- loss of life and personal injury
- direct damage to property, infrastructure and utilities
- contamination and disease from flood and sewer water
- loss of income and delayed economic development
- break-up of communities and social networks
- poor mental health (depression and anxiety) and physical health after a flood
- blight of land and development
- increased costs of insurance (increased premiums, reduced cover and increased excess levels).

Exposure and vulnerability

The consequence of a flood is determined by 'who and what' is exposed to a flood and their vulnerability to it. The Mayor has published a Regional Flood Risk Appraisal[18] (RFRA) to identify 'who and what' is at risk of flooding in London for the areas shown at flood risk in Figure 3.1. The RFRA has revealed that as well as an estimated 1.25 million people and 481,180 properties, there is extensive social and civil infrastructure (such as schools, hospitals and train stations) at high flood risk. It is important to note that over 80 per cent[19] of these properties are at 'low' flood risk, but that there are 42,800 properties at 'moderate' risk, and 40,400 properties at 'significant' risk[20] (see Table 3.1 for definition).

Analysis of the number of properties at risk of surface water flooding in Figure 3.4 suggests up to 680,000 properties are at risk.

People

The exposure and vulnerability of people to flooding are determined by factors that include:

- exposure – for example, living on the ground or lower-ground floor, having limited advance warning of a flood
- vulnerability - for example, age (the very young and old), health, disability, proficiency of spoken English, living alone or not having a support network, low income and inadequate insurance cover.

Independently or in combination, these factors may mean that an individual may be:

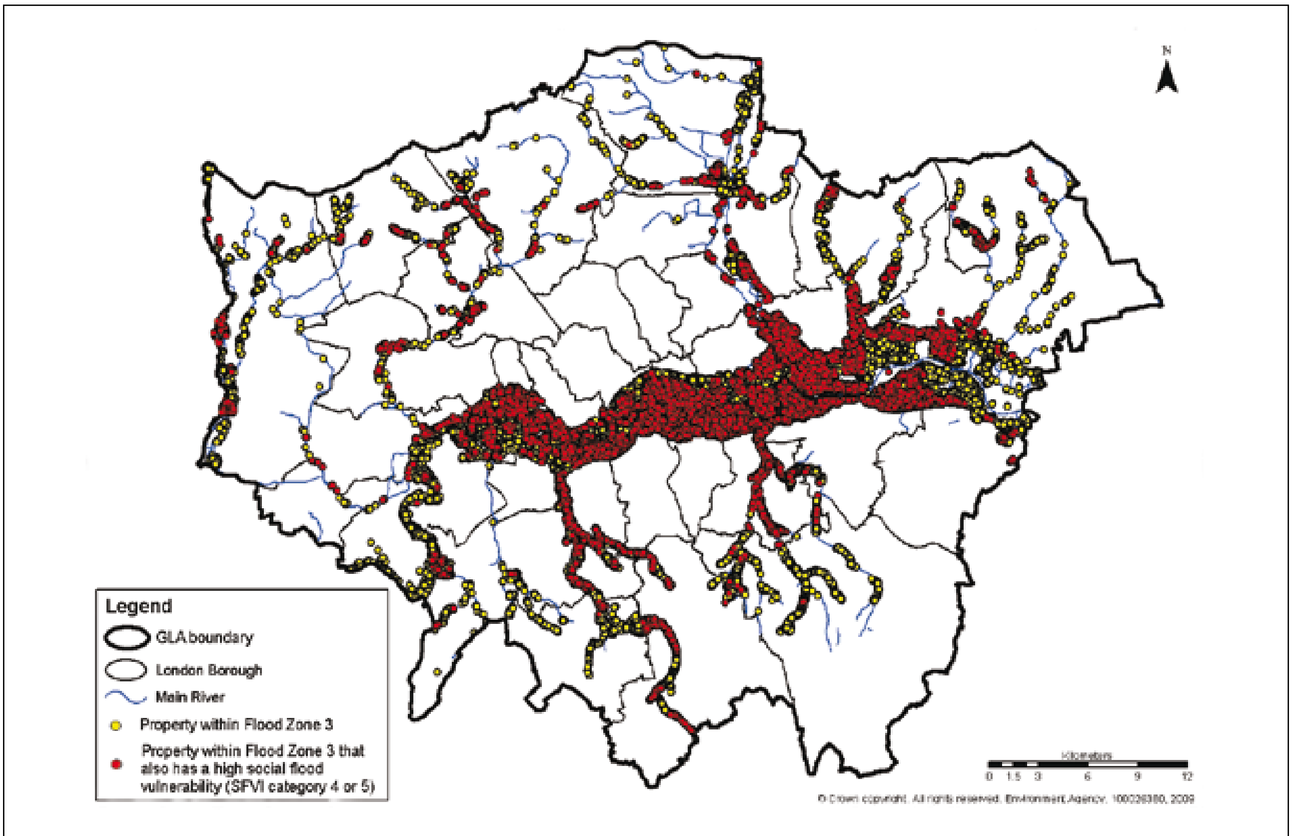
- physically more at risk from a flood if flooding occurs
- less likely to be aware of the flood risk they live at
- less likely to know what to do and be able to do it
- less likely to receive and use information on what to do through regular communications channels
- less likely to be able to recover independently, or access services to aid recovery.

Vulnerability factors can be combined to produce an 'index of flood vulnerability' which can then be plotted using census data to map vulnerability. Figure 3.5 shows the areas of London currently at flood risk from tidal and fluvial flooding. The blue (light and dark blue) areas show the properties that would be flooded by a 1 in 100 year event if there were no flood defences. The light blue areas highlight the households in properties at flood risk that have a high vulnerability to flooding. The shaded area highlights where less than two hours advance warning may be available.

Socio-economic deprivation. Research by the Environment Agency has shown that the poorest ten per cent of Londoners are more likely to live in areas of tidal flood risk, and that both the richest and the poorest ten per cent of Londoners live at fluvial flood risk. This highlights that significant numbers of the poorest Londoners face a high probability of flood risk.

Research by the Scottish Executive[21] has shown that flood victims report that the intangible impacts of flooding - the loss of irreplaceable personal items, the stress of living in temporary accommodation, dealing with the insurance claims process, and the repair of their homes – were greater than the tangible impacts of a flood. Low-income households were more severely affected by the stress of the flood itself and future worry about flooding. This

Figure 3.5 Tidal and fluvial flood vulnerability (source: Environment Agency)



stress often results in long-term depression and anxiety, with increases in time off work, unemployment and family breakdown. As identified previously, the combination of the poorest Londoners living in flood risk areas presents a double challenge.

Advance warning. Advance warning of a flood provides the opportunity to take action before a flood occurs. This warning time can be used by individuals to take personal action to protect themselves, their family and their assets, and for the emergency services and boroughs to initiate their flood plans. Table 3.2 summarises the advance warning times for the key flood sources.

Table 3.2 Advance warning times for flood sources

Flood source	Advance warning	Comments
Fluvial*	May be less than 2 hours (see fig 2.5)	Suitable advance warnings are not possible on all London's rivers as some of them react much more quickly to heavy rainfall.
Surface water	General area warning 24 hours in advance, but little or no warning for specific areas	Thunderstorms can be difficult to predict. Poor maintenance and blockages of the storm drains will affect the ability to predict where and when flooding will occur and provide adequate warning.
Tidal*	2-12 hours	Tidal surges are monitored as they progress down the east coast of the UK, so advance warning is normal. The Environment Agency tests computer predictions of the surge against real-time measurements to improve their predictive capability.

*Breaches of tidal and fluvial defences, by their nature, occur with little or no warning, though it is possible to identify locations where breaches are more likely to occur due to lower ground elevation behind the flood defences, or where poor condition of the flood defence may be identified. Overtopping of tidal defences may be forecast as much as six hours in advance.

The Environment Agency and the Met Office provide an extreme weather and flood risk warning service to the London boroughs and the emergency services. If the weather raises a real risk of flooding, the Environment Agency and/or the Met Office advisors will contact boroughs and the emergencies services and keep them updated on both the weather forecast and observed river levels.

The Environment Agency provides a flood warning service, called Floodline Warning Direct, where a flood warning is sent by fax, email, SMS text, or phone message to people registered for the service when a fluvial or tidal flood is predicted. Nineteen per cent of Londoners living or working in areas of flood risk in London have registered to receive this advance warning. This compares with a national uptake of approximately 24 per cent[22]. For a tidal flood, warnings would also be provided across all media channels. The Environment Agency is planning to launch a new series of flood warnings in early 2010, and will use the launch to increase the number of people signing up to Floodline Warning Direct.

Public awareness. Prior to the construction of the Thames Barrier, regular flood drills were held in London. The presence of the barrier and upgraded defences has meant that many people have become oblivious to the risk of flooding. The Environment Agency estimates that 30 per cent of people would not know what action to take following a flood warning[23].

Insurance. Flood risk insurance is generally provided within standard insurance cover[13]. The uptake of both buildings and contents insurance tends to be lower than average in low-income households[24] and it is estimated that less than one in five households living in social housing make use of the Housing Associations' 'insurance with rent' schemes[25].

Property and assets

Land uses also vary in their vulnerability to flooding. Government guidance on flood risk and development[26] classifies land uses into 'highly vulnerable' to flooding (including police, ambulance and fire stations, emergency command centres and basement dwellings); 'more vulnerable' (including hospitals, dwellings, residential care homes, GP surgeries, prisons, schools and nurseries); 'less vulnerable' (including shops, offices, restaurants, waste and water treatment sites).

It is essential to determine which elements of this infrastructure need to remain operational during a flood, either to manage the flood response, or to ensure that the parts of London not flooded can continue to function as normal. Table 3.3 below identifies the key social and civil infrastructure at flood risk in London.

Key conclusions of baseline assessment

- Approximately one sixth of London's population lives and works at risk of flooding, though the probability of being flooded is considered to be low.
- The poorest in the city are more likely to live at tidal and fluvial flood risk (though more affluent people also live in areas of fluvial flood risk).

Table 3.3 Key social and civil infrastructure at tidal and fluvial flood risk (source: GLA Regional Flood Risk Appraisal)

Social infrastructure	Total in London	Number at flood risk* (% of total)
Schools	3,049	441 (14%)
Hospitals	111	10 (9%)
Civil infrastructure		
Police stations	169	46 (27%)
Fire stations	111	20 (18%)
Ambulance stations	63	9 (19%)
Prisons	8	1 (12.5) - Belmarsh
Railway stations	324	49 (15%)
London Underground stations (including DLR)	291	75 (26%)
Bus depots	84	25 (29%)
Airports	2	1 (50%) – City Airport

*defined as Flood Zone 3 (> 0.5% per annum tidal flood risk or >1% per annum fluvial flood risk)

- There is a low level of public awareness of flood risk and what action to take to prepare for, or respond to a flood.
- There is a lower uptake of insurance for people in social housing or on low incomes.
- Few people at flood risk are registered to receive flood warnings, so the majority of Londoners living and working at flood risk are unable to make use of even short advance warnings of a potential flood.
- A significant proportion of London's critical infrastructure lies in areas of flood risk, including emergency services and utilities that London would be reliant upon to be operational during a flood, or would require to manage the impacts of a flood.
- The growth of London will increase the number of people living and working on the floodplain, and the associated assets at risk would also increase.

Climate change risk analysis

Flood risk in London is already significant because of the extensive population and assets located on the floodplain. Flood risk will increase due to climate change, but also due to further development in areas of flood risk, ageing flood defence infrastructure, the fact that much of the infrastructure was designed to meet lower flood standards, a low level of public flood risk awareness and public capacity to respond to a flood. The following section analyses how flood risk by flood source is projected to increase in London under climate change.

Tidal Thames downstream of the Thames Barrier

The Thames tidal defences provide some of the highest standards of flood protection in the world, and therefore a major tidal flood represents a very high consequence, but very low probability risk. The Thames tidal defences are well maintained and regularly inspected, so a breach from mechanical failure is very unlikely. Rising sea levels and increasing tidal surges (see box) will mean that without further enhancements to the Thames Barrier and associated defences, the current standard of defence they provide will decrease, dropping to 1 in 1,000 (0.1%) by the year 2030 and to 1 in 100 (1%) by the end of the century.

Thames Estuary 2100 Project

The Environment Agency initiated the Thames Estuary 2100 Project (TE2100) in 2002 to identify the next generation of strategic flood risk management options for London and the Thames Estuary. The TE2100 project focuses on the increases in flood risk on the tidal Thames and in March 2009, it published a draft plan, proposing a range of actions over the short (2010-2035), medium (2035-2070) and long (2070-2100) terms. The draft plan can be downloaded from www.environment-agency.gov.uk/te2100

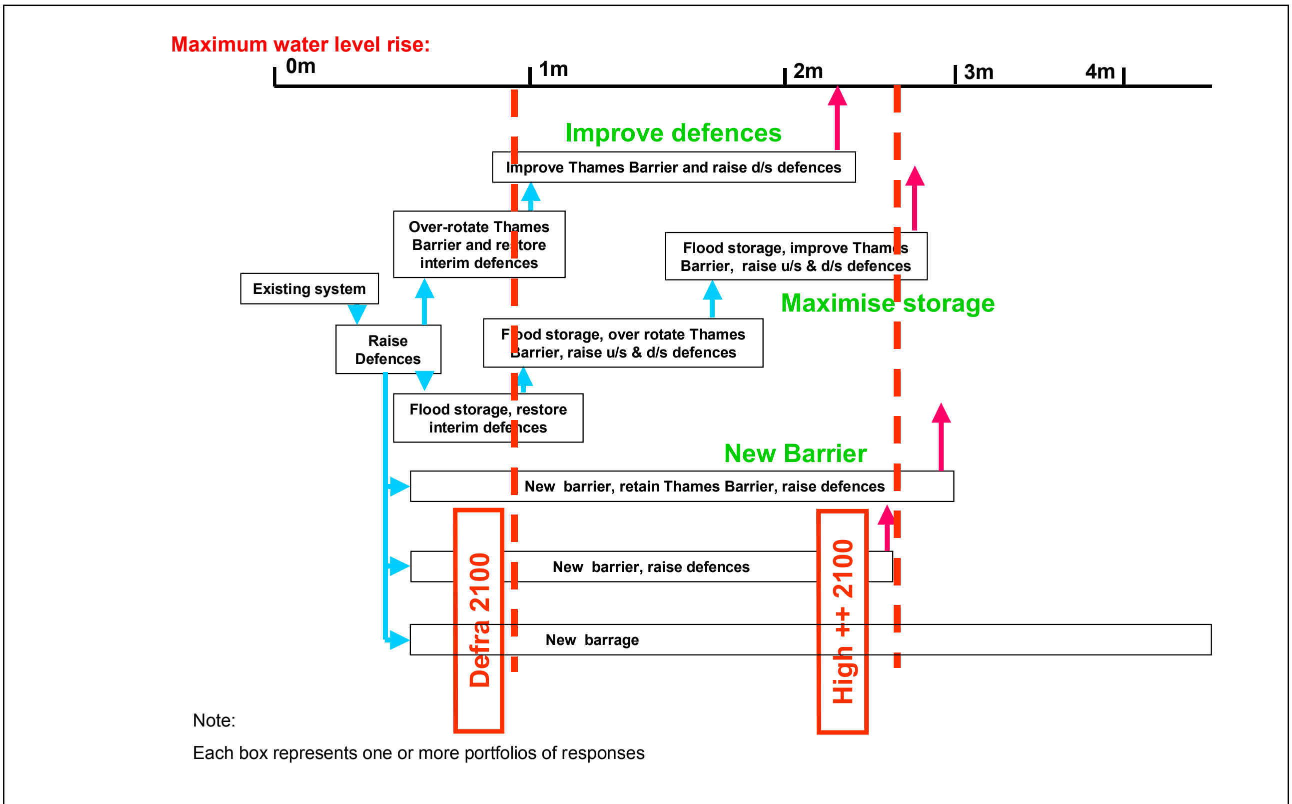
The TE2100 project identified that the current defences provide a higher standard of protection than expected and that based on current projections, no major changes to London's tidal flood defences are required within the next 20 years and it is extremely unlikely that a new Thames Barrier would be required before 2070. The following actions are proposed for the next 25 years:

- maintain the existing defences and stop the removal of temporary additions to the defences in central and west London
- work with the GLA and London boroughs to manage and reduce the consequences of flooding through spatial and emergency planning
- safeguard space for enhancement of the existing defences and opportunities to set back defences through spatial planning
- set up a monitoring regime for indicators such as sea-level rises.

The TE2100 project developed 'decision pathways' to provide a flexible approach to managing the uncertainty associated with predicting sea-level rises. The decision pathways identify the thresholds at which various flood risk management measures fail to provide an acceptable level of protection, and the trigger points, where a different approach to managing flood risk is required in response to a higher sea level rise (for example when to switch from raising flood defences and improving storage to planning for a second barrier).

Figure 3.6 shows the flood risk management options identified through the TE2100 project and the maximum level of water rise they provide protection against. It can be seen that if water levels rise as expected, by about a metre (the left hand dotted line), that all three 'pathways' (improve defences, maximise storage and new barrier) provide protection, but if water levels rise by more than three metres, that only a new barrier will provide protection.

Figure 3.6 TE2100 'decisions pathway'. The flood risk management options are plotted against the maximum level of protection against sea level rise that they can provide. The right hand dotted line shows the worst case sea level rise scenario to the end of the century (u/s = upstream, d/s = downstream) (source: Environment Agency).



Tidal Thames upstream of the Thames Barrier

The protection provided by the Thames Barrier means that the flood defences upstream of the barrier (from the barrier to Teddington in west London) are around two metres lower than defences downstream of the barrier. By using the Thames Barrier to 'keep out the tide', the barrier protects the undefended islands in the main river channel (such as Eel Pie Island) and a few areas where properties are in front of the formal flood defence line from freshwater flows up to approximately a 1-in-50-year return period (two per cent annual probability).

Options to manage flood risk in this section of the Thames include using temporary defences to protect key assets, increasing the height of the river defences, and setting back flood defences from the river's edge to create flood storage areas. The open nature of many of the riverbanks in west London provides the opportunity to consider using areas such as Ham Lands and the Old Deer Park in Richmond for flood storage. Most residents in this part of the river are already aware of local flood risk, and are more likely to be able to adopt local community-based schemes.

The number of times the Thames Barrier can be closed effectively and safely is about 70 times per year. Climate change (rising sea levels, higher tidal surges and higher river levels) will increase the number of times the Thames Barrier needs to be closed in the future. This may mean that towards the end of the century it may not be possible to use the barrier as frequently for 'fluvial dominated closures', and therefore there would be an increased flood risk in West London.

Raising the defences (flood walls) will decrease the number of times the Thames Barrier needs to close, but will increase the residual risk to the people and development behind the defences (because the water would be higher on the river side of the defence and cause more damage if the defence were to fail). It would also reduce access to, and views of the river. Since the barrier was constructed some of the interim flood defences measures (often additional boards or courses of masonry fixed to the river walls) added to protect London while the barrier was being built, have been removed.

Non-tidal Thames

The tide is stopped from going further upstream by Teddington Lock in west London, though only the highest tides get beyond Richmond Lock. Increases in rainfall due to climate change are projected to increase peak river flows in the Thames by up to 40 per cent by the end of the century. It is not possible to store this increase in flow in the upper catchment of the Thames to significantly reduce the flood risk to riverside development in west London. As with the tidal section upstream of the Thames Barrier, existing development adjacent to the flood defences will limit opportunities to set back flood defences, making improved flood prevention measures difficult to implement.

For the non-tidal Thames, more emphasis needs to be given to development control and land-use planning, as well as emergency planning and flood warning to help reduce the consequences of flooding. For development on the unprotected islands and in front of the flood defences, development owners should make their properties flood resilient or flood resistant[27].

Tributaries to the Thames

The heavy engineering approach of straightening the tributaries to the Thames and encasing them in concrete culverts has had a negative impact on biodiversity and amenity, but also encouraged development to encroach immediately adjacent to the watercourses. This makes maintaining and upgrading the defences difficult and expensive to address.

The increased areas of concrete and tarmac in London has reduced the ability for water to drain into the soil and resulted in catchments that are prone to flash flooding, which can go from low-flow to flooding within a couple of hours. Illegal fly-tipping of waste into these rivers and other blockages also significantly increases the risk of flooding and make it difficult to predict when and where flooding may occur.

Climate change is projected to increase peak flows in the tributaries by 40 per cent by the end of the century. This combined with the relatively low standards of protection on some stretches of the tributaries (see Figure 3.3) and the encroachment of development on the flood plain of the tributaries means that for some areas, little can de done in terms of flood risk management other than flood warnings, local flood resilience measures and ultimately evacuation of the areas at risk.

The Environment Agency has published the Thames Catchment Flood Management Plan (TCFMP) covering the Thames and the tributaries in London. The TCFMP identifies the strategic flood risk management options for each of the tributaries. These options are developed by analysing the areas at flood risk today and where climate change will increase the extent and depth of flooding in the future.

Currently the TCFMP only models an increase of 20 per cent on peak flows for climate change. This modelling suggests that increased peak river levels will increase the probability of a flood, but that the consequence of a flood will not drastically increase. This is because higher river levels will not lead to new areas being flooded, but may lead to deeper floods in existing areas at risk. The Mayor believes that the Environment Agency should consider undertaking a sensitivity analysis using a 40 per cent increase in peak river levels.

The Environment Agency is working with the London boroughs to agree the local actions necessary to implement the options identified in the TCFMP. Progress towards delivering these agreed actions is monitored by government through National Indicator 189[28]. The Mayor believes that this is a good start and will work with the Environment Agency and the London boroughs to review the key actions and ensure that long-term actions are integrated into the boroughs' Local Development Frameworks.

All local authorities are required to undertake a Strategic Flood Risk Assessment (SFRA) to assess their flood risk now and in the future. In London, most boroughs have published, or nearly completed their SFRAs. The Mayor recommends that when they review their SFRAs, those boroughs facing a shared flood risk should collaborate in their reviews, to ensure a more integrated approach to flood risk management.

Storm drainage and surface water flooding

As with many urban areas, London has a large amount of impermeable surfaces (roofs, pavements and roads). The capital is therefore reliant upon storm drains and the combined sewer system to take rainwater away to prevent flooding.

The probability of surface water flooding in London is much higher in comparison to tidal flooding, and will increase for the following reasons:

- most drainage systems are designed for high frequency, low volume rainfall

- many drains and gullies are poorly maintained and therefore unable to provide even moderate levels of service
- there is a projected increase in winter rainfall and heavy rainfall events
- the permeability of the urban realm has been reduced by developments using impermeable materials and exacerbated by waterlogged clay soils.

An assessment[29] of London's drainage system concluded that even a small increase in rainfall could require the significant modification of the drainage system to maintain current service levels. Managing surface water flooding will be difficult as the ownership and management responsibilities for drainage systems is complicated. This confusion over responsibilities led the GLA in 2007 to create a partnership of all the agencies responsible for surface water flooding. This partnership, known as the Drain London Forum, has secured funding from DEFRA to undertake a strategic analysis of surface water flood risk in London, prioritise areas of high flood risk and develop a framework for collaborative action (see Actions 2, 3, 4 and 9).

As noted previously, because London's rivers form part of the drainage network, and many of the solutions to managing fluvial and surface water flooding are about reducing the rate at which rain enters the drains and then the rivers, the Mayor proposes that fluvial and surface water management must be considered together.

The London Plan introduced a sustainable drainage hierarchy policy (policy 4A.14) to encourage better surface water management. The policy is beginning to have a positive impact on large developments but also needs to be addressed on smaller sites and infill developments.

