MANAGING RISKS AND INCREASING RESILIENCE

THE MAYOR'S CLIMATE CHANGE ADAPTATION STRATEGY

OCTOBER 2011

MAYOR OF LONDON

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Key authors:
Alex Nickson, Helen Woolston, Juliette Daniels, Isabel Dedring, Kevin Reid, Kulveer Ranger, Louise Clancy, Roger Street, Tim Reeder.

Other contributors:
GLA Group, London Climate Change Partnership, Department for Environment, Food and Rural Affairs, London Assembly Environment Committee, Liberal Democrat Assembly Members, the North London Strategic Alliance, Diocese of Southwark Croydon Area Mission Team, Department of Health, English Heritage, Federation of Small Businesses, London First, London Sustainable Development Commission, Natural Environment Leaders Group, North London Waste Authority, London Wildlife Trust. London Borough of Bexley, London Borough of Brent, London Borough of Westminster, London Borough of Camden, London Borough of Islington, Royal Borough Kensington and Chelsea, Sustainable Water Industry Group.

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FOREWORD

We have all seen the disaster movies, in which a sprawling modern metropolis is brought to its knees by a global-warming induced deluge of Biblical proportions, or plunged into a glacial Ice Age of permanent winter. However, Hollywood hyperbole aside, London's climate is changing. We must take steps now to ensure the city is prepared for the future. Not just to avert environmental disaster but also to preserve and enhance our quality of life and prosperity for generations to come.

Improving our ability to cope with projected climatic shifts is a key part of my vision to 'retrofit' London to manage the challenges we face. Whether this is through installing energy efficiency measures in buildings or providing low and zero-emission transport to limit further climate change, or, as in the case here, improving the resilience of the city to extreme weather and long-term climatic changes.

Inherent in this goal is the drive to attract significant new investment into London, thereby securing tens of thousands of jobs through the delivery of vital infrastructure, goods and services, as well as developing world-class exportable skills. London is already one of the most resilient of the 'world cities' in the face of climate impacts and is well-placed to be the international 'one-stop-shop' for adaptation – exporting our native talent and services to the rest of the world. Furthermore, changes that make us resilient in the century to come also leads to a better city today.

My ambition is to put the village back into the city. What I mean by this is that we can improve the quality of life for Londoners by ensuring that we focus our efforts on delivering a cleaner and greener city with stronger and safer communities through our work to make the city more sustainable and preserving its prosperity for decades to come.

Many of the actions set out in this strategy bring tangible benefits in the present, such as greening London through increasing tree cover and improving parks and public spaces. This makes our city more beautiful, as well as providing shading and flooding protection. But in the future, these adaptations will help the city cope with new weather patterns too.

This strategy also sets out actions to empower Londoners to take action for themselves. We want to help people develop their own flood plans, and provide the information that will enable them to develop the solutions that are best for them and their communities.

With this strategy – a world-first for a city of this size and complexity – we are once again at the vanguard of environmental stewardship. I thank everyone in advance for their involvement in the hard work ahead.

Boris Johnson
Mayor of London


Putting
the village
back into the city
Retrofitting London
Cleaner air for London
Greening London

PREFACE

A strategic framework for enhancing quality of life in London and protecting the environment

The Climate Change Adaptation Strategy is part of a series of strategies that together set out actions and policies to make London the best big city in the world. How? By improving the quality of life of Londoners and making the city more sustainable.

The future of the planet lies in cities. In the 1950s just 29 per cent of people lived in towns and cities. By the close of the 20th century that figure had increased to 47 per cent, and by 2050 it will hit 70 per cent. There are clearly benefits to city living. People live longer, have access to better education, extensive public transport, greater healthcare provision, more social, cultural and economic opportunities and a lower carbon footprint. The Mayor is working to ensure that London not only retains its world city status but remains among the best places on the planet to live, whatever your age or background. He also wants to ensure that the city is liveable and its development is sustainable for future generations.

The Mayor's ambition is to put 'the village' back into the city. What this means is improving the quality of life for Londoners by ensuring that we focus our efforts on delivering a cleaner and greener city with stronger and safer communities through our work to make London more sustainable.