A report by the London Assembly[30] identified that an area in excess of 22 Hyde Parks had been paved to create private parking on the front gardens of domestic dwellings. The Mayor believes that this loss of permeability, in combination with the finite capacity of the drainage network, will lead to increased surface water flooding in the future as rainfall intensifies. The government has changed the regulations on permitted development to require homeowners to seek planning permission to pave an area of front garden greater than $5m^2$ unless using permeable paving.

The London Borough of Camden commissioned consultants to maintain the surface water and foul water drainage network relating to their social housing. The consultants found that many of the drains were operating at less than 40 per cent capacity due to poor maintenance. Effective maintenance was able to restore full capacity to most of the network. The Mayor will work with Thames Water, Transport for London and the London boroughs to encourage these organisations to increase the maintenance of culverts and drainage systems (potentially targeting critical drainage areas ahead of predicted heavy rainstorms).

Emergency planning and response

The efficiency of the response to a flood and the recovery after a flood can be crucial to limiting the impact of a flood. Proactive emergency planning is therefore vital, together with regular exercises to test and review the efficacy of the plans and maintain awareness. Prior to the construction of the Thames Barrier, London relied on the London Flood Plan[31] to co-ordinate a response to a major flood and regular public flood drills were held to maintain awareness. Following the construction of the barrier and the increased level of flood protection it provided, the Flood Plan lapsed and drills ceased.

The London Resilience Partnership[32] has prepared a *London Flood Response Strategic Plan*[33] to replace the outdated London Flood Plan. The main objective of the Plan is to ensure a co-ordinated response to a flood to protect life and wellbeing, but also to reduce damage to the environment and property. The plan covers tidal and fluvial flooding, but the procedures apply also to surface water flooding resulting from excessive rainfall. The plan also identifies the thresholds at which the response escalates from a local response (managed by local emergency services, the affected borough and other resilience partners) to a regional response (managed by a Regional Civil Contingencies Committee[34]).

A flood with only localised impacts is managed by the local emergency services, representatives from the affected borough and other resilience partners using the borough's own Flood Plan and the command and control protocols agreed by the London Emergency Services Liaison Panel (LESLP)[35]. All boroughs are required to produce Multi-Agency Flood Plans by the end of March 2010.

Recovery

Recovery is the final phase of flood risk management, but is a phase that is usually overlooked, or underestimated. Surveys of people who have experienced flooding show that it is the recovery period that causes the most distress and when the costs of a flood event can escalate.

At the Regional level, the London Recovery Management Protocol[36] contains details for the co-ordination of recovery efforts following a regional emergency. The protocol includes details for the membership, agencies' roles and responsibilities and areas of activity for a multi-agency recovery group. This document has been used by some local authorities as a basis for a local recovery plan.

Boroughs should recognise that the impacts of a flood persist long after the flood has gone and initial emergency funding spent. All boroughs are required to produce Flood Recovery Plans and should consider the following issues:

- Community recovery – housing displaced people (sometimes for over a year after the flood), providing assistance with insurance claims, offering long-term counselling for people suffering post-traumatic stress, managing the impacts of increased local unemployment due to local business failing, or people not attending work or losing jobs to look after children unable to attend school.

- Clean up costs – disposing of flood-damaged goods and other waste, decontaminating public buildings and lands, impacts on borough waste targets (note that some local authorities affected by the 2007 floods not only lost funding for being unable to meet their recycling targets, but also had to pay increased landfill taxes to dispose of flood damaged household contents).
- Loss of revenue – temporary suspension of community and business charges and other income sources such as council taxes, parking fees and fines.

Chapter 4 Drought

Vision

To achieve a sustainable balance of supply and demand for water in London by 2030 and make London more robust to drought.

From vision to policy

Policy 2. The Mayor will work with partners to improve the sustainability of London's water supply and demand balance and make London more robust to drought by:

- taking a strategic view of London's water resources
- reducing the demand for water in London
- improving our response to drought.

From policy to action

In an average year, London has enough water for its needs, but only by withdrawing more water from the environment that it can sustain. Climate change and London's growth will put further pressure on London's water supplies. **We need to take a strategic view on London's water resources.**

Action 10. The Mayor will publish and regularly review a London Water Strategy that presents a London-specific view of managing water resources, with the goal of improved water management – both the water we want (such as drinking water) and the water we don't (such as sewage and floodwater in the wrong place).

Action 11. The London Water Group will undertake a study to define 'water neutrality' in London and explore how strategic scale, water-efficiency measures could make London more resilient to drought and long-term changes in water resources.

Action 12. The Mayor will lobby the water utility regulator, OfWat, to encourage and enable the water companies to deliver greater household water efficiency savings and greater investment in London's water infrastructure.

London must reduce the amount of water it consumes, both to reduce our impact on the environment of our demands for water and to improve our resilience to drought.

Action 13. The Mayor will work with the boroughs (through the Home Energy Efficiency Programme) to improve the energy and water efficiency of up to 1.2 million homes across London by 2015 and with businesses and the GLA estate managers to improve the energy and water efficiency of public and commercial buildings in London (through the Green 500, Building Energy Efficiency Programme and the Mayor's Green Procurement Code).

There are national and water company responses to drought, but there is no London-specific emergency drought plan. **We need to improve our response to droughts.**

Action 14. The Mayor recommends that the London Resilience Partnership should review the need for a London-specific Drought Plan.

Background

Water supply

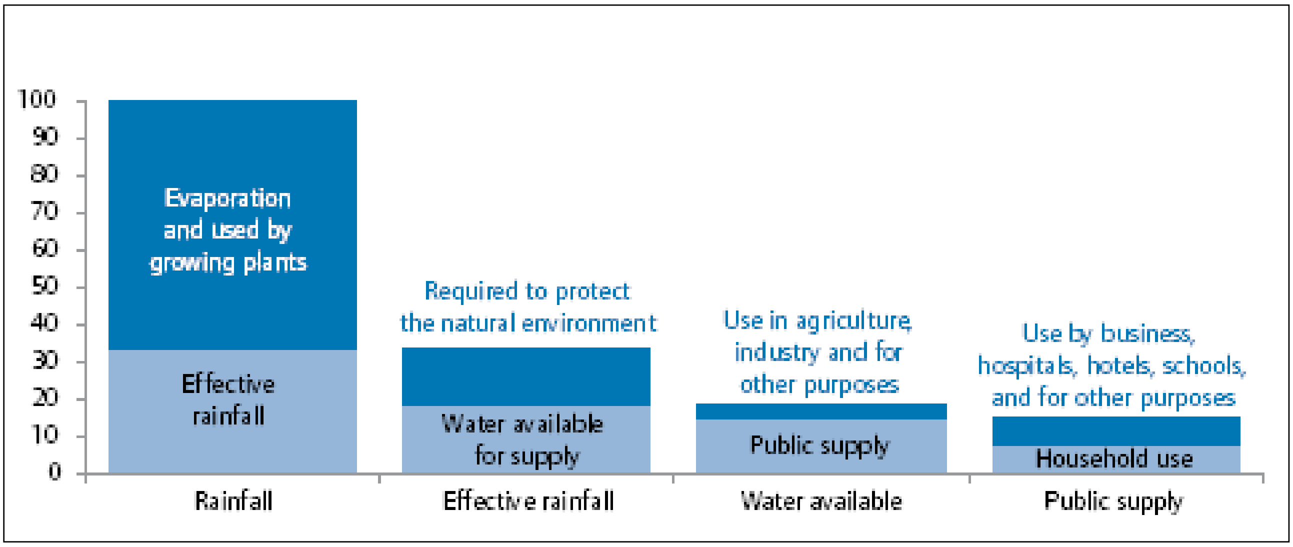
Drought is caused by lack of sufficient rainfall. Droughts can be short and sharp, as experienced in the hot summer of 2003, or prolonged, such as the two dry winters experienced in 2004/05 and 2005/06. However, the way water is managed can affect the way a drought impacts upon us and on the environment. If demands for water are high, a lack of water supplies increases the likelihood and frequency of drought management measures, such as water restrictions.

Eighty per cent of London's water comes from the Thames and the River Lee and is stored in reservoirs around London. The remaining 20 per cent is groundwater, abstracted from the chalk aquifer that lies underneath London. Both the rivers and the aquifer are fed by rainfall. Winter rainfall is particularly important, because it is over the winter months that rainfall replenishes groundwater stores, and it is these stores that help maintain river flows and abstractions in the spring and summer. Reservoirs are also filled over the winter.

The Thames basin is the largest river basin in southeast England and is therefore relatively robust in times of drought. London is in the lower reaches of the Thames basin and this means that it benefits from the combined groundwater discharge into rivers (known as baseflow) from the extensive aquifer systems of the Chilterns, Berkshire Downs and Cotswolds.

An annual average of 690mm of rain falls in the Thames catchment. Two-thirds of this is lost through evaporation, or used by plants, leaving just 235mm. Fifty-five per cent of this remaining portion is then abstracted, a higher proportion than any other region in England and Wales[37], leaving approximately 45 per cent of the 'effective' rainfall to feed our rivers and wetlands (see Figure 4.1). This means that only 13 per cent of the original rainfall actually forms part of our water supply. The large population in southeast England, combined with the relatively low level of rainfall means that the amount of water available per person is strikingly low in comparison to many hotter, drier countries.

Figure 4.1. What happens to rainfall in the Thames catchment



Four water companies supply water to London. Table 4.1 shows the proportion of London's population served by each water company and the amount of water supplied by each company.

Table 4.1 Water company supply statistics for London (source: OfWat 2008-09 June Returns)

Water company	Proportion of London's population served (%)	Overall water supplied in 2004/5 (million litres/day)
Thames	79.5	1,870
Three Valleys	11.9	281
Essex and Suffolk	5.8	136
Sutton and East Surrey	2.8	67
		Total 2,354

Water demand

Domestic water use in London has increased by about 50 litres per person per day since the 1970s. Each Londoner now consumes an average of 161 litres per day, compared to the national average of 150 litres per person per day[38]. This increased consumption is primarily linked to affluence (more water consuming devices per home) and lower occupancy rates (smaller household units, such as flats, each with water consuming devices). Table 4.2 shows how individual water use decreases as the number of occupants increases.

Only one in four households in London has a water meter[39]. The remaining 80 per cent of properties pay a flat rate for their water, largely based on the historic taxable value of their property.

Over 600 million litres a day, nearly a quarter of all the water distributed in the water mains network, is lost in leakage. This is due to three reasons:

- Much of London's mains water network is the legacy of Victorian engineering. Thames Water estimates that nearly a third of the water pipes making up its network are 150 years old, and about half of them are 100 years old.
- A large proportion of London is built on clay, deposited on the former floodplain of the Thames. This clay is prone to shrinking and swelling in response to changes in soil moisture content (respectively known as subsidence and heave). This movement causes the pipes and joints to break.
- London clay is particularly corrosive and weakens the pipes, increasing the risk of breakage due to subsidence and heave and vibrations from construction and transport.

Balancing supply and demand

To avoid running out of water, or abstracting more than the environment can sustainably provide, it is important to balance the supply of, and our demand for, water. In most years, there is sufficient water in the Thames, the River Lee and the aquifer to meet London's current demands, but sustained periods of low

Table 4.2 Water consumption according to household occupancy (source: Thames Water)

Number of occupants	Individual water consumption (litres/person/day)	Reduction per person compared to a single person household (%)
Single occupancy	207	0
2 people	172	17
3 people	148	29
4 people	135	35
5 people	131	37
6 people	127	39

rainfall result in water being drawn from the reservoirs. To manage the remaining reserves, water companies can apply to the government to initiate drought measures.

Water companies must produce Water Resources Management Plans detailing how they currently balance supply and demand for water and how they intend to provide sufficient water to meet demands and protect the environment over the next 25 years. These plans are updated every 5 years, when they are presented to the water regulator, OfWat, along with proposals for the funding the water companies need to deliver these plans. The water companies must also consult the Environment Agency on these plans.

In calculating the supply-demand balance, water companies must make an allowance for uncertainties including the fluctuation in supply due to periods of low rainfall, for other supply-side losses such as leakage and variations in public demand for water. These uncertainties are bundled together in an allowance known as 'headroom'. If a water company predicts that demands plus headroom will exceed supply, its Water Resources Management Plans must state how they will seek to reduce the deficit, such as reducing leakage, reducing demand, and increasing supplies through new abstractions.

Water companies require the permission of the Environment Agency to abstract water from the environment. The Environment Agency produces Catchment Abstraction Management Plans to determine how much water the environment needs and therefore how much water is available for abstraction. The London Catchment Abstraction Management Strategy[40] covers the Thames and tributaries to the Thames and highlights that most of London's catchments are considered to be 'over licensed' or 'over abstracted' – terms that describe the potential for, or actual damage to the environment caused by abstractions when the catchments have low flows. Under the Water Framework Directive, the Environment Agency will be required to identify the catchments where over-abstraction is causing environmental damage, and reduce abstraction through amendments to abstraction licenses.

The Water Act 2003 requires water companies to have sound drought plans in place so that they can continue to supply water to their customers when resources are depleted. Drought management measures can be divided into two approaches: demand-side measures that seek to influence a voluntary reduction in demand from consumers before implementing legislative bans and restrictions on distribution; and supply-side measures that seek to increase the amount of water in supply. Table 4.3 provides examples of Thames Water's drought management measures.

Table 4.3 Examples of drought management measures (source: Thames Water)

Demand-side measures	Supply-side measures
• Promote awareness and voluntary constraint through media campaigns • Enforce sprinkler and then hosepipe bans to reduce water consumption. • Apply for a 'non-essential uses Drought Order' to ban 'discretionary' uses (for example using mains water to irrigate public parks, or sports grounds). • Finally, apply for Emergency Drought Orders to implement cuts to supply and the use of street standpipes and water tankers to provide water.	• Supply is enhanced by maximising output from existing abstractions. • Increase emphasis on finding and fixing leaks as they occur in favour of the mains replacement programme. • Increase supply through strategic groundwater resources, such as aquifer recharge systems. • Apply for Drought Permits to increase levels of abstraction (for up to six months) • Finally, apply for Drought Orders to allow further increases in abstraction

Water companies must apply to the Secretary of State for Environment, Food and Rural Affairs for a Drought Order. Emergency Drought Orders are a last resort method to reduce demand, when all other demand management and supply enhancement possibilities have been exhausted. Emergency Drought Orders may mean that supply restrictions or interruptions are implemented to reduce demand to balance the available levels of supply.

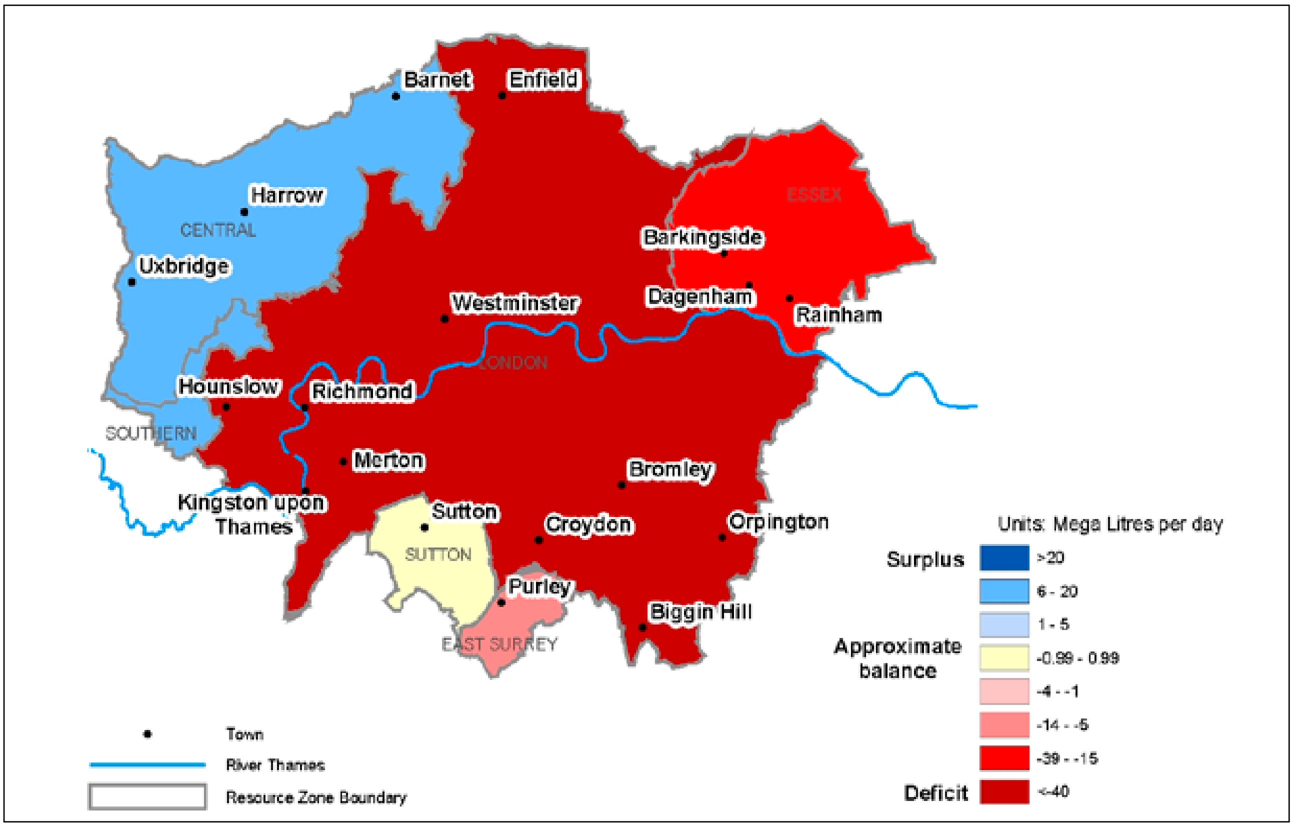
It should be noted that, in practice, rota cuts would not work in London as parts of the mains network would not be able to manage temporary reductions in flow (pipes would break and sediment may enter the network), plus people would be likely to 'hoard' water ahead of a publicised cut, so increasing demand. In case of extreme drought, bottled water may have to be distributed, though it is unlikely that there would be sufficient capacity to do this effectively at a large scale.

Baseline

Probability

The probability of a drought affecting Londoners depends upon how much rain falls, how long periods of low rainfall last (particularly over winter), and how sensitive the supply-demand balance for the area in question is to drought. Water companies divide their supply area into smaller 'water resource zones', which are defined on the basis of water supply connectivity. Figure 4.2 below shows the six water resource zones in London, highlighting the estimated average water availability for 2008-09[41]. It can be seen that only the 'central zone' in northwest London has a surplus, whereas the rest of London has either an approximate balance, or is in deficit.

Figure 4.2 Supply-demand balance within Greater London (in a dry year[42]) for 2008/09 (1 mega litre = 1 million litres), (source: Environment Agency)



In a dry year, Thames Water currently forecasts that its demand for water in its London resource zone (the darker red area in Figure 4.2) would be about 40 million litres per day greater than its available supply[43]. This is equivalent to about half a million people's daily demand. This deficit is largely attributed to the high level of leakage from its distribution network.

Consequence

The consequences of a drought are experienced by those affected by drought management measures. To date the water companies, with the co-operation of the public, have been effective in managing droughts and preventing the need to implement a non-essential uses ban (see Table 4.3). Table 4.4 below lists the demand restriction measures implemented by the water companies supplying London.

Table 4.4 Demand restriction measures in London, 1976 to present

Water company	Demand restriction
Thames Water	Hosepipe ban in 1990 (Oxfordshire/Swindon zone) Company-wide bans in 1976 and 2006
Three Valleys	Hosepipe ban in 1992 and 2006
Sutton and East Surrey	Sprinkler ban from May 1997 to May 1998 Hosepipe ban and non-essential uses ban in 2006
Essex and Suffolk	Hosepipe ban July 1990 – October 1992 (Essex zone) Hosepipe ban June 1997 – April 1998

There is no record of impacts upon the environment, but wetlands and rivers will have been affected by these dry periods.

Exposure and vulnerability

As water companies have a responsibility to provide water to their customers, the main group of people vulnerable to drought are those who would be financially affected by non-essential uses bans enforced in a 'Non-Essential Use Drought Order'. The impact of a non-essential uses ban is widespread, affecting private companies that provide water using cleaning and leisure services, and on the public.

The environment is also vulnerable to drought (see Chapter 7). Wetlands and watercourses can withstand some degree of seasonal fluctuation in rainfall, but extended drought periods will affect the ability of some species to survive, either through wetlands prematurely drying out, or through the higher water temperatures and lower oxygen levels that are associated with low river flows. Low flows also reduce the dilution of any pollution entering the watercourse, so increasing the rate of eutrophication and stagnation.

Many of London's rivers, watercourses and wetlands can be highly eutrophic[44] for parts of the year, through receiving nutrients from agriculture further up the catchment, urban runoff, diffuse pollution (especially miss-connected sewers) and treated effluent from sewage treatment works.

Lastly, the loss of some key species may dramatically affect the composition of some habitats, having a knock-on effect on other species, leading to a fundamental change in the habitat. The use of drought permits to increase abstraction from rivers is particularly damaging, as it reduces the flows in rivers further at a time when they are most needed. Salt-water intrusion from the tidal Thames may also become an issue where coastal groundwater levels drop due to abstraction/reduced recharge and sea level rise.

Analysis

Analysis of the baseline shows that London already faces limited water resources and is currently vulnerable to drought. The impacts of previous droughts have not been severe and the aquifers have been quick to recover following a drought. However, contingency planning for the drought created by the consecutive dry winters of 2004/05 and 2005/06 highlighted that implementing rota cuts and standpipe delivery in London would have disastrous consequences for the city. It is therefore of great importance that London's water supply-demand balance is made resilient to climate change.

- Climate change is expected to affect water availability by:
- reducing river flows
- reducing groundwater replenishment ('recharge')
- increasing evaporation
- increasing loss from broken water mains due to increasing subsidence
- increasing demand for water from people and wildlife.

Water companies present their business plans to OfWat, which then assesses the cost-effectiveness of the proposals. The water industry is regulated to reduce costs and ensure security of supply. This tends to mean that water efficiency measures are more difficult to justify than supply-side proposals. The Mayor believes that OfWat should do more to encourage and enable demand-side measures, particularly in households.

Reducing river flows

Climate change is not projected to alter the amount of rain that falls in a year, but it will affect when rain falls, and how heavily it falls. Drier summers will mean that rivers will receive a reduced contribution in the amount of rainfall that can prevent low flow rates. Heavier winter rainfall will mean that a greater proportion of the rain runs off the ground into rivers, increasing flood risk, rather than being absorbed and adding to the groundwater that provides the baseflow for the following year.

In drought periods, over 75 per cent of the freshwater flows in the Thames can be abstracted, reducing the normal flow of the river. In a severe drought, emergency legislation can allow further abstraction, reducing freshwater flows in the Thames to ten per cent of normal flows. Lower river levels means that pollution becomes more concentrated, so has a greater effect on wildlife.

Reducing groundwater recharge

In the southeast, the amount of groundwater present during the summer and early autumn generally governs whether drought restrictions will be experienced. The level of winter rainfall in turn determines the groundwater levels. Climate change will reduce summer rainfall and therefore reduce the minimal summer groundwater replenishment ('recharge'), while the heavier winter rainfall may run off into the rivers before it is able to be absorbed into the ground to recharge the aquifers.

Increasing evaporation

As stated previously, two-thirds of rainfall in the Thames catchment is lost to evaporation, or used by plants. Hotter summers and more cloud-free days will increase the rate of evaporation even further.

Increasing loss from broken water mains due to increasing subsidence

As described earlier, the combination of a very old distribution network, corrosive soils and ground movement means that London experiences the highest levels of leakage in the UK. More seasonal rainfall will cause soil moisture levels to fluctuate more dramatically, increasing the amount of subsidence and heave, resulting in more damage to the mains distribution network. However, warmer winters with less snow and frost will reduce the amount of water lost through frozen pipes and cold-induced heave.

Increased demand for water from people and plants

In hot weather, peak demand for water increases. This increased demand comes from the need to water gardens, use of paddling pools and people washing more frequently. Analysis suggests that the peak demand in London in 2006 (a drought year) was nearly double that in 2007 (a comparatively cool and wet summer)[45].

Hotter, drier summers will increase the rate of transpiration in plants, drawing more water from the soils. This transpiration has the benefit of providing evaporative cooling, helping to reduce London's temperatures, but can add to the subsidence in soils, contributing to the damage of buildings. Warmer winters will lengthen the growing season, increasing the demand for water from vegetation, and also reduce the winter recharge period for aquifers.

Response

The Mayor's draft Water Strategy[46] proposes a hierarchy of actions for managing water supply and demands in London:

1 = Reduce the loss of water through better leakage management.
1 = Improve the efficiency of water use in residential and commercial development (new and existing).
3 Use reclaimed water for non-potable uses (grey water recycling and rainwater harvesting).
4 Develop, as necessary, those water resources that have the least environmental and climate impact.

The Environment Agency estimates[47] that 89 per cent of all the carbon emissions from water use comes from homes. This is greater than the level of emissions from aviation in the UK[48]. As 27 per cent of the carbon emissions from homes comes from heating water for washing and cleaning, reducing the amount of hot water used in the home can therefore save energy as well as water, reducing both energy and water bills (in metered homes).

The Environment Agency has proposed the concept of 'water neutrality' to help balance the supply and demand for water over the longer term. The basic premise is that new development should not lead to an overall rise in demand for water. The definition of water neutrality used by the government and the Environment Agency is: *'For every new development, total water use across the wider area after the development must be equal to, or less than, the total water use across the wider area before development.'*

The Mayor believes that the concept of water neutrality should include not just keeping demand static, but actually seeking to reduce demand at a rate that provides a buffer against climate induced reductions in supply. The London Water Group[49], chaired by the GLA, will investigate the concept in more detail and how it could be delivered in London. The group's findings will feed into the next review of the London Plan, the Mayor's Water Strategy and the Adaptation Strategy.

Better leakage management

Currently a quarter of the water that has been treated and pumped into the distribution system is lost in leakage. The Mayor's draft Water Strategy calculates that if the amount of water lost through leakage were halved, then an additional two million people could theoretically be supplied with water (at our current daily consumption of 161 litres per person). This would mean that more than double the expected growth in London's population over the next decade could be supplied without any increase in the amount of abstraction.

The water companies, particularly Thames Water, are working to reduce leakage. Thames Water met its leakage reduction target for the first time in 2006/07, but the Mayor believes that the water companies could and should do more to reduce leakage. The high levels of leakage also fuel public resentment towards water companies when drought measures such as hosepipe bans are imposed, making communicating water efficiency measures more difficult.

Improving water efficiency

- Improved water efficiency in London can be achieved through:
- water metering of all properties in London
- improving water efficiency standards in new development
- retrofitting water efficiency measures in existing homes
- changing consumer behaviour to conserve water.

Water metering

Currently only one in four properties in London has a water meter, which is below the national average of one in three properties. Research has shown that household metering reduces water use by 10 – 15 per cent[50].

The low level of metering in London is partly due to the high number of flats in London (nearly a third of all property in London are flats). It is more difficult to fix meters in flats because of the complexity of their plumbing systems and the difficulty in gaining access to flats to rearrange the plumbing system. The Mayor's draft Water Strategy proposes that all houses should have water meters installed within the next ten years and all flats within the next 20 years.

It is important that changing the way people pay for their water does not cause financial problems for those on low incomes. An analysis[51] of how more widespread metering would impact on residents in Southeast England found that on balance, most Londoners would have lower water bills, but that as the amount of metering rose to 90 per cent of households, poorer and larger households could face larger bills. The study also showed that there were a range tariffs which affected the affordability of water, but no single tariff completely removed the price increases for London's poorest families. This highlights the need to twin water metering with water efficiency improvements to help all Londoners save money and water.

Improving water efficiency in new buildings
It is much easier, and cheaper to make new buildings water efficient, rather than retrofitting them at a later date. Research undertaken for the Environment Agency[52] shows that the cost of installing water-efficient fittings and appliances to enable a predicted per capita consumption of 100-120 litres per day would cost between £189 and £284 per household more than regular fittings and appliances.

All new social housing is required to be built to a water efficiency standard of 105 litres per person per day and from April 2010 all private housing will be required to meet a water efficiency standard of 120 litres per person per day. The consultation draft replacement London Plan proposes that all new homes should be built to the 105 litres per person per day standard (Policy 5.15, p132).

Water efficiency can extend outside the home. Water efficient, or drought-resilient landscaping and gardening will help reduce the need for water. These could include planting drought resilient species or those that require little water, using automated irrigation systems that do not irrigate in wet weather or drip feed rather than inundate, reducing evaporation through mulches and watering at night, and using rainwater or grey water (see below).

In London, non-domestic water use accounts for 29 per cent of water consumption. The biggest consumers are the 'service' sector (offices) and education and health services (schools and hospitals). There is therefore significant potential to save water, and as these buildings will be metered, to save money.

Retrofitting existing buildings
The number of new homes built in one year in London is about one per cent of the number of the total number of existing homes. Therefore, to make significant progress in adapting London, we must focus on helping Londoners make their existing homes more water efficient.

The Mayor is committed to improving the water and energy efficiency of homes in London. The Mayor is working with the boroughs to deliver a Londonwide home efficiency upgrade programme that will save water and energy, as well as reducing Londoner's carbon emissions, energy bills and water bills (for those with a meter). This programme is known as the Home Energy Efficiency Programme (HEEP) and is explained in the Mayor's draft Climate Change Mitigation and Energy Strategy (CCMES).

The Mayor is also working to improve the water and energy efficiency of existing office buildings through a number of programmes. The Building Energy Efficiency Programme (BEEP) looks at reducing carbon emissions from public sector buildings, whilst the 'Green 500' is primarily a carbon management programme for large businesses in London, but it will also support businesses in adapting to climate change through activities associated with improving water efficiency and reducing cooling demand. Further details can be found in the draft CCMES.

Changing consumer behaviour

People's habits can contribute to or reduce water efficiency, independent of whether water efficiency fixtures and fittings are in place. Everyday actions can save water, cost nothing and have little, or no impact on the quality of life. For example, showering rather than having a bath can save 35 litres of water (an average bath volume is 80 litres versus the 45 litres used in an average five-minute shower). Helping people to be aware of their actions and opportunities to save water all year round (rather than just during a drought) could significantly reduce the need to implement drought measures.

Using reclaimed water

'Reclaimed water' refers to the use of rain or grey water (water from showers, baths or basins) for non-potable uses, such as toilet flushing or outdoor water uses. As nearly a quarter of our daily domestic water consumption does not require water that is of drinking quality standard, there is clearly a significant opportunity to supplement mains water with reclaimed water. The Mayor's draft Water Strategy proposes that major new developments should provide a significant proportion of their water requirements through water reclamation.

The benefits of reclaimed water

Using reclaimed water requires a storage tank and depending on the intended use, a filtration/treatment system and a separate supply system. Rainwater harvesting is the simplest and least expensive reclaimed water option. Rainwater harvesting can be scaled up from domestic water butts connected to roof gutter downpipes to large storage tanks. While rainwater harvesting will not remove the need for a connection to mains water, it can displace mains water for non-potable uses and simultaneously provide a reduction in flood risk (through reducing surface water flooding and the volume of water entering the combined sewer system). Given that 690mm of rain falls on London annually, rainwater harvesting provides an attractive option to improve water efficiency. It is worth noting that rainwater harvesting does not exclude other climate adaptation options such as green roofs, cool (high albedo) roofs and sustainable urban drainage systems, which also can be designed to encourage biodiversity.

Develop new resources

As previously discussed, abstracting more water from the environment is not a sustainable option. Groundwater levels have been rising below London as industrial use of water has fallen, but the amount of groundwater we abstract has increased to compensate and we cannot now abstract any more without causing damage to the environment. The options to increase supply are therefore fourfold:

- desalination
- effluent reuse
- increase in reservoir capacity
- artificial groundwater recharge.

Desalination

Desalination is the practice of removing the salt from seawater to produce drinking water. Thames Water is building a desalination plant at Beckton in east London, which will abstract and treat water from the Thames. The Mayor will work with Thames Water and the Environment Agency on the terms of operation of the desalination plant to ensure that the environmental impact of the plant is minimised.

Effluent reuse

Effluent reuse is the treatment and use of wastewater discharged from sewage treatment works. As effluent is a predictable, reliable resource, it provides a potentially attractive resource option. The Environment Agency estimates that there is the potential for a 700 million litre supply of water per day from effluent reuse in the southeast. The main concerns with effluent reuse are the need to protect public health, the fact that effluent often forms a significant proportion of some rivers' flows in dry periods, and that effluent treatment is also an energy-intensive process. Essex and Suffolk Water have operated an effluent recycling plant at Langford since 2003, which can provide up to 35 million litres of water per day.

Increase in reservoir capacity

As 80 per cent of London's water already comes from reservoirs, increasing the size or number of reservoirs around London presents an obvious option to improving supply, and seven water companies operating in the southeast of England have proposed extending or creating new reservoirs. The only reservoir proposal of potential benefit to London is Thames Water's Upper Thames Reservoir in Oxfordshire. The cost of building this reservoir is about £1 billion and it would be paid for through water bills.

Reservoirs require large areas of land, are costly to build and are reliant upon winter rainfall to provide water for later in the year. Any assessment of reservoirs as a supply-side option should consider the increasing seasonality of rainfall, together with the ability to capture and store peak river flows.

Artificial groundwater recharge

An alternative to storing water in reservoirs above ground in a reservoir is to inject water into the underground aquifer. Thames Water operates the North London Aquifer Recharge Scheme (NLARS), where water is abstracted from the River Lea in winter, the water is treated and injected into the aquifer and then abstracted from the aquifer during dry periods. This option requires the water to be 'double-treated' before being put into distribution – once before being injected into the aquifer and once again when abstracted before being put into distribution, and therefore has a high associated energy cost. There are also very few sites where this option is practicable, as it is reliant upon the geology of the aquifer being suitable for storing additional water.

Emergency response

The drought of 2004-06 showed that London is vulnerable to prolonged periods of drought, and that many demand management measures for coping with extreme situations, such as cuts and standpipe delivery would be very difficult to implement in London. The Mayor recommends that London Resilience should review the need for a London-specific Drought Plan.

Subsidence and heave

Much of London is built on clay deposited on the former floodplains of London's rivers. Clay expands and shrinks according to its water content. Dry clay shrinks, causing land levels to fall locally, whereas wet clay expands and land rises. More seasonal rainfall due to climate change may cause greater seasonal soil movement. For most of London, this movement is minimal and unnoticed. But some buildings (such as those without foundations) and some infrastructure (such as escalators and soil embankments) are more susceptible to soil movement.

For individual properties, insurance and remedial work (such as underpinning) are the solutions to soil movement and therefore beyond the Mayor's influence. From a strategic perspective, the key challenges are for the transport infrastructure (see Chapter 8) and managing the perception that trees are mainly responsible for causing, or accentuating subsidence (see Chapter 6).

Vision

To make London a more comfortable city to live, work and play in, and to ensure that a robust emergency plan exists for heatwaves.

From vision to policy

Policy 3. The Mayor will seek to reduce and manage the impact of hot weather on Londoners by working with partners to:

- improve the understanding of overheating risk in London by identifying who and what is affected and where is most at risk
- manage rising temperatures in London by increasing the amount of green space and vegetation in the city
- reduce the risk of overheating and the need for mechanical cooling in new and existing development and infrastructure
- ensure London has a robust heatwave plan.

From policy to action

We currently have a poor understanding of how temperatures vary across London, how the city's microclimate will intensify rising temperatures in the future and who and what are vulnerable to high temperatures. **We need to improve the understanding of overheating risk and target priority areas**.

Action 15. The Mayor will work with partners to undertake a feasibility study into creating and maintaining a network of weather stations across London to improve our understanding of London's microclimate and the impact of urban greening measures on managing temperatures.

Action 16. The Mayor will work with the SCORCHIO and LUCID projects to improve our understanding of how climate change will affect summer temperatures in the future, and to identify and prioritise areas of overheating risk and risk management options.

We believe that by increasing green space and vegetation cover in the city, we can manage and offset rising temperatures (and manage flood risk).

Action 17. The Mayor will work with partners to enhance 1,000ha of green space by 2012 to offset the urban heat island effect, manage flood risk and provide biodiversity corridors through the city.

Action 18. The Mayor will work with partners to increase green cover in central London by 5 per cent by 2030 and a further 5 per cent by 2050, to manage temperatures in the hottest part of London.

Action 19. The Mayor will work with partners to increase tree cover across London by 5 per cent (from 20 to 25 per cent) by 2025.

Action 20. The Mayor will work with partners to enable the delivery of 100,000m2 of new green roofs by 2012 (from 2008/09 baseline).

We need to reduce the risk of overheating and the demand for mechanical cooling in new and existing development and infrastructure.

Action 21. The Mayor and the Chartered Institution of Building Services Engineers will publish design guidance for architects and developers to reduce the risk of overheating, and encourage its use through the revised London Plan.

Action 22. The Mayor has proposed a new 'cooling hierarchy' policy in the draft London Plan which requires developers to reduce potential overheating and the need for mechanical cooling.

Action 23. The London Development Agency will work with the boroughs to map the opportunities for decentralised energy (power, heat and cooling) and with business, through a range of energy-efficiency programmes.

Action 24. The London Climate Change Partnership will work with a social housing landlord to undertake a demonstration project to retrofit a social housing development to reduce risk of overheating, using passive measures.

Action 25. The Mayor will work with partners to assess and promote 'cool roof technology' (highly reflective, well-insulated roofs) in London to reduce demand for mechanical cooling.

We want to ensure London has a robust heatwave plan and that Londoners know what to do during a heatwave to stay cool and save energy.

Action 26. The Mayor recommends that London Resilience Partnership should assess the benefits of having 'heatwave refuges' (publicly accessible cooled building) that can be used to provide temporary shelter during heatwaves.

Action 27. The Mayor will review the lessons learned from developing the community flood plans (see Action 9) to determine how best to encourage and enable a community-level response to heatwaves.

Background

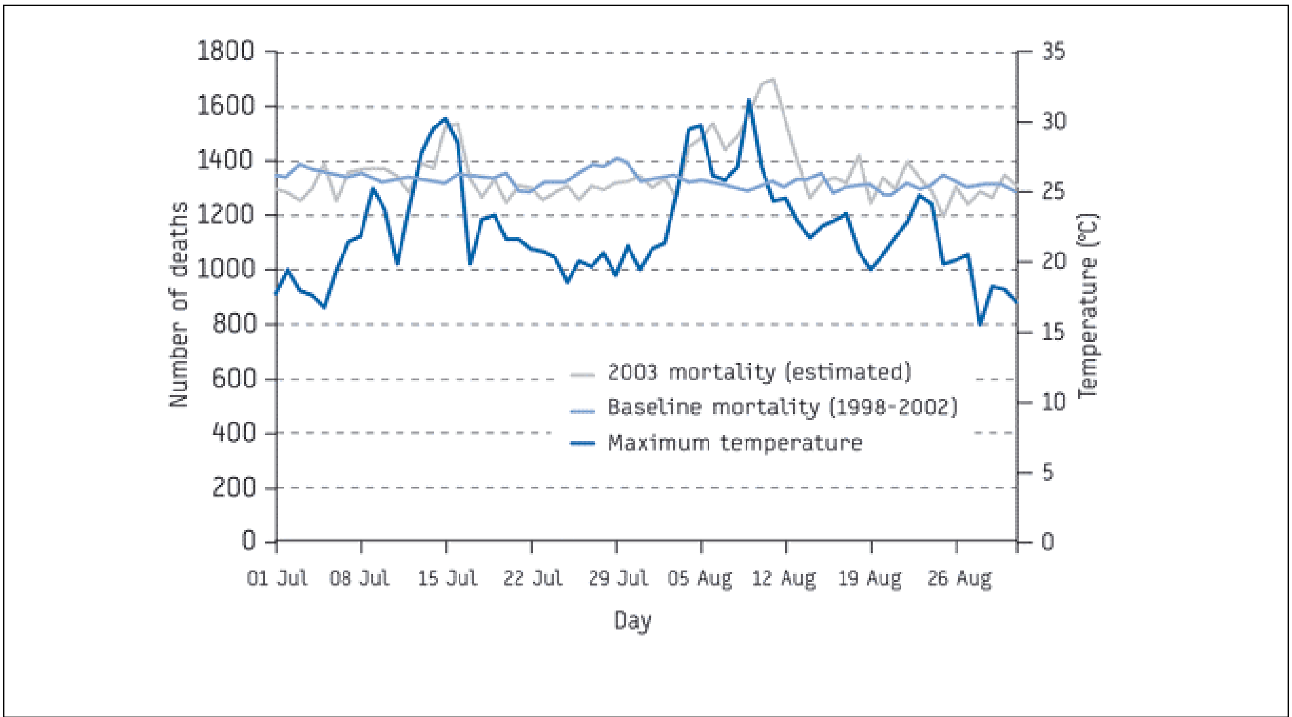
'Overheating' is a term used in this strategy to describe when temperatures rise to a point where they affect the health and comfort of Londoners. High temperatures also have an impact on London's infrastructure, buckling railway lines, melting road surfaces, making travel in the capital uncomfortable and increasing water usage and energy demand for cooling.

London's summers are still mild enough for any significant health impacts due to high temperatures to be linked to uncommon, extremely hot weather events such as heatwaves. Summers are, however, already getting warmer in London. An analysis[53] of summer temperatures in London over the past century has revealed that summers are getting progressively warmer and that the temperatures of the hottest day in each year are rising even more quickly. Nights are also getting hotter at a rate above the average rate of warming.

Extreme weather events

In England and Wales, there were 2,139 excess deaths during the August 2003 heatwave. Figure 5.1 below shows the number of deaths and maximum temperatures during the 2003 heatwave period. It can be seen that the number of deaths closely follows the maximum temperature.

Figure 5.1 Number of deaths during summer 2003 (source: London School of Hygiene and Tropical Medicine)



The August 2003 heatwave provided a dramatic example of how vulnerable London is to heat. It is estimated that at least 600 people died in London[54] because of the heatwave. The impact of the 2003 heatwave on the London population appears to have been greater than anywhere else in the UK[55]. An analysis of the excess deaths during the August 2003 heatwave for each UK government region shows that though London did not experience the highest temperatures, London had the highest number of excess deaths for any region, when adjusted for population.

Further research[56] suggests that the health response to rising temperatures in London starts at 24°C (higher than any other UK region), but once temperatures rise above 24°C, Londoners are more sensitive to temperature than any other region. The reasons for this vulnerability are thought to be a combination of a large elderly population, poor air quality (see chapter 5) and high night-time temperatures due to the urban heat island effect.

The urban heat island

The 'urban heat island' describes the warmth of the surfaces and atmosphere that urban areas often experience in comparison to the rural areas that surround them. This warmth can be seen in the way that trees come into leaf earlier in the spring in cities than in rural areas, and the reduced number of nights with frost.

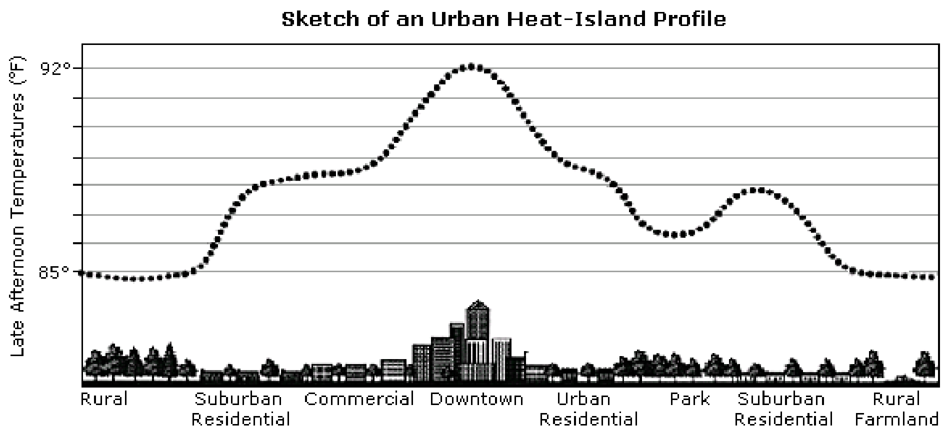
On an average summer day, the centre of London is marginally cooler (0.5 - 1°C) than rural areas, as the fabric of the buildings and roads that make up the urban realm absorbs solar energy. By early evening, the buildings and roads start to radiate this stored energy as heat, which escapes slowly, especially in narrow or tall streets where it is re-absorbed and re-radiated from the buildings that line the street. This absorption and retention of heat is why urban areas can be warmer at night than rural areas and is known as the 'urban heat island effect'.

Figure 5.2 shows the typical temperature profile of an urban heat island, highlighting how temperatures rise from the rural fringe towards the city centre. The profile also demonstrates how temperatures can vary across a city depending on the nature of the land cover, such that urban parks are cooler than adjacent areas covered by buildings, and high-density areas are hotter still.

The urban heat island effect in London peaks between 2 am and 4 am, when the air temperature in the centre of London can typically be 3-4°C warmer than outlying rural areas. This temperature differential is known as the 'urban heat island intensity'. During prolonged periods of hot, dry weather, the intensity of the urban heat island can build up night after night. During the heatwave of 2003, the centre of London was up to 10°C warmer than the surrounding greenbelt.

Cloudy, windy, or rainy days limit the intensity of the urban heat island by either preventing the buildings from absorbing as much solar energy, or by mixing the warm air with cooler, fresher air from outside the city.

Figure 5.2 Typical temperature profile of an urban heat island



In some cities, the heat generated in the city by traffic, air conditioning systems and other energy uses adds to the heat being radiated from the buildings and roads, further raising temperatures. This 'anthropogenic' (man-made) contribution to the urban heat island is currently thought to be minimal across the whole of London, but is significant in high-density areas in the centre of the city. For example, in Westminster and the City of London, modelling suggests that the anthropogenic contribution, calculated using the total energy demand for buildings and traffic, may be a significant contribution to urban heating[57]. If the use of air conditioning were to become widespread, the area affected by a significant anthropogenic contribution would increase.

The amplified night-time temperatures are important during hot weather because:

- Cool nights help people recover from the heat of the day. Hot nights therefore provide more limited recuperation, so contributing to deaths associated with prolonged hot weather (especially for the ill and the elderly).
- Hot nights prevent the city from cooling off, so increasing the demand for cooling (leading to a feedback loop of increased waste heat and rising demand for cooling).
- Hot nights can affect people's sleep, so having a negative effect on the economy and education.

Baseline

Probability

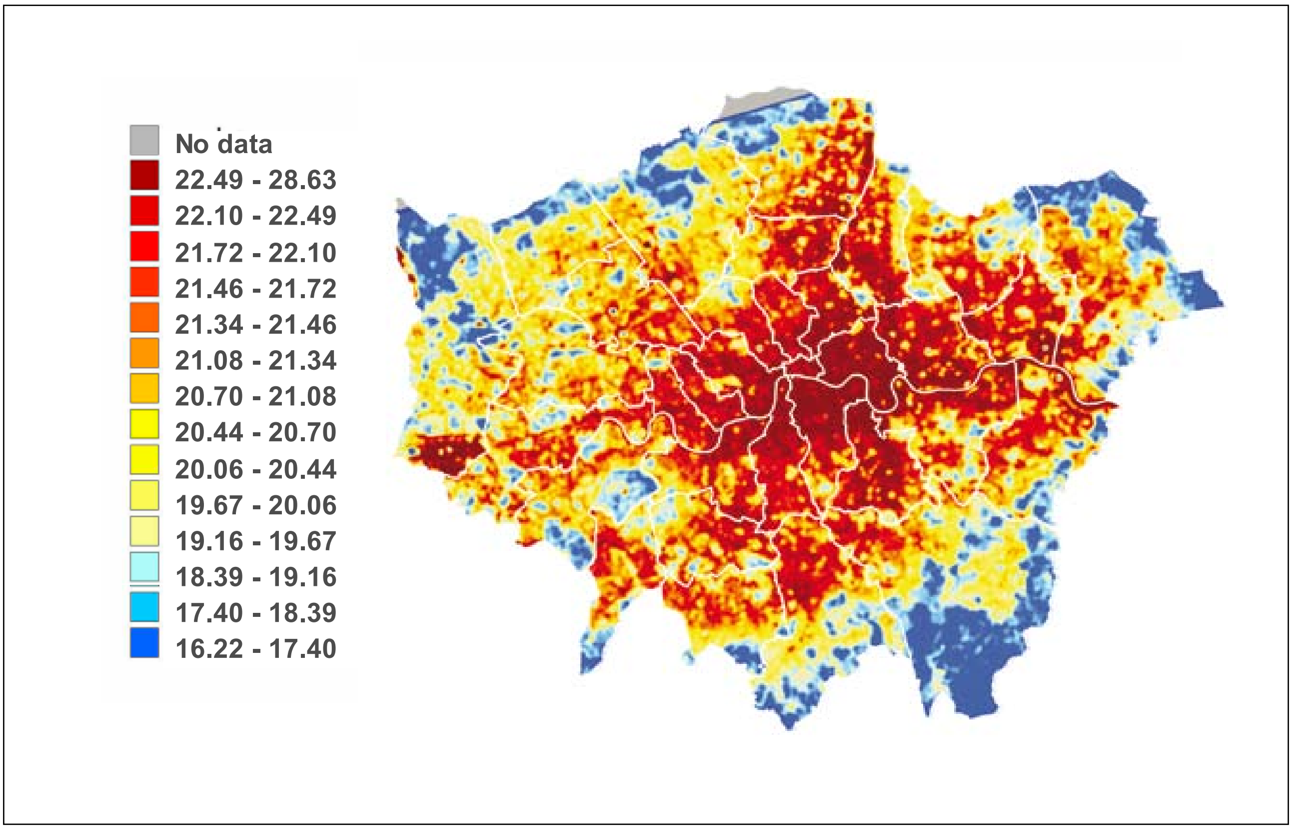
With flood risk, it is possible to map the probability of being flooded from the sea or from rivers by measuring the different standards of protection provided by the flood defences and then mapping the area protected by those defences. Mapping the probability of high temperatures in London in the future is more complicated for three reasons:

1 Unlike floodplains, heatwaves do not have defined geographic boundaries. Heatwaves typically affect the whole of the southeast of England.
2 London does not have a network of weather stations, so analysis of how the climate varies across London must be extrapolated from limited data.
3 The majority of Londoners spend a large proportion of their time indoors. Buildings modify the outdoor climate and therefore, our exposure to high temperatures (the temperature inside a building is dependent on the design of the building, its location, aspect and whether it has a mechanical cooling system).

As heatwaves affect the whole of the city, mapping the intensity of the urban heat island represents the best available measure of determining how temperatures vary across London during the summer, and therefore provides a proxy for determining areas of higher risk.

Figure 5.3 shows the surface temperature of London at a resolution of 90m on the night of 12th July 2006 as the heatwave was starting to build. It can be clearly seen that the surface temperature rises towards the centre of London, with surface temperature in the central London boroughs 5°C warmer than the suburbs.

Figure 5.3 Surface temperature (°C) in London at 21.43pm on 12 July 2006 (source LUCID)



Consequence

Individual days of very hot weather do not appear to have a significant impact on the health of Londoners, or on London's infrastructure. Prolonged periods of high temperatures, and particularly those where the night-time temperatures remain high, have the most profound effect on our health (see figure 5.1).

The consequences of prolonged high temperatures are:

- an increase in heat-related discomfort, illness and death, increasing pressure on health and emergency services
- an increase in demand for energy intensive cooling, such as air conditioning
- an increase in social inequality relating to those who live in poorly designed and/or overcrowded buildings and who have limited capacity to take measures to reduce or escape the heat (blinds, awnings, mechanical cooling, access to green spaces etc)
- a rise in the demand for water, increasing the pressure on limited water resources
- damage to temperature sensitive infrastructure (such as electrical systems and transport networks)
- an increased risk of blackouts due to increased demand for energy for cooling
- a decrease in air quality during heatwaves.

Exposure and vulnerability

The following factors are important in determining exposure to high temperatures:

- housing (building type, condition and insulation, which floor, aspect, the presence and use of air conditioning or ventilation)
- place of work (working outside, or considering workplace characteristics as above)
- level of physical activity (overexertion or inactivity).

Factors that increase vulnerability to high temperatures include:

- age (under 4 years or 65 and over, with those aged 85 and over experiencing the most severe effects)
- gender (women are more vulnerable than men[58])
- pre-existing medical conditions (such as heart and respiratory diseases)
- use of certain medications and substances (medicines, drugs and alcohol)
- impaired cognition (such as dementia)
- social factors (homelessness, those living alone or with no support network, low incomes).

Heat-vulnerable land uses are therefore buildings that accommodate heat-vulnerable people, like schools, old peoples' homes, hospitals and care centres; or heat-sensitive equipment, like electrical switching gear or data storage equipment.

A comparison[59] of the health response to high temperatures for each of the nine UK regions suggests that Londoners have a higher threshold to rising temperatures than other regions, but that once this threshold (approximately 24°C) is exceeded, the health impact on Londoners is more severe than for any other region.

Research by the GLA[60] shows that the London's older population (people aged 60 or over) will increase both in absolute numbers by 2031, and as a proportion of London's population as a whole. London's ageing population will mean that a greater proportion of the population will be vulnerable to higher temperatures in the future.

The Met Office is able to forecast heatwaves at least 24 hours in advance. This time can be used to warn and inform vulnerable people and to ensure that the health services are prepared for the potential increase in demand.

Analysis

London will experience an increasing risk of overheating due to:

- climate change
- the intensification of the Urban Heat Island (UHI) effect from:
  - climate change
  - increase in development density from London's growth
  - increase in man-made heat contributions as a response to higher temperatures (e.g. air conditioning) and London's growth
  - reduced evaporative cooling due to drier summers.

It is important to note that in the next couple of decades, temperatures high enough to significantly affect health will be limited to extreme weather events, aggravated by the urban heat island effect. By mid-century however, the increases in average summer temperatures will mean that most summers will be the equivalent of 'heatwave' temperatures today, and a new intensity of extreme high temperatures above that will be experienced.

Climate change

The 2003 heatwave was 3.4°C above average maximum summer temperatures. The UKCP09 project that by the 2050s (medium emissions scenario) that average maximum summer temperature will increase by 2.7°C, with a 10 per cent probability of temperatures exceeding 27°C (+ 6.5°C on top of baseline). These projected increases are now almost unavoidable. Only urgent and sustained global action to reduce carbon emissions can slow further climate change and therefore reduce the risk of even further increases in temperature in the second half of the century.

The climate models that produce the UKCP09 cannot model urban land cover and therefore assume a rural land cover for the whole of the UK. This means that the urban heat island effect is not represented in the models and therefore the models are likely to under-predict future urban temperatures.

In addition, 'heatwaves' are usually caused by high-pressure weather systems known as anticyclonic weather systems, or 'blocking highs' [61]. Climate models are poor at predicting how climate change will affect the frequency and longevity of blocking highs in the future and so it is not possible to predict whether London will experience more heatwaves in the future.

Intensification of the urban heat island effect

As described previously, there are four factors that may contribute to the intensification of the urban heat island in London:

Intensification due to climate change

There is little evidence to suggest that the intensity of the urban heat island effect in urban areas around the world is significantly affected by absolute temperatures, so any increase of the urban heat island intensity due to hotter summers is expected to be marginal.

Climate change is expected to increase the number of cloud-free days. As the urban heat island is caused by the urban fabric absorbing solar energy, an increase in the number of cloud-free days will increase the frequency of conditions that lead to the creation of an intense heat island, so the number of hours an intense heat island effect exists will increase. Initial modelling[62] suggests that the number of hours that an intense heat island (defined as +4ºC above rural temperatures) exists may increase by up to 30 per cent by the end of the century.

The lack of detailed data on London's existing land cover, and the fact that the regional climate models cannot represent urban land cover, means that understanding how climate change and London's growth will intensify the urban heat island is at an early stage.

The GLA is involved in two research projects to improve understanding of how climate change will affect the urban climate. Both three-year research projects will conclude in 2010, though the outputs will be used in the preparation of the final Mayor's Adaptation Strategy and inform the review of any future strategy.

- The SCORCHIO[63] project will develop a computer model of urban areas that will use land cover types to more accurately represent the urban climate feedbacks, and so produce assessments of vulnerability to urban heat island and climate change and possible adaptation options.
- The LUCID[64] project will take a more detailed focus on how the character of the local environment in London can influence local climate and explore the effect of changes to density, land use, energy use, street width and greenery on the local climate. The outputs of the project will be used to help determine actions to manage the urban heat island and mitigate effects on public health.

Intensification due to increasing density

There is a strong relationship between density of development and intensity of the urban heat island. London's population is expected to increase by 810,000 people by 2026. The London Plan proposes that much of this growth will be accommodated in a number of 'Opportunity Areas', which will increase the area of high-density urban development and may intensify the urban heat island. More than half of the Opportunity Areas are within the central

London boroughs where the urban heat island effect is most intense.

Increasing the density of development in London will increase the intensity and size of the urban heat island unless efforts are made to offset the urban heat island effect.

Intensification due to anthropogenic contributions

There is currently little data to determine the significance of the anthropogenic contribution to London's urban heat island. Examples from cities such as Hong Kong and Tokyo show that anthropogenic contributions, particularly the widespread use of air conditioning, can make a significant contribution to the urban heat island and create a self-reinforcing problem. London's growth will also increase the amount of energy used in the city and so generate more heat. An analysis[65] of future demand for air-conditioning in London suggests that the amount of energy vented from air-conditioners may increase by 227 per cent by 2030[66]. Increased anthropogenic heat emissions will increase both the intensity of the urban heat island and the size of the heat island core.

Intensification due to drier summers

Green spaces reduce the urban heat island by reflecting more of the incoming solar energy than urban materials, as well as absorbing energy through photosynthesis and providing cooling through evaporative transpiration.

The increasing risk of drier summers and drought periods (see Chapter 3) will mean that the evaporative cooling benefit from vegetation will lessen. Grassy areas such as playing fields and public parks are particularly prone to drying out due to the shallow root systems of grass and are among the first to lose their cooling potential.

Response

It is not possible to prevent heatwaves from occurring, but it is possible to limit how much the urban realm intensifies a heatwave, and to improve how effectively we prepare and respond to them. It is also possible to design buildings and infrastructure to minimise overheating in hot weather and therefore to avoid mechanical cooling which would otherwise increase the urban heat island.

This section of the strategy will therefore focus on achieving three inter-related aims:

- managing rising temperatures and London's urban heat island
- designing new, and adapting existing buildings and infrastructure to minimise the need for cooling as far as possible
- ensuring that where cooling is still required, that low-carbon, energy-efficient methods are used.

Managing rising temperatures and London's urban heat island

It is possible to manage London's urban heat island at three distinct levels, with action at each level having benefits at all other levels:

- citywide
- neighbourhood
- individual building.

Citywide management
At all physical levels, the type of land cover is the key factor determining the strength of the urban heat island effect. This is not surprising, given the fact that the urban heat island is caused by replacing green space with urban materials that absorb more of the sun's energy. The simplest method of managing the urban heat island, therefore, is to increase the amount of green space cover, by protecting existing green spaces and encouraging new opportunities for urban greening.

GLA research into London's urban heat island shows that maximum urban heat island intensity increases with the percentage of continuous urban development. At 30 per cent continuous development, a maximum intensity of 4°C is observed, at 70 per cent this rises to 6°C. Modelling work based on Manchester suggests that increasing the green space cover by 10 per cent in high-density residential areas and town centres could keep surface temperatures at or below the baseline 1961-1990 level for most of the century. However, removing 10 per cent green cover from these areas, increased maximum surface temperatures by up to 8.2°C by the 2080s, assuming the highest emissions scenario[67].

The strategy recommends the following actions at a city level to manage the urban heat island:

- defining the Central Activity Zone as an 'urban heat island action area' where the Mayor will work with the boroughs and developers to increase the green space and vegetation cover by 10 per cent. Major new developments would be required to:
  - avoid the need for cooling using the cooling hierarchy
  - have a green roof (and where this is not technically feasible a cool roof[68])
  - vent any waste heat from a mechanical ventilation or cooling systems above the roof level
  - contribute to the planting and maintenance of additional street trees, soft landscaping and pocket parks.
- initiating a pan-London Urban Greening Programme to identify, prioritise and implement opportunities to enhance and increase urban greening
- requiring all London boroughs to use their Open Space Strategies to manage the urban heat island by protecting local green spaces and identifying opportunities for urban greening, helping deliver the Londonwide Green Grid (see Chapter 7 for further explanation).

Neighbourhood management
At a neighbourhood level, or for instance, in the case of a major redevelopment (such as in the Thames Gateway), opportunities should be taken to:

- create breeze pathways that enhance natural ventilation
- orientate streets to optimise solar gain

- punctuate new development with green spaces
- optimise the street width to allow for appropriate scale deciduous street trees
- use high-albedo (pale and reflective), low emissivity[69] and permeable paving materials.

Building management
The cumulative benefits from adapting individual buildings to manage their contribution to the urban heat island will have a local and larger scale effect as well. The following measures will reduce a building's contribution to the urban heat island:

- incorporating green roofs and green walls
- avoiding high glare facades and finishings
- planting and managing deciduous street trees and/or garden trees to provide dense summer shade
- ensuring that mechanical ventilation or cooling systems vent waste heat above the roof level
- ensuring that the intake for ventilation and cooling systems draws in cool air (such as air from the north side or shaded side of the building, or from over a green roof).

Reducing the need for cooling in buildings

Our indoor climate depends upon how much of the outdoor climate our buildings filter or transmit, and how much heat is generated internally. The Chartered Institute of Building Services Engineers (CIBSE) uses an 'overheating criterion' to determine if a building is overheating. The criterion has two temperature thresholds, demonstrated in Table 5.1 below.

Table 5.1 Overheating criterion thresholds in buildings (source: CIBSE Guide A)

Building type	'Warm' threshold temperature/°C	'Hot' temperature threshold/°C	Overheating criterion
Residential - living areas - bedrooms	 25°C 21°C	 28°C 25°C	 1% occupied hours over 28°C 1% occupied hours over 25°C
Offices	25°C	28°C	1% occupied hours over 28°C
Schools	25°C	28°C	1% occupied hours over 28°C

Table 5.2 Modelled predicted overheating for 1930s house in July (source: LCCP)

1930s house	Overheating current	Overheating 2050s (un-adapted house)	Overheating 2050s (adapted house)
- Living room - Bedroom	30% 6%	>50% 20%	2.2% 1.1%

Existing development

Most development in the UK has an intended lifespan of 60-80 years, but in practice, given the current rate of replacement, has an effective lifespan well in excess of 100 years. Nearly a third of London's housing stock was built before 1919. Seventy per cent of our existing housing stock will be providing accommodation in the 2050s.

Research commissioned by the LCCP[70] compared how much a 'typical' 1930s house would overheat (using the CIBSE overheating criterion) in July in the current climate and in the projected climate of the 2050s. The research also examined the effect of a package of passive actions (including behavioural and physical measures) on reducing overheating. The research shows that there are affordable and effective measures to adapt existing buildings to manage overheating. Table 5.2 summarises the findings of the research.

New development

With good design, in warm weather, the internal temperature of buildings should not exceed the external temperature. With careful design it is possible to keep the building close to the daily average temperature, or even lower, through the course of a warm period without mechanical cooling – this is known as 'passive design'. It is important that efforts to make new development ever more energy efficient do not increase the risk of the development overheating. Table 5.3 sets out a range of design options, working from the outside of a building inwards, that will assist in keeping buildings cool. The draft replacement London Plan sets out a 'cooling hierarchy' (Policy 5.9) which planners and developers should use to manage the risk of overheating.

In some buildings (such as offices and schools) the amount of heat generated internally by people and electrical appliances means that even optimum application of passive cooling design may still result in overheating. One solution is to adopt 'mixed mode' ventilation, in which mechanical cooling systems operate once internal temperatures rise beyond a comfort threshold. With careful design and management, mixed mode ventilation can be relatively energy efficient.

Architects and engineers use building simulation programmes to model the energy use of their buildings in response to the external climate. The simulations are reliant upon hourly weather data for each season. The GLA has developed a bespoke set of Design Summer Years (DSYs) with CIBSE for London[71] that can be used to take a risk-based approach to modelling overheating risk. These DSYs are the first in the UK to take account of future summer temperatures (previous DSYs were based on the summer of 1983), the effect of the urban heat island, and the fact that health impacts increase with rising temperatures[72]. The GLA will encourage the use of these DSYs through the review of the London Plan.

The Department of Health does not require contractors to consider climate change scenarios, or use temperature design guidance in the design, construction, or renovation of the health estate[73]. This is of particular concern

Table 5.3 Cooling adaptation options for development

Building layout	Orientation (aspect) profile	external
External shading (particularly on southern aspect)	Deciduous street trees Brise soleil ('sun breaker') External blinds and awnings Vegetated walls	external
Albedo	High albedo value	external
Improving insulation and air tightness	Good thermal insulation (roof and walls) Window size and shading Controlled airflow into buildings Low emissivity materials (such as glass) Green roofs	external
High thermal mass	Exposed, internal high thermal mass	internal
Energy-efficient ventilation and cooling	High ceilings Dual aspect Effective passive ventilation Night-time purge ventilation Heat stack design/wind towers Forced air cooling Groundwater cooling/chilled beams District cooling Absorption chillers (where waste heat available)	internal

for the construction of the next generation of hospitals in the Hospital Building Programme and NHS London's planned investment in new community health facilities or 'polyclinics'. Not incorporating an allowance for warmer summers will increase the risk that these buildings will overheat, and not be fit for purpose without costly retrofit. The Mayor recommends that the NHS consider using the London-specific summer design guidance to enable buildings to be designed to be comfortable and sustainable in future summers.

Single aspect developments (buildings with external openings on only one side, such as flats in a tower block) should be discouraged as effective passive ventilation (such as cross-ventilation) can be difficult or impossible to achieve, making many single aspect developments entirely reliant upon mechanised ventilation to cool the building. This increased demand upon London's energy supply will increase the risk of energy shortages and potentially leave mechanically ventilated buildings un-cooled during power shortages.

Emergency 'heatwave plan'

Climate change is projected to result in an increase in the intensity and frequency of heatwaves in the future. Even allowing for acclimatisation, these will impact upon the health of Londoners, particularly the vulnerable. It is therefore vital to ensure that a tried and trusted emergency plan exists and is fully implemented.

Following the August 2003 heatwave, the Department of Health produced a National Heatwave Plan for England (see box), which was first published in 2004 and has been revised annually[74]. The plan spells out the responsibilities at national and local level for alerting people once a heatwave has been forecast, and advising them what to do during a heatwave.

The Heatwave Plan for England

The main component of the Heatwave Plan is a 'Heat Health Watch' system, which operates from 1 June to 15 September each year. This system comprises four levels of response, based on threshold day and night-time temperatures, which vary by region. London has the highest thresholds nationally, 32°C by day and 18°C by night. The four levels are:

1. **Awareness** – The Department of Health disseminates advice to the public and health care professionals. Primary Care Trusts and borough Social Services identify who is at risk and review staffing levels in case of high demand. NHS Trusts will check the resilience of their estates and equipment.
2. **Alert** – The Met Office alerts the Department of Health and other organisations that it forecasts that heat thresholds are to be exceeded for three days ahead. Warnings are broadcast to the public via television and radio weather reports. More specific information is released to health and social care professionals and additional information is targeted at those at risk.
3. **Heatwave** – The Met Office confirms that threshold temperatures have been attained and provides a forecast on how long they will last. Health advice is issued through targeted media channels. Additional support for the highly vulnerable is commissioned through the Primary Care Trusts and borough Social Services. Primary Care Trusts and NHS Trusts will ensure that hospital services are prepared for any rise in admissions.
4. **Emergency** – At this stage a heatwave is judged so severe and/or prolonged that its effects extend outside the health and social care system, such as power or water shortages, and/or where the integrity of health and social care systems is threatened. Level 3 responsibilities continue and a 'major incident' may be declared.

The Heatwave Plan also calls for government departments, local authorities, the NHS and public health authorities to promote the greening of the built environment, shading and insulating buildings, with specific recommendations for hospitals estates and care homes.

A significant component of the Heatwave Plan relies on GPs and social services identifying people vulnerable to high temperatures and maintaining a register of heat vulnerable people that can be contacted when Level 3 of the plan is initiated. However, many GPs do not have such a list and as a person's vulnerability to heat can vary from day-to-day (for example, their vulnerability may be dependent on how they are feeling on a given day, or whether their care or support is available on that day), the value of such a list is questionable. In addition, many potentially vulnerable people do not consider themselves as 'vulnerable' and are therefore unlikely to actively respond to passive information, such as leaflets and radio broadcasts.

The Mayor believes that engendering a 'sense of community' where known and trusted neighbours look out for vulnerable members of their community is a significant step in ensuring that the heatwave plan is robustly delivered. The work of the Drain London project in developing community flood plans will provide an insight into community-level responses to extreme weather (see Action 9). The London Resilience Partnership will begin work on the London Regional Heatwave Plan in Autumn 2010.

Part III – Assessing the impacts on cross-cutting issues

Chapters 6-9 summarise how the risks examined in Chapters 3-5 impact on four cross-cutting issues – health, environment, economy and infrastructure. The purpose of these chapters is to look at how the range of climate change risks impact on a particular issue. This cross-cutting analysis is intended to help decision-makers working on these policy areas understand the climate risks and opportunities relevant to their policy area and highlight links with other chapters.

For some of these issues, the analysis of how climate change will impact upon them is at an early stage, and therefore further work is required to understand the challenges and relevant actions in more detail. Many of the more profound impacts (such as experiencing heatwave temperatures every year) are very unlikely to occur in the short to medium term, but will require a systemic approach to successfully manage the risks they present. This requires action now to ensure that we design our buildings and infrastructure, much of which will be around for at least 50-100 years, for the climate they will experience over their design life.

Chapter 6 Health

Actions

As health is a cross-cutting issue, actions in Chapters 3-5 generally apply to this chapter, but there are two specific actions.

Action 28. The London Climate Change Partnership will work with the London Regional Public Health Group to undertake a London-specific assessment of the impacts and opportunities of climate change on London's health services. The study will provide recommendations to the health sector on the priority risks and opportunities.

Action 29. The Mayor will work with the London Regional Public Health Group, NHS London and the London Primary Care Trusts to ensure that climate risks are addressed in their refurbishment programmes and the commissioning of health services.

The World Health Organisation defines health as 'a state of complete physical, mental and social wellbeing, and not merely the absence of disease, or infirmity'[75]. Implicit in this definition is an understanding that health is influenced by many factors, and not solely determined by age, gender and ethnicity. It is therefore necessary, when developing policies and proposals to improve the quality of life of Londoners, to consider a wide range of factors that are collectively referred to as the 'wider determinants of health'. These include education, employment, income, housing, social networks, environmental factors such as air quality, access to affordable, nutritious food and quality green spaces, and access to public services, including health and social care[76].

The impact of climate change on the health of Londoners is a complex issue, and the benefits for, or threats to health may be direct, or indirect. Managing these impacts is therefore the responsibility of a wide range of agencies, both within the health sector, and beyond[77].

Climate change will affect the quality of life of all Londoners, but there are dramatic inequalities in the health of Londoners[78] and climate change is likely to increase these inequalities. This is both because it will have a disproportionately negative impact on those already experiencing poorer wider determinants of health, and because these same groups are less likely to be able to take advantage of the health-related opportunities presented by climate change.

This section will summarise the impacts of climate change on health and provide cross-references to where health-related issues are covered elsewhere in the strategy.

The impact of the changing climate on health can be considered under three headings:

- direct impacts on health and health inequalities (positive and negative)
- indirect impacts on health, affecting the wider determinants of health (positive and negative) and health inequalities
- direct effects on the delivery of health services (including those people working within the health and social care sector, and also the buildings and infrastructure required to deliver these services).

Direct impacts on health

Each of the effects identified in Table 6.1 above are discussed in detail below.

Increasing temperatures

It is expected that the increases in summer and winter temperatures due to climate change may, on average, improve people's health. Milder winters will reduce the number of excess winter deaths, and the predicted reduction in snow and ice may lead to a reduction in slips and trips in winter. In addition, warmer summers may encourage people to spend more time outside and engage in more physical activity, both for leisure, or walking and cycling to work. As the average summers become increasingly hot, and heatwaves occur more frequently, the increases in temperatures may negatively affect people's health.

Table 6.1 below identifies the principal effects of weather on health outcomes[79]

Health outcome	Known effects of weather/climate
Heat stress, cold stress	Deaths from heart- and lung-related diseases increase with hotter and colder temperatures. Heat-related illnesses (heat cramps, heat exhaustion and heat stroke) and death increase during heatwaves.
Air pollution related morbidity and mortality	Weather affects air pollution concentrations. Weather affects the distribution, seasonality and production of air-transported allergens.
Morbidity and mortality resulting from weather disasters	Floods and windstorms cause direct effects (deaths and injuries), infectious diseases, long-term mental health problems, and indirect effects (temporary limitations on access to health and social care services).
Vector-borne diseases	Higher temperatures shorten the development time of pathogens in vectors and increase the potential transmission to humans.
Water- and food-borne diseases	Survival of important bacterial pathogens is related to temperature. Increases in drought conditions may affect water availability and water quality (chemical and microbiological load) due to extreme low flows. Extreme rainfall can affect transport of disease organisms into water supply.
Cataracts, skin cancers and sunburn	More cloud-free days and higher temperatures may encourage potential risk of over-exposure to UV radiation.

Warmer winters

There is a strong link between external temperature and excess winter mortality[80]. Despite having a relatively mild climate, the excess winter mortality ratio is high in Britain, compared with countries with similar or colder climates[81]. In London 3,000 pensioners died of cold-related illnesses in the winter of 2004/05[82]. Warmer winters due to climate change may reduce the number of excess winter deaths and the number of people experiencing fuel poverty. But as the amount of winter warming projected for this century is less than the natural variability of winter temperatures, the reduction is likely to be small. The Mayor and government are working to reduce fuel poverty through improving housing conditions and providing a winter fuel subsidy in cold winters. Improved thermal insulation should also help keep homes cool in the summer.

Hotter summers

Increasing summer temperatures will have both positive and negative effects on the health of Londoners. Generally, a positive health response is seen as temperatures increase. Above 22°C, the health response becomes increasingly negative. External factors such as housing quality and occupancy, work conditions and opportunities to escape from the heat also affect how people respond to higher temperatures. Chapter 5 analyses the risk of high temperatures in London and provides recommendations as to how these risks should be managed.

The longer growing season brought about by milder winters will mean that the 'allergy season' may increase in length, and the timing that certain species of tree or plant flower or seed will also change. The change in climate may also, over a period of time, affect the diversity or dominance of plant species, so bringing new allergens as well as altering the timing and relative abundance of existing allergens.

Air quality

Climate change may somewhat reduce winter air pollution levels but may increase summer air pollution. Wetter winters will 'wash' the pollutants from the atmosphere. Higher summer temperatures, less rainfall and less cloud cover are projected to increase the formation of ground level ozone, and periods of little or no wind usually associated with heatwaves may mean that pollution in the city - including particulate matter which is particularly harmful to health - will be less easily dispersed.

Higher temperatures also make people vulnerable to air pollution more sensitive to air pollutants. Poor air quality is thought to have contributed to the high death toll during the 2003 heatwave. Air pollution episodes will have the greatest impacts on certain groups – particularly older people and those with pre-existing respiratory conditions (those that are most vulnerable to the effects of poor air quality). It also affects those living in areas that experience the poorest levels of air quality, such as those living near major roads and airports. People living in these locations are more likely to be from lower socio-economic groups, as housing tends to be more affordable in these areas.

The Mayor's draft Air Quality Strategy[83] sets out a range of measures to improve air quality in London. The strategy takes these impacts into consideration, including proposing more robust measures for ensuring that the vulnerable part of the population are aware of, and can avoid exposure to, air pollution episodes.

Weather disasters

Climate change is projected to increase the frequency and intensity of extreme weather, therefore increasing the risk of weather-related disasters, such as floods and storms. Chapters 3 and 5 identify the principal consequences of floods and heatwaves. In addition to these impacts, there is projected to be an increase in the frequency and intensity of windstorms, though there is greater uncertainty around this projection. The direct health impacts of weather disasters include death and personal injury, contamination and disease from flood and sewer water, and subsequent impacts on mental and physical health.

While the immediate effects of a flood or a windstorm are apparent, the latent after-effects are less obvious. Studies of the effects of single and multiple flood events have shown that there can be long-term mental health impacts on people affected by these events. In some instances flooding can hasten mortality among older people and the chronically sick[84].

Vector-borne diseases

Vector-borne diseases are diseases that are transmitted to humans or other animals by an insect. The principal vector-borne diseases that could increase under a changing climate are malaria and tick-borne Lyme disease[85]. Malaria used to exist in the southeast of England, but was eradicated by improved standards of living (particularly housing), so is unlikely to re-establish to the UK [86].

Tick-borne infections are determined by the distribution, abundance, and pattern of activity of the ticks, in combination with the leisure pursuits that bring humans into contact with ticks. Lyme disease is widespread throughout Europe and the UK, though the number of cases in the UK is far lower than in mainland Europe, despite similar densities of infected ticks. This may be due to a large number of cases not being detected, or reported. Research[70] shows that there is no simple correlation between temperature and the incidence of Lyme disease, but summer dry spells reduce the activity of ticks looking for hosts. Adult ticks feed upon sheep, cattle and deer, so within London only the Royal Parks, Country Parks and the green belt are considered areas where contact with ticks is likely. The risk of Lyme disease may therefore increase as the conditions for tick activity improve.

It is important that adequate health surveillance is maintained so that the introduction of new infectious diseases or disease vectors is detected in a timely manner. GPs and health professionals should be trained to identify and encouraged to report infectious diseases, as well as bites and stings from insects that may be new to the UK[74].

Exposure to ultra-violet radiation

Warmer temperatures and more cloud-free summer days may result in more people overexposing themselves to ultra-violet radiation (UVR). The NHS is projecting an expected increase in skin cancers and cataracts across the UK[87]. Over the last 25 years, the incidence of malignant melanoma has increased more than any other major cancer in the UK[88].

The main preventable risk factor for melanoma is excessive exposure to UVR. Surveys in the UK have revealed that the majority of people regard a sun tan as a sign of health and few are knowledgeable about the dangers of UVR. However, there is evidence that there has been modest behavioural change particularly with regard to protecting children from over-exposure to sunlight.

Food and diet

Climate change will have an impact on food safety and hygiene. Higher temperatures are expected to increase:

- the risk of bacterial enteric infections such as *Salmonella* and *E.coli*
- contact between food and pests, especially flies, rodents and cockroaches (house and blow-fly activity is largely driven by temperature)
- temperature-related changes in food preparation and eating practices, with increased likelihood of food being not properly stored, cooked or transported (as is more common with BBQs, buffets and picnics).

Food hygiene is the most important factor for prevention of food-borne diseases. The fact that food poisoning peaks in the summer highlights the role of climate in food poisoning[89]. Research indicates that a 1°C increase in temperature might result in a 4.5 per cent increase in food poisoning[70]. Studies have also shown that it is the temperature the week before illness (when food is prepared and stored) that most increases the risk of transmission. Food retailers and restaurants will need to be particularly aware of the increased risks, given that any food hygiene problems at this level can affect a large number of people.

Climate change is likely to affect what food is available, when and what can be grown in the UK over the long term. However it is difficult to predict what these impacts might be. Warmer winters may extend the UK growing season of some fruit and vegetables, so increasing the diversity and availability of locally grown produce. Hotter summers may also increase the availability and diversity of locally grown produce. However, changes to weather patterns, the increased risk of extreme weather events, including flooding, and the increasing frequency and length of droughts could have contrary effects, such as temporary shortages and price volatility. While changes in climate may not necessarily reduce overall productivity in the long term, unpredictability and lags in adaptability of local farming and related systems are likely to have short- and medium-term adverse consequences.

Dehydration

Higher temperatures increase perspiration and evaporation, so increasing the risk of dehydration. Older people and the young are particularly at risk, as the thirst response in older people decreases with age, and younger people require more water to maintain their growth and energy demands.

In the early stages, dehydration affects mental wellbeing, causing anxiety, irritability, a short attention span and similar symptoms. Mild dehydration can therefore have an indirect impact upon London's economy – by negatively impacting on performance at work and the ability for schoolchildren to learn. The increased risk of overheating in schools due to poor design may increase the risk of dehydration among school children. There is evidence that dehydration can sensitise individuals to allergens and bring on allergies[90].

The Mayor wants to encourage people to keep hydrated but reduce the demand for bottled water. The Mayor has therefore worked with Thames Water to promote drinking tap water through the 'London on Tap' campaign (www.londonontap.org). The Mayor will also look for opportunities to install publicly accessible drinking water fountains in public realm projects that the GLA group is involved in, such as:

- the £6 million 'Priority Parks' make-over projects
- the Mayor's Great Spaces programme
- new and innovative solutions with both the public and private sector across London.

Ambient noise

Ambient noise is an ongoing challenge for any large city such as London. Noise sources and public sensitivity to noise may increase under climate change because hotter summers may lead to an increased ambient noise from air-conditioners. Hotter nights, aggravated by the urban heat island effect, may mean that people will prefer to sleep with their windows open. This may result in more people being kept awake by external noise, including that from people in the street. The volume of street noise may increase as more people are out for longer and later on warmer nights.

Indirect effects on health

The introduction to this chapter highlighted that the health of individuals results largely from their access to a wide array of social and environmental determinants of health such as education, housing and employment. It is likely that climate change will increase health inequalities because it will have negative impacts on those who already have limited access to the determinants of good health, while potentially offering health benefits to those groups who are already advantaged. The principal issues expected are outlined below.

Working conditions

People working outside, engaged in heavy manual labour, or working in buildings that are not well ventilated or thermally regulated, will experience increasing occupational health risks.

Those Londoners who work in poor quality environments tend to be from the lower socio-economic groups who, on average, have worse health outcomes than other groups. Climate change may exacerbate these inequalities.

Education

Educational attainment may be adversely affected in schools that are prone to overheating in hot weather, or schools that lie in the flood zone, or have been identified as rest centres for people displaced by flooding. Additionally, in London many schools do not have access to a quality outdoor space for children to play in during their breaks and after school. The government's Building Schools for the Future Programme should ensure that school renovation programmes take account of the changing climate.

Living conditions

Climate change will disproportionately affect those living in poor quality or overcrowded homes. London's existing housing stock is older than the national average, with 60 per cent of homes built before 1945. London also has a higher proportion of private rented homes where the owner will often have little interest in adapting the property for climate change. London also has more non-decent homes[91] than other regions. In 2003, over one million homes failed to meet the government's Decent Homes standard, 71 per cent of which were in the private sector[92]. Black, Asian and minority ethnic households were disproportionately likely to live in housing in a state of disrepair[93].

Overcrowding is one of the London's most pressing housing problems. Estimates suggest about 150,000 households are overcrowded, and 61,000 severely overcrowded[94]. Over a quarter of a million children in London live in overcrowded homes. Overcrowding both increases vulnerability to climate change (more people at risk) and residents of overcrowded households are more likely to struggle to adapt[95].

People living in poor-quality housing or overcrowded conditions are also more likely to live in areas with limited access to quality green spaces, unattractive streetscapes, higher crime rates and lower air quality. All of these factors will mean that these groups are likely to be negatively affected by any increase in hot weather.

Chapter 3 highlighted that people on low incomes and living in social housing are less likely to have contents insurance and therefore would be less able to recover following a damaging storm or flood, and are more likely to suffer long-term mental health problems.

The Mayor has a statutory duty to produce a Health Inequalities Strategy for London. The draft London Health Inequalities Strategy[96] recognises that climate change will affect health inequalities in London and provides an action plan for the GLA and other stakeholders to address these issues.

Direct effects on the delivery of health services

- Extreme weather events may affect the people working in and supporting health and social care services at a time when demand for such services are high. Impacts may include:
- staff being physically affected themselves
- staff being unable to get to work where transport systems are affected
- poor working conditions (such as high temperatures in hospitals) affecting staff.

Most social care and health facilities have emergency staffing plans, which should include a range of impacts from extreme weather events. International evidence indicates that social and health care services can be crippled by an absence of staff that is often not considered in emergency plans (such as cleaners and administrative staff).

Climate change may change the epidemiology of diseases and may also increase the incidence of some health problems, such as heat stress and skin cancers. Health practitioners' training must be continually updated as the climate changes so that service providers, particularly GPs and nurses working in primary and community care settings, are able to recognise and treat new symptoms and diseases.

As with much of London's development and infrastructure, many of the facilities from which social care and health services operate are not located and designed for the climate of the 21st century. Changes to the average climate may make working or recovering in these buildings uncomfortable, while the risk of extreme weather events causing damage to these buildings and their occupants may increase. The principal risks to these buildings are the same as those identified in Chapters 3-5.

Flooding

The London Regional Flood Risk Appraisal identifies that there are ten hospitals and nine ambulance stations in the current flood zone. Further work is required to identify where additional primary and secondary care buildings and other essential social care and health infrastructure, such as blood banks, supported accommodation, diagnostic laboratories may be located in areas of high flood risk. All essential health facilities at flood risk should have an emergency plan that considers how they would manage during a flood, how patients would be evacuated and how the services they provide would be delivered if that asset were affected, or closed.

Chapter 2 highlighted that new health services should not be located in the flood zone unless their location in the flood plain is essential for community support. They should also be designed to be flood resilient and accessible if required to be operational during a flood, or ensure that the services they provide can be managed by other facilities out of the floodplain during a flood.

Frequently the most expensive and most flood-vulnerable machinery and assets (back-up generators, water pumps, heating and ventilation systems, lift machinery, cyclotrons, laboratories, computer servers, x-ray machines, patients' records library etc) are located in the basement or ground floor of health buildings, where they are at greatest risk of flooding. Hospital trusts and GPs should ensure that their contingency plans either provide an ability to relocate flood-vulnerable assets out of flood risk, or to retrofit the areas where flood-vulnerable assets are situated to be flood resilient. In case of a flood, ambulances stationed at ambulance stations at risk of flooding should be moved to locations at less risk.

Overheating

Most hospitals and health facilities are designed to be warm to provide a comfortable environment for convalescing patients. Many hospitals also have large windows to maximise natural light. This design emphasis can mean that health facilities are at greater risk of overheating in hot weather.

Many hospital buildings, including those built and planned under the PFI programme, do not have space cooling[97] and are therefore reliant on using portable air conditioners to cool priority areas only (operating theatres and intensive care wards)[98]. Examples of temperatures in wards exceeding 35°C have been reported in hospitals in London[99]. The Mayor recommends that the Department of Health should encourage NHS Trusts in London to require developers to use the CIBSE Design Summer Year guidance to reduce the risk of overheating.

Actions

As this is a cross-cutting issue, actions proposed in Chapters 3-5 apply to this chapter, particularly Actions 17-20 and the following action.

Action 30. The Mayor will work with the Environment Agency and other partners to restore 15kms of London's rivers by 2015 through the London Rivers Action Plan.

London's ecosystem services

London is the greenest world city, and the quality and abundance of its green spaces provides the opportunity for Londoners and visitors to have access to wildlife in an urban setting. London's green spaces (private gardens, public parks, wild spaces, urban forest, river and transport corridors) perform a range of functions known as 'ecosystem services' that improve the quality of life in London. These include:

- supporting biodiversity
- reducing flood risk by absorbing and temporarily retaining rainfall
- moderating the temperature by offsetting the urban heat island effect
- reducing energy demand by providing shade and reducing windspeeds
- helping to reduce noise and air pollution
- providing places for recreational and leisure activities that improve health.

These ecosystem services are essential to the wellbeing of Londoners and London's resilience to climate change. Improving the quality, quantity, connectivity and diversity of London's green spaces will increase their resilience and therefore increase the capacity of London and London's biodiversity to adapt to a changing climate.

Some of the adaptation measures required to ensure London continues to offer its residents a high quality of life will also increase, or add to the city's biodiversity. Table 7.1 highlights the multiple benefits provided by green spaces and street trees.

Table 7.1 Ecosystem services provided by green spaces and street trees

Ecosystem service	Green roofs/ walls	Street trees	Wetlands	River corridors	Woodlands	Grasslands
Reduce flood risk	✓✓	✓	✓✓✓	✓✓✓	✓✓	✓✓
Offset urban heat island	✓✓	✓✓	✓✓	✓✓	✓✓✓	✓
Reduce energy demand	✓✓	✓✓			✓	
Reduce noise/air pollution		✓✓			✓✓	
Support biodiversity	✓✓	✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
Recreation/Leisure	✓		✓	✓✓	✓✓✓	✓✓✓

The Green Grid for East London (see box) is an example of where green infrastructure is being located and designed through the regeneration of a sub-region of London to maximise ecosystem services. The Mayor is now working to expand the Green Grid approach to the rest of London.

Green Grid for East London

The vision for the Green Grid is to create a network of interlinked, multi-purpose open spaces in east London to support the wider regeneration of the sub-region. The Green Grid is being delivered through a programme of projects that are designed to enhance the potential of existing and new green spaces to connect people and places, to absorb and store water, to cool the vicinity, and to provide a diverse mosaic of habitats for wildlife. More than £20 million-worth of projects have already been delivered. The Mayor has published Supplementary Planning Guidance[100] to enable the implementation of the Green Grid through borough and sub-regional planning. The same principles will apply to the Londonwide Green Grid.

The Mayor has identified the following five categories of actions to enhance the ecosystem services performed of London's green spaces and street trees:

- Quality: improve the resilience of London's green spaces and networks through proper management and by reducing harmful impacts, such as pollution and invasive species.
- Quantity: protect existing green spaces and increase the area of green space in London by looking for new opportunities, even where there is no apparent 'space' for greening the city, considering options such as street trees, green roofs and green walls.
- Function: design new green spaces into new or refurbished development to maximise their use (such as in cooling or flood storage). Identify and pursue opportunities to enhance the function of existing green spaces (for example, SUDS[101] and flood storage in riverside parks).
- Connectivity: Many of the ecosystem services provided by green spaces would be enhanced by increased connectivity. New green spaces should be designed to improve links between new and existing spaces for people and wildlife.
- Communication: ensure good communication and coherency across all organisations working on delivering new green spaces and managing existing ones.

Climate opportunities and impacts on London's habitats

Climate, particularly temperature and rainfall, is one of the main factors that affect the distribution of plants and animals. As the climate changes, so will the climate space of individual species. For example, the geographical area that has the appropriate climate-dependent ecological conditions for the species may change. For some species it will expand, for others it will contract, and for some it may move totally outside their existing range. The impacts of climate change will be complicated by interactions between species.

Actual distributions of species are almost always less than the whole of their climate space, due to the habitat fragmentation caused by urbanisation and agriculture, and this fragmentation may impair the ability of plants and animals to adapt to climate change by moving with their climate space.

It is essential to continue to protect the most important sites for nature conservation (see box). These are generally the sites that are subjected to the least pressures from other adverse influences, and hence are likely to be the most robust in the face of a changing climate. Management of these sites may need to be modified and conservation priorities may move away from trying to protect individual species.

London's biodiverse wild spaces

London contains five internationally important wildlife sites, protected under the European Union Habitats Directive or Birds Directive. These are Richmond Park, Epping Forest, Wimbledon Common, Kempton Park Reservoir (part of the South West London water bodies) and Walthamstow Reservoirs (part of the Lea Valley water bodies).

There are 38 Sites of Special Scientific Interest in London. These are nationally important sites, protected under the Wildlife and Countryside Act 1981.

In addition, about 1,400 sites, covering almost one-fifth of London's land area, have been identified as non-statutory wildlife sites of metropolitan, borough or local importance.

London has a varied and fragmented collection of habitats, including remnant marshes, ancient woodlands and meadows, rivers and reservoirs, brownfield sites, parks and private gardens.

London is predicted to experience the same changes to the climate as the rest of southeast England, but the urban heat island effect, which already influences the range of species that occur in London, will mean that the impacts of climate change will be felt more acutely.

The projected hotter, drier summers and warmer, wetter winters are likely to be beneficial to some species and habitats. The net impact is likely to be that species' ranges will move northwards. This means that species at the northern edge of their European range are likely to occur more frequently and establish viable populations. For example, mainland European species that were rare or uncommon in the UK, such as Cetti's warbler, wasp spider and small red-eyed damselfly, are rapidly expanding their ranges and can be found in several places in London. Conversely, the few species at the southern edge of their range in London, such as the native bluebell and the beech tree, may become less widespread or disappear.

Without appropriate action, the adverse impacts of climate change on London's biodiversity could be severe, while the benefits will be unpredictable and sporadic. These impacts are likely to be more significant for some habitats than others, with wetlands being particularly sensitive. The actions required to enhance the ecosystem services and help London's biodiversity adapt to climate change are discussed below.

Rivers and wetlands

Rivers and wetlands are sensitive to changes in the flow, water temperature and water chemistry. The projected reduction in summer rainfall could lead to low flows in rivers and seasonal drying out of wetlands. Reduced flows will concentrate pollutants and, coupled with projected increases in temperature, reduce oxygen levels.

The projected increase in high intensity downpours, or prolonged periods of heavy rain, will increase the frequency of flash flooding. This can physically scour and remove aquatic life from river channels, and increase the amount of pollutants and organic matter entering rivers, exacerbating the effects of low flows on pollution and oxygen levels.

Rivers and wetlands are quicker to recover from damage than most terrestrial habitats and, given time, even heavily affected systems can recover. For example, many fish have returned to the River Thames since the 1960s following significant reductions in pollution. However if the frequency or intensity of these events increases, then the losses from each event will outstrip the ability of the system to recover.

London has important areas of freshwater grazing marsh at Rainham, Crayford and Erith Marshes. These are nationally important habitats. The quality and quantity of water reaching these marshes will be affected by low flows, flash flooding and eutrophication in the same ways as described for the rivers mentioned above. Furthermore, rising sea levels and the increased frequency and height of tidal surges will increase the saline intrusion and the possible risk of inundation from the Thames. The use of at least some of the freshwater marshes as tidal flood storage is being considered as an option by Environment Agency's Thames Estuary 2100 project. Should this option be taken, the existing freshwater grazing marsh would be lost, albeit replaced by other valuable habitats such as saltmarsh.

The London Rivers Action Plan[102] identifies opportunities to restore and enhance London's rivers through actions such as freeing rivers from their concrete culverts and allowing natural processes, such as seasonal flooding, to occur by creating flood plains and providing adjacent areas of habitat for refuge. The Mayor will work with partners to restore 15kms of London's rivers by 2015. The Drain London Project will seek to identify further opportunities for encouraging sustainable urban drainage schemes to reduce flash flooding.

Many of London's rivers and wetlands are affected by diffuse pollution[103]. This pollution can be reduced by fixing sewer misconnections and reducing contamination from urban runoff, thereby increasing the resilience of aquatic environments. The Mayor's draft London Water Strategy recommends that the Royal Institution of Chartered Surveyors should consider including a survey of sewer misconnections as part of home surveys at the time of sale.

The River Thames

The Thames is tidal for most of its length through London. Development has reduced the width of the river by as much as half at some points, decreasing the foreshore area. As sea levels rise, those important marginal habitats that do exist – mudflats and salt marsh - will face further pressure. The Mayor's London Plan[104] supports the setting back and staggering of flood defences to provide additional flood storage and space for new habitats (such as on the east side of Greenwich Peninsula).

In the combined sewers, rainwater from surface water drains can overflow during heavy rainstorms into the foul water sewer, resulting in the need for the emergency discharge of dilute, untreated sewage from combined sewer outfalls into the Thames. These 'combined sewer overflows' (CSOs) can kill large numbers of fish and create offensive conditions in the river due to the amount of sewage-derived material. Climate change will see a higher frequency of these events as the number of heavy rainstorms increases.

The Mayor supports the principle of the Thames Tideway Tunnel to reduce the impacts of CSOs. The project involves the construction of two overflow tunnels, the first from the Lee Valley to Beckton and the second from west London, approximately Chiswick, to Beckton. The mayor also supports the upgrade of London's sewage treatment works to improve the quality of sewage effluent discharge.

Grassland

Grassland is the most widespread habitat in London, ranging in quality from frequently-mown amenity grassland in parks and sports fields, to biologically important acid grassland, found mostly in Richmond, chalk grassland found around the southern edge of London, ancient herb-rich meadows in Barnet, and the 'Thames terrace' grassland habitats which have developed on brownfield land in east London. Most grassland habitats are relatively drought tolerant and the additional seasonal rainfall in climate projections may even improve the diversity of wildflowers, though species composition may change. Some butterflies and other invertebrates are highly sensitive to soil surface temperatures and their distribution is likely to change.

Hot, dry summers will increase public usage of open spaces, particularly parks and amenity green space. More frequent use will increase the general wear and tear of grasslands and increase the amount of disturbance to wildlife. Prolonged summer drought can result in short-mown amenity grassland becoming browned and hard-baked, providing limited amenity value and further reduced biodiversity interest. Conversely warmer, wetter winters will prolong the growing season, requiring more maintenance. Grassland managers will need to balance the improved drought resilience and biodiversity benefits of allowing grass to grow longer, with the increased fire risk.

The Mayor's policy[105] of expecting developers to incorporate green roofs and walls where feasible on new development will help replace brownfield land lost to new development, as well as providing some ecosystem services in built-up urban areas.

Urban forest

An estimated 20 per cent of London's land area is under the canopy of individual trees. Approximately a quarter of London's seven million trees are in woodlands.

Mature woodlands are relatively robust, and in the medium term, climate change is not likely to have a serious adverse impact on existing trees, although increased drought stress may shorten their lifespan. However, over time, the species composition of London's forests may change as the changing climate benefits some species and hinder others.

The planting and management of street trees and other trees in parks and gardens may require new approaches, to ensure that new trees are suitable for the changing climate, and to manage the claims of tree-induced subsidence. The 'Right Place, Right Tree' approach promoted by the London Tree and Woodland Framework is designed to ensure that these factors are considered.

The Mayor, the Royal Horticultural Society and Forestry Commission have jointly produced the 'Right Trees for London's Changing Climate' database of tree species and their climate sensitivity. The database offers users the ability to identify suitable tree species to replace and supplement London's existing tree stock according to the conditions of the proposed planting site and a range of climate variables. Further research will identify and provide planting and maintenance best practice to manage urban trees under a changing climate and to minimise vandalism.

The Mayor will work with partners to increase London's tree cover by five per cent by 2025 (see Action 19). As a first step, the Mayor has funded the planting of 10,000 new street trees over the next four years, targeting areas with few trees and 'hot spots' in the urban heat island.

Garden and street trees are often perceived as causing subsidence, though further investigation often reveals other causes. The London Tree Officers' Association has published guidance[106] for local authorities and the public on how to manage trees to minimise subsidence risks.

Pests and diseases

Increasing trade between nations is resulting in a homogeneity of pest species across the world. While this issue is predominantly a function of London's international connections rather than climate change, some pest species from warmer climes will do better due to climate change. Equally, native species which are not currently regarded as problematic because the traditional climate – particularly cold winters – is regulating and limiting the population, may become pests due to their impact on human activities, or on more fragile species and habitats.

Alien and invasive species, such as Chinese mitten crab, harlequin ladybird, floating pennywort, Himalayan balsam and Japanese knotweed are increasing in London. Climate change could further upset the balance between native and alien species increasing the problems these plants and animals cause.

Actions

The actions identified in this strategy will help to improve the resilience of London's economy to climate change.

Action 31. The Mayor will engage with business organisations and other key stakeholders to consider how to raise awareness of the need to integrate climate risks and opportunities into their routine risk management and planning, and whether there is further practical assistance that can be given to London's businesses, including its SMEs.

Action 32. The Mayor will work with the insurance sector in calling for the government to amend building regulations to require buildings being rebuilt or renovated to be climate resilient.

All major cities are vulnerable to climate change because of the agglomeration of people and assets in a relatively small area, and a city's reliance on importing people, food, water, energy and products for it to thrive. London's position as one of the world's foremost cities also exposes it to the impact of climate change beyond its boundaries – both nationally and internationally.

London's ability to remain a leading world city in an increasingly competitive and globalised economy over the next 20 years depends on a number of factors, but particularly its ability to continue to attract and retain internationally competitive firms in the finance and business sectors. This chapter focuses on four key areas where the Mayor believes London's economy and business community needs to adapt for a changing climate:

- ensuring that London is perceived as a safe and secure place to do business
- identifying the segments of the financial services sector most exposed to climate change
- enabling London to become the world exemplar in tackling climate change
- enabling London's businesses to become more climate resilient.

A safe place for business

London is ranked the ninth most vulnerable megacity[107] on a risk register of natural hazards for the worlds' 50 megacities[108]. Figure 8.1 below lists the top ten most vulnerable megacities ranked by their risk index of insured natural hazards. It shows that London is less vulnerable than some of its principal world city competitors (New York and Tokyo), but highlights that all of London's natural hazards are weather-related and underlines that the probability of all these risks is predicted to increase as the climate changes.

Figure 8.1 Megacities ranked by their exposure to natural hazards (source: Munich Re (2004), Megacities – megarisks: trends and challenges for insurance and risk manager)

Rank	City	Country	City GDP as % of country's GDP (1)	Risk index (2)	Natural Hazards (3)							
					Earthquake	Volcanic eruption	Tropical storm	Winter storm	T'storm/ hail/tornado	Flood	Tsunami	Storm surge
1	Tokyo	Japan	40	710								
2	San Fransisco Bay	USA	<5	167								
3	Los Angeles	USA	<10	100								
4	Osaka, Kobe, Kyoto	Japan	20	92								
5	Miami	USA	<5	45								
6	New York	USA	<10	42								
7	Hong Kong	China	10	41								
8	Manila, Quezon	Philippines	30	31								
9	London	UK	15[a]	30[a]								
10	Paris	France	30	25								

Sources:
1 Statistical authorities, various websites
2 Munich Re, 2004
3 Munich Re, Topics 2002
[a] GLA DMAG estimates

The Mayor believes that for London to maintain its world city status it must continue to provide a safe and secure place to do business, and therefore must adapt to the key climate risks and exploit opportunities to provide the skills, knowledge and products that the world will increasingly need to adapt to a changing climate. The preparation of this strategy is an important step in ensuring that London is prepared for the impacts of climate change.

Effects of climate change on London's financial services sector

The financial services sector is spatially and temporally exposed to climate change: spatially because of its global coverage, and temporally, because of the time taken for the maturation of asset values against which loans and pensions are secured, or derivatives traded. Although some segments of financial services seem to be more exposed than others, the interconnectivity of financial interests and the overarching responsibilities of regulators and policy-makers highlights the indirect risk to all financial services posed by climate change[109].

Analysis of how climate change will affect financial markets is still at an early stage. Some financial institutions have sensed an 'early bird' competitive advantage and moved to provide financial instruments to manage the risk of extreme events, but for the majority of the financial services sector, the impacts of climate change are considered to be beyond the time horizons upon which they base their decisions.

The Mayor believes that the financial services should recognise the business opportunity that tackling climate change presents – both in providing the skills and services the world needs and in creating jobs in London. In parallel, the financial services sector should prepare for further climate change in the advice they offer, the assets they invest in, the systems they use, and the business continuity plans they develop.

The different segments of the financial services sector each have differing risks and opportunities. For example, assets that are vulnerable to climate change may lose value and fund managers may be held accountable for not considering climate impacts; professional advisers will be expected to identify and advise on reasonably foreseeable risks and their associated uncertainty, and regulators can help ensure disclosure of exposure to climate risks.

The insurance sector has a key role in climate risk management. Weather-related insurance claims have risen steadily over the past decades and are projected to continue to rise as climate change intensifies. The Association of British Insurers[110] predicts that worldwide extreme storm damage could increase to £222 bn by 2080 (at 2004 prices), and the costs of flooding could increase by 15-fold by the 2080s under a high emissions scenario.

The insurance industry can be divided into two parts: life insurance and general insurance. Both life and general insurance are exposed to climate risks through the people and assets they insure, and the portfolio of assets they own to pay for insurance claims. General insurers face two key risks under a changing climate: an increase in the number of claims being made due to changes in the frequency, intensity and location of extreme weather events, and a potential devaluation of the capital assets they own to payout on claims. Insurers and reinsurers hold a vast amount of equities and corporate bonds for catastrophe payouts; for example, insurance companies are the largest domestic owners of UK shares - owning 17 per cent of UK shares[111].

As extreme climate events become more frequent and potentially more predictable, insurance companies may decide to:

- not provide insurance cover for certain risks, such as flood damage, in some areas (a practice known as 'red-lining')
- raise the price of premiums to provide the same (or reduced) levels of cover
- require or raise the excess payment on certain risks
- require those seeking insurance to take steps to reduce risk to the insured property (for example, by installing flood resilience measures).

The general insurance industry typically works on an annual model, where insurance cover is offered for one year and when the cover expires at the end of this period, the terms of the cover (including the price and the details of the cover) are renegotiated if the insured party wishes to renew the cover. In this way, the general insurance industry can incorporate new climate information into their policies, and the changes in risk are reflected in the pricing of the premium. This, in theory, makes the general insurance industry relatively resilient to climate change. If, however, the pricing of premiums is based on past data and does not take account of climate change, this can mean that risks are miscalculated. This is particularly the case where data is sparse (such as pricing for natural catastrophes) and analysts have to look back many years – maybe hundreds of years for hurricanes and thousands for earthquakes.

Insurers generally offer 'like-for-like' replacement of insured property. This means that if an insured house was flooded, the insurers would only cover the costs of restoring the property to its previous standard, despite the fact that the property may be likely to be flooded again. Insurers argue that to restore a property to a more flood resilient standard would require them to either increase their premiums, and so make them uncompetitive, or to act in unison with all other insurers and raise their premiums across the industry, which would be against the competition law.

Climatewise (a global collaboration of leading insurers focused on reducing the risks of climate change) published a statement[112] at the Copenhagen Climate Summit stating that if the government amended the building regulations that apply to rebuilding and renovation to require climate change adaptation, this would be an important step in enabling insurers to drive adaptation through the claims process. The Mayor supports this approach and will work with insurers to make the case to the government.

Enabling London to become the world exemplar in tackling climate change

The Mayor is committed to making London a world exemplar in tackling climate change. Globalisation and London's position as a world city mean that London is uniquely placed to provide the skills, advice and products to manage the changing climate risks.

Demand for these services will extend beyond the financial services sector. Business services such as law, accounting, business and management consultancy, management activities (such as holding companies), architects and engineers will all be required to assess and advise on climate risks. The impacts of climate change will mean that the advice and management systems currently supplied may not provide the same level of service in the future. Many business services will need to ensure that the advice they provide takes account of the 'reasonably foreseeable' impacts of climate change – this will be especially true of advice or services with a long-term impact, such as that from architects and engineers.

The London Climate Change Partnership is leading research into the legal responsibilities of professional advisers to consider and advise on the relative risks and opportunities presented by the changing climate.

Effects of climate change upon London's businesses

Climate change will affect businesses in two ways:

- incremental changes that mean current business models become increasingly unsustainable, or opportunities are missed
- direct or indirect impacts from extreme weather events, that interrupt business and cannot be managed under a business-as-usual approach.

Businesses can respond to the climate risks and opportunities by undertaking a climate risks assessment and preparing a Business Continuity Plan. The UK Climate Impacts Programme has developed the Business Areas Climate Impacts Assessment Tool [113] (BACLIAT) – a checklist to assist businesses in identifying the challenges and opportunities presented by climate change. These risks and opportunities can be assessed under seven headings:

- *finance*: implications for investments, insurance, stakeholder reputation and corporate pension funds
- *market*: changing demand for goods and services
- *logistics*: vulnerability of supply chain, utilities and transport infrastructure
- *process*: implications on production processes and service delivery
- *people*: implications for workforce, customers and changing lifestyles
- *premise*: impacts on building design, construction, maintenance and facilities management
- *management implications:* responsibility to manage foreseeable climate risks.

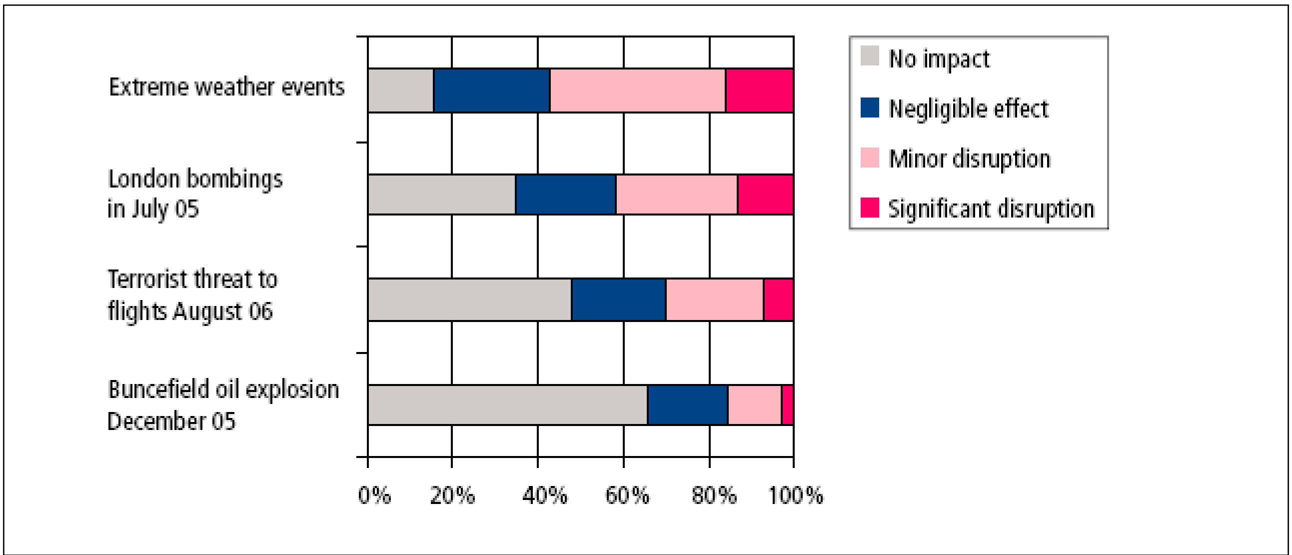
Business Continuity Management (BCM)

The Chartered Management Institute (CMI) defines BCM as

> 'a holistic management process that identifies potential threats to an organisation and the impacts to business operations that those threats, if realised, might cause, and which provides a framework for building organisational resilience with the capability for an effective response that safeguards the interests of its key stakeholders, reputation, brand and value-creating activities.'

Interviews conducted by the CMI[114] with its members highlighted a sharp increase in the number of businesses affected by extreme weather events, with 28 per cent of business interviewed reporting that they had been affected by extreme weather in 2007. This ranked third after 'loss of IT' and 'loss of staff' in order of disruption to business continuity. Figure 8.2 below charts the relative disruption caused by specific recent significant events to CMI members.

Figure 8.2 Business disruption due to external impacts (source: CMI)



Less than half the CMI's members interviewed had a business continuity plan in place, despite the fact that 94 per cent of those with a plan in place reported that it had significantly reduced disruption. Following the Carlisle floods, it has been estimated that 60 per cent of local businesses that did not have some form of a business continuity plan went bankrupt within a year of the flood[115]. Many of these were not directly affected by inundation of their premises by the flood, but through disruption to the supply chain or through their staff being unable to work.

Since May 2006, local authorities have been required to promote BCM to business and voluntary organisations in their communities. Currently there are no available figures on the degree to which BCM has been taken up, nor how frequently the plans that are made are tested and reviewed.

Actions

The actions identified in this strategy will help to improve the resilience of London's infrastructure to climate change.

Action 33. TfL will undertake a climate risk assessment of their assets and operations and develop prioritised action plans for key climate risks.

Action 34. The Mayor believes that London should have a resilient energy supply and will work with the Distribution Network Operator and the energy retailers to ensure that the distribution infrastructure is resilient to climate impacts and that energy suppliers can meet seasonal variations in demand.

This chapter looks at the impact of climate change on London's infrastructure – transport, energy and waste (water infrastructure is covered in Chapter 4, on the drought impacts).

Transport

London's transport network is the lifeblood that supports the city. However, transport as a sector is usually analysed for its contribution to climate change, rather than its vulnerability to it, or the opportunities that the projected changes may bring. Table 9.1 summarises the potential key impacts that may affect London's transport network.

Transport providers in London include Transport for London (TfL) - comprising London Underground, London Overground, Docklands Light Railway, London Buses, London Trams, London River Services, Public Carriage Office (taxis) and the Transport for London Road Network - British Waterways, the train operating companies, Network Rail, London Borough Road Network and private hire companies. TfL is one of the GLA's agencies and is chaired by the Mayor.

TfL is preparing, and other transport providers and operators should prepare adaptation strategies to increase passenger safety, improve the resilience of the existing network, and ensure that new transport infrastructure is appropriately climate resilient. The TfL adaptation strategy will include:

- undertaking a climate impacts risk assessment of their network and operations for each of the modes, to identify challenges and opportunities
- ranking the identified risks and developing action plans to manage the prioritised risks and plan investment
- ensuring major procurement contracts (including design, construction and maintenance) demonstrate a climate risk assessment for the lifetime of the investment.

Table 9.1 Potential climate impacts and opportunities for London's transport networks

Mode	Flooding	Drought	Overheating
London Underground, London Overground rail and trams, and mainline rail	Flooding of stations, tracks, trains, depots and supporting infrastructure, causing delays and suspension of services. Staff unable to work if personally affected by flooding, or unable to get to work.	Fluctuating soil moisture content due to more seasonal rainfall may cause ground instability on clay soils, affecting escalators, cuttings embankments, and water mains. Increased risk of trackside fires. Restrictions on washing trains while drought measures in place.	Hotter summers may make travel more uncomfortable for everyone, and potentially dangerous for vulnerable people. Increased risk of speed restrictions, rail buckling and trackside fires. Warmer winters will reduce delays and damage due to frost, snow and ice.
Surface transport (buses, taxis, lorries, cars walking and cycling)	Flooding of the highway and greenway network, in particular underpasses, subways and tunnels, may cause full or partial closure leading to diversions and delays. Flooding of the command centre, bus depots or buses may affect services.	Restrictions on washing buses during drought measures.	Hotter summers will affect the health and comfort of passengers on public transport and those walking, cycling and in private vehicles. Damage to road surfaces due to melting binder.
River transport	Waterborne freight and Woolwich ferry may be affected by more frequent closures of the Thames and Roding Barriers.	Low flows in the Thames, Lea and Roding may cause access problems to jetties and wharves	No identified impact

Background

Flooding

As described in Chapter 3, London is at risk of flooding from five different flood sources – tidal, fluvial, surface water, sewer and groundwater.

Water will naturally flow to the lowest point, thus low-lying transport infrastructure such as the London Underground network, low-lying sections of the mainline railway and road network, plus pedestrian tunnels and underpasses are inherently more vulnerable to flooding. The extensive roof spaces of some of the mainline stations, together with their location in high density areas means that options for managing rainfall run off is often limited to the capacity of the local drainage system. London's 12,000km of roads and pavements provide an extensive impermeable surface and again rely on drainage to prevent surface flooding.

Higher fluvial and tidal flows in the Thames may lead to an increase in the frequency and duration of closures of the Thames Barrier and associated gates (such as that on the River Roding). This will have an impact on the transport of freight on the Thames and tidal tributaries, as well as the operation of the Woolwich Ferries. The Thames Estuary 2100 project is considering the impact of increased barrier closures and has consulted the Port of London Authority and freight organisations to determine what frequency of closures are economically sustainable for the Port of London.

The following section looks at the impact of flooding on London's transport modes.

Tidal and fluvial flooding

While London enjoys a high standard of protection from tidal flooding and variable standards of protection from fluvial flooding, a significant proportion of London's transport network is located at high flood risk. In Chapter 3 (Table 3.3), 75 London Underground and DLR stations, 49 overground railway stations, 25 bus depots, London City Airport, and four road tunnels were identified as at tidal and fluvial flood risk. Where transport infrastructure is located above current and future flood levels, other entry points for water (such as electricity conduits for the Underground) and key supporting infrastructure (including control centres, train depots and electricity substations) could still be at risk, effectively rendering lines inoperable if flooded.

London Underground

The London Underground network is vulnerable to tidal, fluvial and surface water flooding. The impacts can include:

- flooded tracks leading to delays on, or temporary closure of the line
- flooded ticket halls, platforms and concourses, leading to temporary closure of stations
- increased risk of injuries to passengers from slipping on wet platforms and concourses and in ticket halls.

London Underground maintains flood plans to manage the impact of such flooding at vulnerable locations and to minimise the effect on services as far as practicable. However, more seasonal rainfall and heavier rainfall events are expected to increase the incidence of flooding and may require a significant extension of the flood plans and their frequency of use.

Mainline rail

The mainline rail system is less vulnerable to flooding, largely due to the elevation of many routes on embankments or viaducts. The mainline terminal stations can be vulnerable to flooding from heavy downpours due to large roof expanses and limited drainage capacity. On 7 August 2002, five of London's mainline stations were closed or were significantly disrupted by flooding following a summer thunderstorm. Opportunities to capture and use, or temporarily retain rainwater should be investigated.

Surface transport

The effect of flooding on London's highways and greenways is less well understood, as TfL, the Highways Agency, Thames Water, and the London boroughs do not keep systematic data on the location and probable cause of surface water flooding. The rainstorm on the 7th August 2002 that affected London's mainline rail stations also caused significant surface water flooding in Camden, with an estimated cost in excess of £1 million in delays to commuters alone[116]. Similar events have been experienced across London in recent years, particularly in July 2007.

Unlike trains and trams, buses do not operate on a fixed track and so are able to respond to needs to change their routes. This flexibility means that buses can be more responsive to the impacts of climate change on their routes. Buses can be removed from their depots ahead of a flood if advance warning is given, but are dependent upon their depots for refuelling.

Drought

Drought has two main impacts on the transport network:

- During a prolonged drought, water companies can apply for drought restrictions including a restriction on the use of water for non-essential uses, such as cleaning trains and buses.
- The increasing seasonal variation in rainfall will cause greater fluctuation in soil moisture content, which is predicted to increase the shrinking and swelling of London's clay soils. This ground instability affects escalators, embankments and cuttings, road surfaces and particularly water mains pipes. Engineers will need to allow for increased levels of subsidence and heave in the future. Repairing broken water mains causes delays to road traffic and an inevitable impact on the economy. Thames Water's Victorian Mains Replacement Programme (see Chapter 4) will over time reduce the number of burst mains and closer liaison between TfL and Thames Water has helped to reduce the disruption associated with burst water mains.

Overheating

High summer temperatures already affect both passengers and transport infrastructure. Climate change will affect the frequency and intensity of hot weather episodes and therefore increase the frequency and severity of problems. The key issues from high temperatures are:

- passenger health and comfort on public transport and while walking or cycling
- thermal expansion of rails and bridges
- impact on temperature-sensitive equipment, such as switching gear
- melting of road surfaces
- the security of the power supply to transport infrastructure, given increased energy demand for cooling across all sectors.

Passenger health and comfort on public transport

London Underground network

The London Underground network can be uncomfortably hot in the summer, and during hot weather some sections of the network can reach temperatures that affect the health of vulnerable passengers.

Temperatures on the Underground

The main sources of heat on the London Underground are electricity, passengers' body heat, sunlight and heat from braking trains. The power used to drive the trains, and to light and ventilate the trains, platforms and stations produces heat. The one billion people that travel on the tube also emit 56 GigaWatts[117] of heat each year.

The London Underground network can be divided into deep level, sub-surface and surface sections of lines. The temperatures on the network vary depending on the external climate and where on the network the temperatures are being recorded. In general:

- Trains tend to be 2°C warmer than platforms, but up to 4°C warmer on overcrowded trains (due to the body heat from passengers).
- The deep-level sections of lines are insulated from external temperatures and therefore tend to be warmer in winter and cooler in summer than the rest of the network[118].
- The sub-surface sections of the lines are more open to the surface and therefore more closely follow external temperatures.
- Fifty-five per cent of the Underground is actually above ground, so trains travelling above ground are exposed to the sun. Trains and stations on the surface sections of the lines can experience the highest temperatures due to solar heat gain. Temperature monitoring undertaken during the extremely hot summer of 2003 revealed maximum temperatures on a train above ground reached in excess of 40°C[119].

Managing high temperatures on the Underground

As most of the London Underground was built before air-conditioning was invented, and the tunnels were designed with only enough room for the trains, cooling the London Underground network is a highly complex engineering problem. In addition, London Underground is preparing to increase passenger transport capacity on the network by 300,000 passengers a day by 2016, with longer and more frequent trains. Together these will increase temperatures on the London Underground by several degrees, adding to the anticipated cooling requirement caused by climate change.

London Underground's aim is to minimise the heat generated by the existing network and planned upgrade of the service, so that further energy is not required to offset the heat that is generated. The interventions to cool temperature increases caused by the line upgrades will also help to manage the higher temperatures caused by climate change[120].

Optimising the energy efficiency of the service through driving the trains more efficiently will reduce the heating contribution from the operating regime. TfL is also looking at how to balance the need to move more passengers more quickly against the thermal comfort of the passengers and the investment required to cool the London Underground.

The cooling strategy for the London Underground network involves a mix of measures:

- delivering new air-conditioned carriages on the sub-surface lines from 2010 onwards
- investigating further opportunities to use groundwater cooling systems[121]
- improving the ventilation shafts to help more heat escape from the network
- replacing and upgrading out-of-service fans across the network
- placing industrial fans or chiller units on the concourses of key interchange stations.

Despite these efforts, temperatures on the Underground will continue to be uncomfortable in hot summers, so London Underground will continue to advise passengers to prepare for travelling in warmer conditions. Passengers are advised to travel with a bottle of water and disembark if they feel unwell. The 'Hot Weather' poster campaign and improved staff vigilance has been successful in raising passenger awareness and response to high temperatures on the Underground. This has resulted in a reduced number of passengers being taken ill, and has cut delays caused by passengers pulling the passenger alarm.

The hot weather programme on the London Underground network (public awareness campaign, cooling fans on station concourses etc) is triggered when temperatures exceed 24°C. UKCP09 projections suggest that on a summer day by the 2030s, there is a 24-27 per cent probability of temperatures being warmer than 24°C. By 2050s, this rises to 62-75 per cent and 70-91 per cent by 2080s. This compares to 11 per cent probability today.

Docklands Light Railway (DLR)

The large windows on DLR trains mean that the carriages receive a lot of heat from solar gain, but air conditioning and frequent stops ventilate the carriages, enable the DLR to remain relatively comfortable in hot summers. Increasing numbers of commuters, leading to fuller carriages, may cause temperatures to increase on board but there is no evidence to suggest that these could become dangerous.

Mainline trains

Nearly half the rolling stock of mainline train services into London has now been fitted with air conditioning. This proportion is lower on the inner urban routes, but will increase as the train operating companies replace their existing rolling stock.

Buses

Buses are exposed to high solar heat gain in the summer and can become uncomfortably hot, particularly on the upper deck of double deckers, and on the side receiving sunshine. To help keep buses cool in summer, all new buses operating under contract to TfL are required to have air conditioning in the driver's cab, an automatic ventilation system, opening windows on all full size window bays and specifically on the front two windows on the upper-deck, tinted windows, white-painted roofs and full roof and body thermal insulation.

A programme of retrofitting existing buses with white painted roofs and automatic ventilation system is also underway. Across the fleet, 270 double decker buses have been installed with cooling systems. Further retrofitting will be rolled out as the funding becomes available. The specifications of the cooling requirements will be reviewed and updated as technology and manufacturing capability develops.

Thermal expansion of rails

High temperatures can cause railway tracks to expand, leading rails to buckle and potentially causing trains to derail. London Underground and Network Rail therefore restrict train speed or even close lines in hot weather[122]. The imposition of speed restrictions inevitably leads to passenger delays and congestion on rail networks. Seasonal track stretching[123] and rail replacement programmes will have to consider projected future peak temperatures and address rail design to minimise speed restrictions.

Embankments, cuttings, tunnels and bridges

Long-lived infrastructure, such as embankments, cuttings, tunnels and bridges will be exposed to more climate change than short-lived infrastructure. Many of these will be particularly prone to climate-induced stress as they are already over a century old. Embankments and cuttings will face increased stress from more intense rainfall and greater ranges of inter-seasonal soil moisture variation. To date, there has been little research into the effect of climate change upon embankments and cuttings, though there is growing awareness of the potential scale of this issue.

Warmer winters will increase the length of the growing season of trackside vegetation and affect the date of leaf fall. Together with the rising probability of summer drought conditions and the increasing fire risk, the costs of maintaining railway corridors is likely to increase. Railway corridors are important biodiversity corridors that will enable species to move to adapt to the changing climate. Rail infrastructure companies should therefore consider how to incorporate opportunities for biodiversity in their rail corridor management regime.

Bridges face two main threats from climate change. Higher temperatures and more cloud-free days may lead to increased thermal stresses on metal bridges. Bridges spanning the Thames may experience increased scouring of their footings due to stronger currents from higher fluvial and tidal flows. Engineers should monitor the undermining of bridge footings.

Security of energy supply

London's public transport systems are reliant upon a stable, predictable supply of electricity and diesel. Increases in electricity demand due to hot weather, or impacts on supply during extreme weather will threaten the security of supply. As part of its review of energy sourcing options, TfL should consider the resilience of its energy supply.

Warmer winters

The projected warmer winters will be beneficial to transport through reducing damage from ice and snow and reducing the energy needed to heat trains and buses. As demonstrated by the unusually cold winters of 2005/06 and 2008/09, cold winters will still occur, and new transport systems should be designed and maintained to retain a capability for cold weather periods. However, warmer winters will also extend the growing period of track and roadside vegetation, requiring a change in maintenance.

Energy

Changes in the climate will affect the amount of energy we use and the time at which we use it. At the same time, these changes provide opportunities to generate energy both more efficiently and from cleaner sources. The Mayor is producing a Climate Change Mitigation and Energy Strategy that will consider the following issues in greater detail.

Change in seasonal demand

Warmer winters and hotter summers will change the seasonal pattern of energy use. Warmer winters will reduce the demand for winter space heating, while hotter summers, amplified by the urban heat island effect, will increase energy demand for summertime cooling in London. Research by the GLA[124] estimates that within London there has been a decrease of 156 heating degree days[125] per decade for the period 1977-2006, while the number of cooling degree days has increased by nearly the same amount. This is a significant issue, as mechanical cooling is a more energy-inefficient and carbon-intensive process than heating. In the future, the potential increase in summer energy demand for air conditioning may offset, or even exceed the estimated 12-19 per cent energy use savings that could be expected from the predicted warmer winters[126].

Fuel poverty

Fuel poverty is the term used to describe a lack of household income to adequately heat a home. Fuel poverty depends upon the characteristics of the occupants (elderly, or single parent, for example), housing standards (insulation, heating and ventilation), occupancy issues (both occupancy levels and occupancy patterns), energy price fluctuations and payment problems.

In the UK, the major focus of action on fuel poverty so far has been on reducing the numbers of people unable to heat their homes in winter by providing winter fuel subsidy payments and subsidised thermal insulation for the property. As winter and summer temperatures in London increase over the coming years, the following may result:

- Fewer people in fuel poverty in the winter due to the 'heating season' becoming shorter and less cold, so leading to a reduction in the cost of maintaining a home at a comfortable temperature. However, there are still likely to be people who are concerned about putting their heating on as they fear they won't be able to pay the fuel bills.

- The increase in summer temperatures may lead to the creation of summer 'cool poverty', where the design, construction and overcrowding of housing may cause internal temperatures to become uncomfortable and unhealthy. Currently, there is no subsidy structure for summer energy consumption in vulnerable households and unlike individual responses during cold weather, wearing less clothing is only marginally effective.

Opportunities for renewables

Longer growing seasons, more cloud-free days and potentially windier weather may benefit the generation of renewable energy through biofuels, wind turbines, and photovoltaic and solar thermal arrays.

Photovoltaic and solar thermal arrays may become more economical as the number of cloud-free days increases. The lower air temperatures produced by the evaporative cooling of green roofs has been shown to improve the efficiency of photovoltaics in comparison to those situated on a tile, or tar roof.

Climate risks to energy generation and transmission

Climate change will have a profound effect on the energy industry. Research conducted by the Met Office on behalf of the energy industry[127] found that more than a third of the energy industry processes had a fundamental sensitivity to climate variability – especially temperature, wind, precipitation, sea level and soil moisture.

Power generation, transmission and distribution efficiency can be reduced in hot weather, at a time when demand is peaking. Energy generation is the single biggest water-consuming industry in the UK. Many coal and gas-fired power stations are reliant upon river water for cooling and may be affected by lower summer river levels. It is possible that a power station would have to reduce its power output to remain within its abstraction license (as was experienced in France during 2003). All of the UK's nuclear power stations, and many coal, oil and gas-fired power stations, are located on the coast, where they are vulnerable to tidal flooding. Any future construction of new nuclear power stations is also likely to occur on these existing sites.

Power transmission and distribution is also affected by temperature and rainfall. Higher temperatures increase the resistance in overhead and underground power cables. Overhead cables can sag in hot weather, and the increasing risk of more frequent and more intense winter storms will increase the risk of storm damage to all parts of the generation and transmission network. Milder winters, on the other hand, will reduce the snow and ice damage to these networks.

There are a small number of major electricity substations in and around London that are critical to London. If they were affected by a climate- or weather-related impact, it would significantly affect the security of our supply. The Distribution Network Operator must ensure that critical points in the distribution network are identified and made appropriately climate resilient.

As noted previously, rising summer temperatures will also place increasing seasonal variation on London's energy demands. EDF, the principal energy supplier to London stated that peak electrical energy demand in summer 2006 exceeded the peak winter demand for the first time. During the 2006 heatwave, more than 1,000 properties in the West End were affected by blackouts caused by demand for air-conditioning.

The Mayor believes that London should have a resilient energy supply and will work with the Distribution Network Operator and the energy retailers to ensure that the distribution infrastructure is resilient to climate impacts and that energy suppliers can meet seasonal variations in demand.

The increasing demand for cooling provides opportunities for decentralised power, specifically Combined Cooling Heating and Power (CCHP). In most cases, absorption chillers are chosen as a less environmentally damaging alternative to other technologies, by making use of heat that would otherwise be wasted in summer, which can help improve the business case for decentralised energy schemes.

The proposed move from centralised to decentralised energy generation, together with a more diverse mix of generation types (including renewables and energy from waste) will improve the resilience of London's energy supply to the impacts of climate change, as well as reducing carbon emissions.

On an international scale, extreme climate variability may affect the pricing and availability of imported energy sources. Melting of the permafrost may affect long distance oil pipelines, while extreme weather events may affect offshore oil and gas platforms, refineries and the shipping of oil and gas by tanker.

Waste

London produces approximately 20 million tonnes of waste every year. The quantity and rate at which London is using resources and producing waste is unsustainable. Although London currently recycles over half of all its waste (57 per cent), our performance is poor particularly on municipal waste (25 per cent) compared to other UK regions and international cities. As a result, London continues to rely excessively on landfill to manage its waste, particularly on sites outside the Greater London area.

Waste is another issue where the focus on climate change has been predominantly on mitigation, and to date there has been very little conclusive research into the impact of climate change on waste production and waste management. However, climate change will affect waste management through:

- potential changes in the profile and volume of municipal waste
- impacts on the waste management process (from collection through to treatment and final disposal).

Potential changes in the profile and volume of municipal waste

Higher temperatures and rainfall may drive a change in the packaging of consumer goods, particularly food. Perishable goods may need to be vacuum packed, double wrapped, or packaged in packaging made of thermally stable, watertight and UV impervious materials (potentially with lower recycled and recyclable content). In parallel, public behaviour may change in response to climate change, for example with a possible move to more bottled water being consumed during hot weather.

Warmer, wetter winters will extend the growing season of most vegetation, while summer droughts may temporarily reduce the rate of growth. The overall effect may be an increase in the total volume of green waste produced throughout the year, but with fluctuations in the volume and weight of green waste during a longer growing season. This may affect both green waste collection operations and also the size of plant required to process green waste.

One public response to higher temperatures may be an increased demand in air conditioning and refrigeration. Air conditioners and fridges require special facilities for treatment prior to disposal, and an increase in supply will lead to an increase in demand for disposal facilities.

After the floods in Carlisle and Lewis, the volume of waste from flood damaged homes (white goods, kitchen units, furniture, spoiled food etc) overwhelmed the capacity of the local waste services. Emergency plans will need to consider how London would manage its waste following a severe flood. The plans will need to address both the interruptions to the normal daily municipal waste operation and the extra volume of waste from the flood-damaged properties.

Impacts upon the waste treatment process

Climate change may affect the waste management process at each stage, from collection through to disposal. The emphasis in the Mayor's Municipal Waste Management Strategy and the London Plan is on London taking responsibility for most of its own waste. New facilities will need to be located, designed and managed to minimise the impact of waste management upon neighbours and to ensure that they can operate during extreme weather and can manage longer-term climate risks.

Part 4 Implementing the strategy

Action	Lead	Partners	Delivered by
To improve our ability to predict and manage flood risk			
1. Improve flood risk maps.	Environment Agency	Mayor of London, boroughs, London Resilience, London Climate Change Partnership	Winter 2010
2. Develop a surface water management plan.	Drain London Forum	DEFRA	Spring 2011
3. Create a web-based portal for collating and sharing information on surface water flood risk.	Drain London Forum	DEFRA	Spring 2011
4. Create a single flood reporting system.	Drain London Forum	DEFRA	Autumn 2010
5. Ensure that flood risk management is integrated across borough boundaries and within borough teams.	Mayor of London	Association of London Borough Planning Officers, London Resilience Forums, Drain London	Spring 2011
To prioritise actions to reduce the risk to critical assets and vulnerable communities			
6. Identify critical assets and vulnerable communities at flood risk.	Environment Agency	Mayor of London, boroughs, London Resilience, London Climate Change Partnership	Autumn 2010
7. Improved drain and gully maintenance programme.	Transport for London	Thames Water, boroughs	Spring 2011
To raise individual and community-level awareness and capacity to cope and recover			
8. Increase sign-up to Floodline Warning Direct and improve capacity of Londoners to prepare and respond to a flood.	Environment Agency	Mayor of London, boroughs	Spring 2011
9. Develop two community flood plans.	Drain London	Boroughs	Spring 2011
To take a strategic view on London's water resources			
10. Publish a water strategy for London.	Mayor of London	Environment Agency, Thames Water	Summer 2010
11. Undertake a study to define water neutrality in London and how it can be achieved.	Mayor of London	London Water Group (London Councils, Government Office for London, Greater London Authority, Thames Water, Veolia Water, Essex and Suffolk Water, Sutton and East Surrey Water, Environment Agency)	Autumn 2010

Action	Lead	Partners	Delivered by
12. Lobby the water utility regulator (OfWat) to encourage and enable the water companies to deliver greater household water efficiency savings and greater investment in London's water infrastructure.	Mayor of London		
To reduce our demand for water			
13. Improve the energy and water efficiency of up to 1.2 million homes by 2015.	Mayor of London	Boroughs, GLA Estate Managers, businesses	Trial of 10,000 homes in 2010. Aim to have improved 189,000 homes by 2012 and 1.2m by 2015
To improve our response to droughts			
14. London Resilience will review the need for a London-specific Drought Plan.	London Resilience Partnership		Ongoing
To improve the understanding of overheating risk and target priority areas			
15. Undertake a feasibility study into a network of weather stations.	Met Office	Mayor of London, London Climate Change Partnership, OPAL network, London Grid for Learning	Winter 2010
16. Improve our understanding of how climate change will affect summer temperatures in the future and identify and prioritise areas of overheating risk and risk management options.	Mayor of London	LUCID project SCORCHIO project	Winter 2010
To manage temperatures by increasing green space in the city			
17. Enhance 1,000 ha of greenspace, through: Implementing the Green Grid	London Development Agency	East London Green Grid Partnership	Summer 2012
Preparing Supplementary Planning Guidance for a Londonwide Green Grid	Mayor of London	London Development Agency	2011 (subject to the publication of the London Plan)
Supporting boroughs and other partners in creating projects.	London Development Agency	Londonwide Green Grid Partnership	Ongoing

Action	Lead	Partners	Delivered by
18. Increase green cover in the Central Activities Zone by five per cent by 2030 and a further five per cent by 2050.	Mayor of London	London Boroughs of Lambeth, Southwark, Tower Hamlets, Hackney, Islington, Camden, Westminster, Wandsworth and City Corporation of London.	Five per cent by 2030 10 per cent by 2050
19. Increase tree cover by five per cent by 2025 Planting 10,000 street trees	Mayor of London	Boroughs and voluntary sector	Summer 2012
Identifying planting opportunities and funding	London Tree and Woodland Implementation Group	TfL, boroughs, voluntary sector and developers	Ongoing
20. Enable the delivery of 100,000m2 of new green roofs (through preparing a prospectus on the benefits of green roofs).	Mayor of London	Drain London Forum, boroughs, homeowners and developers	Summer 2012
To reduce the risk of overheating and the need for mechanical cooling			
21. Publish bespoke design guidance for developers to reduce overheating risk.	Chartered Institute of Building Services Engineers	Mayor of London	Spring 2010
22. Implement a new 'cooling hierarchy' policy in the replacement London Plan.	Mayor of London		Winter 2010
23. Map opportunities for decentralised cooling.	London Development Agency	Boroughs	Summer 2010
24. Retrofit a social housing development to reduce risk of overheating.	Social housing provider	London Climate Change Partnership	Spring 2012
25. Assess and promote 'Cool Roof' technologies.	Cool Roofs Consortium	Mayor of London, Brunel University	Autumn 2011
To ensure that London has a robust heatwave plan			
26. Assess the benefits of heatwave refuges.	London Resilience		Summer 2011
27. Determine how best to encourage and enable a community-level response to heatwaves.	Mayor of London	Boroughs, Regional Public Health Group	Autumn 2011
Mainstreaming adaptation across the GLA group and key sectors in London			

Action	Lead	Partners	Delivered by
28. Undertake an assessment of impacts of climate change on the health sector in London.	London Climate Change Partnership	Regional Public Health Group, NHS London	Summer 2010
29. Ensure that climate risks are addressed in the hospital refurbishment programme and commissioning of health services.	Mayor London	Regional Public Health Group, NHS London	Summer 2010
30. Restore 15kms of London's rivers.	River Restoration Centre	Mayor of London, Environment Agency, boroughs	2015
31. Engage with business organisations and other key stakeholders.	London Development Agency	Mayor of London, boroughs, London Councils, Environment Agency, business-to-business organisations, DEFRA	Ongoing
32. Lobby the government to amend building regulations to require buildings being rebuilt or renovated to be climate resilient.	Climatewise	Mayor of London	Summer 2010
33. Undertake a climate risk assessment of TfL's assets and operations and develop a prioritised action plans for key climate risks.	Transport for London	Mayor of London	Summer 2010
34. Work with the Distribution Network Operator and the energy retailers to ensure that the distribution infrastructure is resilient to climate impacts and that energy suppliers can meet seasonal variations in demand.	District Network Operator (EDF)	Mayor of London	Summer 2011

Appendix 1: Acronyms

ABI	Association of British Insurers
BACLIAT	Business Areas Climate Impacts Assessment Tool
BCM	Business Continuity Management
BEEP	Building Energy Efficiency Programme
BIONICS	Biological and Engineering Impacts on Climate Change on Slopes
CCHP	Combined Cooling Heating and Power
CCMES	Climate Change Mitigation and Energy Strategy
CET	Central England Temperature series
CFMP	Catchment Flood Management Plan
CIBSE	Chartered Institute of Building Services Engineers
CLIFFS	Climate Impact Forecasting for Slopes
CMI	Chartered Management Institute
CO2	Carbon Dioxide
CSOs	Combined Sewer Overflows
Defra	Department for Environment, Food and Rural Affairs
DLR	Docklands Light Railway
DSY	Design Summer Year
EA	Environment Agency
GHG	Greenhouse gas
GLA	Greater London Authority
HEEP	Home Energy Efficiency Programme
IPCC	Intergovernmental Panel on Climate Change
LCCP	London Climate Change Partnership
LESLP	London Emergency Services Liaison Panel
LRP	London Resilience Partnership
LU	London Underground
LUCID	Local Urban Climate model and its application to the Intelligent Design of cities
NHS	National Health Service
NLARS	North London Aquifer Recharge Scheme
Ofgem	Office of the Gas and Electricity Markets
OfWat	Office of Water Services

PFI	Private Finance Initiative
PM10	Particulate matter (smaller than 10 micrometres)
PR09	Price Review 2009
PTSD	Post-traumatic stress disorder
RFRA	Regional Flood Risk Appraisal
SCORCHIO	Sustainable Cities: Options for Responding to Climate cHange Impacts and Outcomes
SFRA	Strategic Flood Risk Assessment
SMEs	Small and medium sized enterprises
SRES	Special Report on Emissions Scenarios
SUDS	Sustainable Drainage Systems
SWMP	Surface Water Management Plan
TCFMP	Thames Catchment Flood Management Plan
TCP	Tunnel Cooling Programme
TE2100	Thames Estuary 2100 Project
TfL	Transport for London
TRY	Test Reference Year
TW	Thames Water
UHI	Urban Heat Island
UKCIP	UK Climate Impacts Programme
UKCIP02	UK Climate Impact Programme 2002
UKCP09	UK Climate Projections 2009
UV	Ultra violet
UVR	Ultra-violet radiation
WRMP	Water Resource Management Plan

Appendix 2: Checklist against statutory requirements

Requirement	Reference	How addressed
General Duties Relating to all Strategies		
Promoting economic development and wealth creation	GLA Act 1999 s 30(2a)	Throughout strategy in particular chapter 8
Promoting social development	GLA Act 1999 s 30(2b)	Throughout strategy, in particular chapter 6
Promoting improvement of the environment	GLA Act 1999 s 30(2c)	Throughout strategy, in particular chapter 7
Equality of opportunity	GLA Act 1999 s33 (1c)	Throughout strategy
Keep Strategies under review and make such revisions as considered necessary	GLA Act 1999 s 41(2)	See Introduction
Have regard to principal purposes of the GLA	GLA Act 1999 s 41(4a)	(see S30 (2a-c above)
Have regard to health of persons in London	GLA Act 1999 s 41(4bi)	Throughout Strategy, in particular chapter 6
Have regard to health inequalities between persons living in London	GLA Act 1999 s 41(4bia) as amended by GLA Act 2007 s24 (3b)	Throughout Strategy, in particular chapter 6
Achievement of sustainable development in UK	GLA Act 1999 s 41(4bii)	Throughout strategy
Contribute to the mitigation of or adaptation to, climate change in the UK	GLA Act 1999 s 41(4c), as amended by GLA Act 2007 s 40(3)	Throughout strategy
Consistent with national policy and notified international obligations	GLA Act 1999 s 41(5a)	Through strategy
Consistent with other Mayoral strategies	GLA Act 1999 s 41(5b)	Yes, although note that Strategies are consistently revised in an on-going cycle
Resources available for implementation	GLA Act 1999 s 41(5c)	Yes, Actions listed in Chapter 10 are achievable within the resources available.
Desirability of promoting and encouraging the use of the river Thames safely, in particular for passenger and freight transport	GLA Act 1999 s 41(5d)	Chapter 3 and 9

Requirement	Reference	How addressed
Specific Duties in Legislation Relating to the Strategy		
Assessment of the consequences of climate change for London	GLA Act 1999 s 361D 2a (as amended by GLA Act 2007 s44	Chapters 3-9
Proposals and policies for adaptation to climate change	GLA Act 1999 s 361D 2b (as amended by GLA Act 2007 s44	Throughout strategy, particularly chapters 3-5
Specific Requirements in Guidance		
Use of Powers, Resources and influence	GoL Guidance May 2008 (para 4.4)	Throughout strategy, in particular chapter 10
How London can manage the effects of flooding, overheating and more limited water resources	GoL Guidance May 2008 (para 4.5)	Throughout strategy, in particular chapters 3-5
Have regard to latest evidence of climate change, in particular UKCIP and IPCC	GoL Guidance May 2008 (para 4.6)	Throughout strategy, in particular chapters 3-5
Consistent with Climate Change Act 2008	GoL Guidance May 2008 (para 4..7a)	Throughout strategy
Consistent with Consistent with UK Climate Change Programme	GoL Guidance May 2008 (para 4.7b)	Yes uses latest 2008 projections
Consistent with Adaptation Policy Framework	GoL Guidance May 2008 (para 4.7c)	Throughout strategy
Consistent with PPS1	GoL Guidance May 2008 (para 4.7d)	Yes, throughout document
Consistent with PPS25	GoL Guidance May 2008 (para 4.7e)	Yes see chapter 3
Consistent with Future Water	GoL Guidance May 2008 (para 4.7f)	Throughout strategy, particularly chapter 4
Not have an adverse impact on East of England or South East England	GoL Guidance May 2008 (para 4.8)	Through Integrated Impact Assessment

Appendix 3: Statutory Consultees

The London Assembly

Functional Bodies

Each London Borough

Common Council (Corporation of London)

East of England Development Agency

English Heritage

Environment Agency Thames Region

London First

London Resilience

Natural England

NHS London

South East England Development Agency

Gas and Electricity Markets Authority (Ofgem)

UK Climate Impacts Programme

Essex & Suffolk Water Company

Sutton & East Surrey Water Company

Thames Water

Veolia Three Valleys (formerly Three Valleys Water)

Appendix 4: References

1 HMSO (2007) The GLA Act 2007

2 GLA (2010). *The draft London Climate Change Mitigation and Energy Strategy*. Consultation draft for the London Assembly and Functional Bodies

3 HM Treasury (2007) *The Stern Review of the economics of climate change*

4 Under the Climate Change Act (2009), the GLA is proposed as one of the public bodies that should report on climate risks facing London to government. The first report is due 2010, the second report is due 2014/15.

5 Intergovernmental Panel on Climate Change, 2007, Working Group 1, Fourth Assessment Report

6 http://ukclimateprojections-ui.defra.gov.uk

7 The UKCP09 results show that southern parts of England are likely to experience greater warming than northern parts of England. The change in mean summer temperature (^{0}C) to the 2080s under the medium emissions scenario and at the 50% probability interval is 0.2^{0}C higher for southern areas than for northern areas. Warming will be greater during the summer than the winter months. The increase in mean summer temperature (^{0}C) to the 2080s under the medium emissions scenario and at the 50% probability interval is 3.9^{0}C for London, whereas the increase in mean winter temperatures is 3^{0}C.

8 The Gulf Stream keeps the UK warmer in winter than it should be for its latitude. A weakening of the Gulf Stream caused by climate change is projected to cause the UK climate to cool slightly and is factored into the projections. The risk of the Gulf Stream completely failing has been explored, but is considered highly unlikely.

9 Further information on probabilistic projections is available at http://ukclimateprojections.defra.gov.uk/content/view/1119/9/

10 This allows decision-makers to make better risk-based decisions by providing more information - for example, if you know that you have to change the way you manage your system at a given temperature, say 32˚C and the projections tell you how often temperatures are likely to exceed 32˚C in the future, you then have more information upon which to act.

11 The Met Office predicted at the end of November 2009 that there was a 20% chance that the winter would be colder than usual, but a 50% chance that it would be warmer than usual. By the end of December this prediction had been reversed to a 45% chance of a colder than average winter and a 25% of a warmer than average winter. This underlines the difficulty in predicting seasonal forecasts and in communicating probabilities.

12 The 'average' is taken to be the 50th percentile. The extreme figures quoted use the 10th or 90th percentiles.

13 http://www.defra.gov.uk/environment/flooding/manage/propertylevel.htm

14 The 'return period' is how often a flood of a given magnitude would be expected to occur over a long period of time. For example '1 in 100' means that a flood of that severity would occur on average only once every hundred years over a long period of time (for example a thousand years). The annual percentage expresses the probability as a percentage, therefore a '1 in 100' return period is the same as a one per cent chance in any one year.

15 The Association of British Insurers (ABI) has revised its *statement of principles on the provision of flood insurance* (July 2008), stating that until 30 June 2013 its members will a) continue to provide flood insurance to homeowners and businesses as part of the standard insurance provision where flood risk is not 'significant' (less than 0.3% annual probability), b) will continue to offer flood insurance where the flood risk is significant, but the Environment Agency is committed to reducing the risk within 5 years, and c) this commitment does not extend to building built after 1 Jan 2009.

16 http://www.environment-agency.gov.uk/homeandleisure/37837.aspx

17 1 in 200 year rainfall is a very unlikely event today, but still represents a real challenge- the rainfall event that caused the flooding of Sheffield in 2007 was a 1 in 150 year event.

18 GLA (2009) Regional Flood Risk Appraisal http://www.london.gov.uk/mayor/strategies/sds/docs/regional-flood-risk09.pdf

19 Environment Agency (2005) Flood Risk Key Facts Report

20 Environment Agency (2008) NaFRA database (rounded to the nearest 100 properties)

21 Scottish Executive Publication (2007) Exploring the social impacts of flood risk and flooding in Scotland

22 Environment Agency Service Levels 2008/09 - Service Level FRM30

23 Environment Agency, personal communications

24 ONS (2005) ONS Family Spending 2005: A report on the 2004-05 Expenditure and Food Survey

25 ABI, personal communications

26 DCLG (2006) Planning and Policy Statement 25: Development and Flood Risk

27 Flood resistance refers to taking measures to make sure that flood water cannot enter a property. Flood resilience refers to taking measures to minimise flood damage when a property is flooded and ensure that it can be brought back into full use as quickly as possible.

28 http://www.defra.gov.uk/environment/localgovindicators/ni189.htm

29 UKWIR (2004) Report 03/CL/10/2

30 London Assembly (2005) Crazy Paving. The environmental importance of London's front gardens

31 Prepared by the Greater London Council

32 The London Resilience Partnership is a coalition of key agencies responsible for the strategic emergency planning and preparation for London

33 http://www.londonprepared.gov.uk/londonsplans/emergencyplans/flooding.jsp

34 http://www.londonprepared.gov.uk/downloads/ccprotocol_august2008.pdf

35 LESLP is a multi-agency panel composed of the emergency services, including the Metropolitan Police, City of London Police, British Transport Police, London Fire Brigade, London Ambulance Service and local authorities. The Port of London Authority, Maritime and Coastguard Agency, the military and voluntary sectors may also be represented.

36 The London Recovery Protocol is a generic document, detailing generic arrangement, which can be applied to the impact of any incident. http://www.londonprepared.gov.uk/londonsplans/emergencyplans/recovery.jsp

37 Water resources for the future – a strategy for Thames region, 2001

38 Greater London Authority (2009) *draft London Water Strategy*

39 OfWat 'June returns' 2008-09

40 Environment Agency (2005) *The London Catchment Abstraction Management Strategy*

41 The supply-demand surplus or deficit is calculated by comparing the water the company has available for use with the predicted demand in a dry year (see below for definition), plus an allowance for uncertainty called 'headroom'. If supply is less than (demand plus headroom), the company cannot confidently meet its levels of service, and hosepipe bans etc might be needed more frequently. There may also be a risk of needing standpipes or rota cuts in the event of a very severe drought.

42 A "dry year" is the driest conditions water companies plan to cater for without introducing restrictions such as hosepipe bans. Demand in dry years is higher than in normal years by a factor of 2 to 5%. Depending on the company's stated levels of service a dry year can be conditions that recur on average every 10 or 20 years.

43 Thames Water (2009) *draft Water Resources Management Plan*

44 Excess nutrients in watercourses and water bodies enhance plant growth. When these plants die their decomposition uses the dissolved oxygen in the water, starving aquatic organisms of oxygen. This

feedback cycle accelerates until the waterbody is effectively dead, in a state know as eutrophic.

45 Environment Agency, personal communications

46 GLA (2009), *The draft London Water Strategy*

47 Environment Agency (2008), *Greenhouse gas emissions of water supply and demand management options*. Science report SC070010.

48 Environment Agency [press release http://www.environment-agency.gov.uk/news/106050.aspx

49 The London Water Group is a forum of organisations with responsibility for water issues in London. The Group includes representation from the 4 water companies supplying London, the financial and environmental regulators, consumer and environmental NGOs and London Councils.

50 Herrington. P (1996), Pricing water properly. Discussion papers in public sector economics. No 96/6. University of Leicester

51 Environment Agency and GLA (2009), Impact of household water metering in South East England. ISBN: 978-1-84911-081-5 http://publications.environment-agency.gov.uk/pdf/SCHO0709BQSO-E-E.pdf

52 Marshallsay D., Trew J., Waylen C., (2006) *Assessing the cost of compliance with the Code for Sustainable Homes*. Prepared for the Environment Agency

53 GLA (in prep.), Understanding London's urban climate: Climate change and the heat island

54 Office for National Statistics. Excess deaths are calculated by subtracting the number of expected deaths from the number of observed deaths. These are estimates because it is not possible to define the cause of death being due to high temperatures.

55 Johnson H., Kovats R.S. et al (2005) *The impact of the 2003 heat wave on daily mortality in England and Wales and the use of rapid weekly mortality estimates*

56 Armstrong BG, Chalabi Z, Fenn B, Hajat S, Kovats S, Milojevic A, Wilkinson P. (in prep)

57 Hadley Centre, personal communications

58 Women are more vulnerable than men for various reasons, including having a higher core body temperature, the adverse effects of menopause on thermoregulation and some social differences

59 Paper in prep

60 GLA (2007) Round Population Projections

61 The term 'blocking high' refers to the ability of anticyclonic systems to 'block out' other weather systems and so persist for several weeks

62 GLA (2006) London's urban heat island : A summary for decision makers

63 Sustainable Cities: Options for Responding to Climate cHange Impacts and Outcomes (SCORCHIO), led by University of Manchester

64 The Development of a Local Urban Climate Model and its Application to the Intelligent Development of Cities (LUCID), led by University College London

65 Adapted from GLA (2008) *Forecasting future cooling demand in London. Technical Report: Supporting London Plan Policy.* Produced by London South Bank University

66 Assumes a current demand of 5,500,000 MWh rising to 12,500,000MWh by 2030 (high emissions scenario) from above report.

67 Gill, S. Handley, J. Ennos, R. Pauliet, S. (2006), *Adapting cities for climate change : the role of green infrastructure*

68 A 'cool roof' has a high albedo (reflective) surface to minimise the amount of heat absorbed by the roof, and good thermal insulation to prevent any heat absorbed being transferred to the building below

69 'Emissivity' refers to the ability of a material to radiate heat. Low emissivity materials therefore radiate less heat and so can contribute to reducing the urban heat island.

70 London Climate Change Partnership (2008), *Your home in a changing climate*

71 In prep. To be launched late 2009. Working title Technical Manual 49 (TM49)

72 The London Design Summer Years use 'weighted cooling degree hours' to define overheating risk, where the weighting of every degree above 28°C is quadratically scaled to represent the increased health impact.

73 Department of Health, personal communications

74 Department of Health, 2009. *Heatwave Plan for England*

75 World Health Organisation (1947) *The Constitution of the World Health Organisation*

76 GLA (2007), *Best Practice Guidance. Health issues in Planning*

77 SNIFFER (2007) *Preparing for a changing climate in Northern Ireland*

78 GLA (2007) *Reducing health inequalities – issues for London and priorities for action*

79 Adapted from Kovats et al (2005) *Climate change and human health in Europe*

80 Excess winter mortality is calculated as winter deaths (deaths occurring in December to March) minus the average of non-winter deaths (April to July of the current year and August to November of the previous year).

81 The reason may be the large proportion of homes that are energy inefficient and, therefore, difficult to keep warm and the fact that a disproportionately high number of those living in such homes are those who are most vulnerable to the health effects of cold – e.g. older people and those with long term health conditions. Fuel poverty, which is described as the inability to affordably maintain adequate warmth (19-21°C) in the home, depends on the building fabric, air-tightness and heating systems as well as household income and energy costs

82 Help the Aged, personal communications

83 GLA (2009) *Clearing the Air. The Mayor's Draft Air Quality Strategy*

84 Bennett G. (1970) *Bristol floods. Controlled survey on effects on health of local community disaster*

85 Lyme disease is caused by the bacterium *Borrelia burgdorferi*, and is transmitted to humans by the bite of infected ticks. Typical symptoms include, fever, headaches, fatigue and skin rashes.

86 Health Protection Agency (2008) *Health Effects of Climate Change in the UK 2008*

87 NHS Confederation (2007) *Taking the temperature. Towards an NHS response to global warming*

88 Statistical Information Team Cancer Research UK

89 Department of Health (2008) *Health effects of climate change in the UK 2008: an update of the Department of Health report 2001/2002*

90 Foltz and Ferrara (2006) *Dehydration's hidden symptoms*, The Chiropractic Journal

91 A 'non-decent' home is any home that does not meet the government's definition of a decent home, which is provided in CLG (2008) *A Decent Home: Definition and guidance for implementation*

92 Communities and Local Government (2003) *English House Condition Survey*

93 GLA (2005) *London and Sub Regional Strategy Support Studies*

94 London Councils (2004) *Overcrowding in London*. Based on Census 'persons per room' measure, where a household with over 1 person per room is overcrowded and one with over 1.5 persons per room is severely overcrowded.

95 London's black, Asian and minority ethnic communities and poorest households are disproportionately affected by overcrowding and more likely to be unable to receive and use information on adaptation. Overcrowding has almost doubled in local authority housing and is now higher among local authority tenants than private sector tenants. It is also concentrated in the poorest areas and more prevalent in inner London

96 GLA (2009) *The London Health Inequalities Strategy. Draft for public consultation*.

97 Kovats and West (2005)

98 Health Protection Agency (2007) *National Heatwave Plan* (2007 revision)

99 NHS London, personal communications

100 GLA (2007) *Post Consultation Draft : East London Green Grid Framework*

101 Sustainable Drainage Systems (SUDS) is an approach to drainage that considers the quantity, quality and amenity value of managing surface water. SUDs are more sustainable than conventional methods because they manage the impact of urbanisation on flooding, protect or enhance water quality, and provide wildlife habitat.

102 River Restoration Centre (2009) *London Rivers Action Plan*.

103 Diffuse pollution is pollution from a non-specific source, e.g. agricultural run off, run off from roads and where sewer pipes are miss-connected into the surface water drainage system.

104 GLA (2009) *The London Plan, Consultation Draft Replacement Plan* - Policy 5.2, and GLA (2008) *The London Plan* - Policy 4.12

105 GLA (2007) *Further Alterations to the London Plan*, Policy 4A.11,

106 The 3rd Revision of the LTOA's *A Risk Limitation Strategy for Tree Root Claims* was published on the 31st of May 2007 and is available to download from www.ltoa.org.uk.

107 A megacity is defined as a city conurbation with more than 10 million inhabitants.

108 Munich Re (2004) Megacities – megarisks: trends and challenges for insurance and risk managers

109 LCCP (2006) *Adapting to climate change*: Business as usual ?

110 Association of British Insurers (2005) *Financial Risks of Climate Change*

111 Association of British Insurers (2005) *UK insurance – key facts*

112 http://www.climatewise.org.uk/storage/ClimateWise%20Copenhagen%20Statement.pdf

113 UCKIP (2005) *A changing climate for business*

114 Chartered Management Institute (2007) *Business Continuity Management*

115 National Flood Forum, personal communication

116 London Borough of Camden (2003) *Floods in Camden: Report of the Floods Scrutiny Panel*

117 the equivalent of 63,925 hundred-watt light bulbs burning continuously.

118 Analysis of temperatures during the extremely hot period of July 2006 shows that while the external temperatures varied by as much as 11°C, the platform air temperature on deep tube lines (Bakerloo, Central, Piccadilly, Northern and Victoria lines) varied by an average of 2°C, to a maximum of 4°C.

119 BRE (2004) *Understanding thermal comfort on London Underground trains and stations – summer survey.* Report No 211739

120 London Underground aims to achieve tunnel and platform air temperatures of 29°C in an average summer. This target temperature is based on a balance between thermal comfort and practicable cooling solutions. Using the 29°C criterion, and the 2-4°C temperature fluctuations experienced during the 2006 heatwave, this would mean that most stations during a heatwave would reach 31°C, with small sections of the network rising to 33°C.

121 Groundwater cooling has been successfully used to cool the Victoria Line platforms at Victoria Station by using cold groundwater in fan coil units above the platforms. This technology is limited to sites where there is practical access to a sustainable source of groundwater.

122 Railtrack Company Specification, 2002

123 Rail tracks expand and contract with changes in temperatures. Railway companies therefore stress or de-stress continuously welded tracks at different times of the year to limit rail buckling. Changes to

the seasons and peak temperatures will affect when and how much the tracks are stretched.

124 in preparation

125 Cooling and heating degree days provide a simple measure of the energy required to keep the internal environment of buildings comfortably cool in warm weather and comfortably warm in cool weather. Cooling degree days are defined in this strategy as the number of days per year when temperatures exceed 22°C and heating degree days when they drop below 15.5°C.

126 H. Graves and M. Phillipson (2000) *Potential implications of climate change in the built environment*, BRE

127 Met Office (2006) *Climate change and energy management*

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Hindi

यदि आप इस दस्तावेज की प्रति अपनी भाषा में चाहते हैं, तो कृपया निम्नलिखित नंबर पर फोन करें अथवा नीचे दिये गये पते पर संपर्क करें

Vietnamese

Nếu bạn muốn có văn bản tài liệu này bằng ngôn ngữ của mình, hãy liên hệ theo số điện thoại hoặc địa chỉ dưới đây.

Bengali

আপনি যদি আপনার ভাষায় এই দলিলের প্রতিলিপি (কপি) চান, তা হলে নীচের ফোন্ নম্বরে বা ঠিকানায় অনুগ্রহ করে যোগাযোগ করুন।

Greek

Αν θέλετε να αποκτήσετε αντίγραφο του παρόντος εγγράφου στη δική σας γλώσσα, παρακαλείστε να επικοινωνήσετε τηλεφωνικά στον αριθμό αυτό ή ταχυδρομικά στην παρακάτω διεύθυνση.

Urdu

اگر آپ اِس دستاویز کی نقل اپنی زبان میں چاھتے ھیں، تو براہ کرم نیچے دئے گئے نمبر پر فون کریں یا دیئے گئے پتے پر رابطہ کریں

Turkish

Bu belgenin kendi dilinizde hazırlanmış bir nüshasını edinmek için, lütfen aşağıdaki telefon numarasını arayınız veya adrese başvurunuz.

Arabic

إذا أردت نسخة من هذه الوثيقة بلغتك، يرجى الاتصال برقم الهاتف أو مراسلة العنوان أدناه

Punjabi

ਜੇ ਤੁਹਾਨੂੰ ਇਸ ਦਸਤਾਵੇਜ਼ ਦੀ ਕਾਪੀ ਤੁਹਾਡੀ ਆਪਣੀ ਭਾਸ਼ਾ ਵਿਚ ਚਾਹੀਦੀ ਹੈ, ਤਾਂ ਹੇਠ ਲਿਖੇ ਨੰਬਰ 'ਤੇ ਫ਼ੋਨ ਕਰੋ ਜਾਂ ਹੇਠ ਲਿਖੇ ਪਤੇ 'ਤੇ ਰਾਬਤਾ ਕਰੋ:

Gujarati

જો તમને આ દસ્તાવેજની નકલ તમારી ભાષામાં જોઈતી હોય તો, કૃપા કરી આપેલ નંબર ઉપર ફોન કરો અથવા નીચેના સરનામે સંપર્ક સાધો.

MoL/Jan10/VL D&P/GLA1437

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