The Mayor's environment strategies and programmes are built on three policy pillars. These are retrofitting London, greening London, and cleaner air for London. These pillars aim to improve the quality of life for Londoners and visitors, and to make the capital more attractive. The Mayor's programmes that underpin these pillars are delivering targeted improvements and benefits that Londoners can see and experience around them. They also aim to make public services more efficient and less of a burden on tax payers, whilst delivering wider environmental benefits such as conserving water, saving energy or reducing waste.

The three 'pillars' and example programmes:

Retrofitting London

Retrofitting London's existing buildings is not only crucial to tackling London's CO_2 emissions, it also reduces energy and water use, delivers new jobs and skills, as well as saving London businesses and homes money on energy bills. Almost 80 per cent of the 14,000 low carbon jobs that could be created per year from delivering the Mayor's CO_2 target and two thirds of the £721 million of annual low carbon economic activity would come from retrofitting.

Our homes and workplaces are responsible for nearly 80 per cent of the city's emissions. Fundamentally 80 per cent of these buildings will still be in use by 2050. The RE:NEW programme which installs a range of energy and water efficiency measures in homes, enables Londoners to save money on their energy bills while making their homes more energy efficient. The RE:NEW demonstrations in 2010, have shown that households could save over £150 annually through retrofitting actions.

Greening London

The Victorians bestowed on us a city softened by trees and green spaces. Greening London builds on this legacy and aims to improve the look and feel of our city, making it more attractive whilst reducing the impact of noise and air pollution. Greening London also makes the city more resilient to flooding and extreme weather events, and can contribute to a healthy mind and body. The Mayor through his RE:LEAF programme and the London Green Grid has an ambition to increase tree cover by five per cent by 2025, therefore achieving one tree for every Londoner and creating a better network of interlinked, multi-functional and high quality open and green spaces.

Cleaner air for London

Air pollution is a serious health issue and the Mayor is determined to reduce its impact. Actions being taken to improve air quality include introducing the first ever age limit for black cabs, tougher standards for the Low Emission Zone, new cleaner hybrid and hydrogen buses and fitting older buses with equipment including filters to curb pollution. The new bus for London, which will be launched in 2012, will use the latest green technology making it 40 per cent more efficient than a conventional double decker. The Mayor is working to introduce more electric vehicles onto London's streets. In May this year, he launched Source London, the UK's first citywide electric vehicle charging network and membership scheme and we are also now investing record amounts to deliver a cycling revolution in London. Additional steps are being taken to tackle pollution levels at some of the busiest roads in central London. This includes utilising dust suppressant technology that prevents PM10 from re-circulating, installing green infrastructure to trap pollutants and a no engine idling campaign to reduce engines running unnecessarily when stationary. Eco-marshalls are also being deployed to help both monitor and reduce the impact of taxis on air quality.

London continues to attract people and businesses and therefore continues to grow. The London Plan forecasts the city's population could increase from 7.6 to 8.8 million by 2031. These strategies show that making London a sustainable city and protecting the environment does not mean we all have to be eco-warriors or make sacrifices to our standard of living. We can work to lessen our impact on the city while at the same time improving the environment and our quality of life.

In a post-Olympic London, we can also grasp the opportunity to make the capital a digital leader, an intelligent city. By harnessing the power of data, we can run our city more efficiently, understand environmental trade-offs, and communicate better with Londoners, enabling them to make better informed and sustainable choices in how they live and work. This is already happening through the explosion of social media and digital applications that encourage behaviour change based on the choices an individual makes. Data visualisation is also allowing us to understand complex data sets, telling us the results of the millions of decisions we make, on us, on our neighbourhoods, on our city and beyond.

Transitioning our city to a sustainable low carbon economy will also bring economic opportunities for London in terms of jobs and investment. Despite the economic downturn, the value of London's low carbon and environment sector is now worth over £23 billion, growing by over four per cent a year. As London and the rest of the world continue to reduce their greenhouse gas emissions over the coming decades, the economic opportunities from that activity will be huge. London must make sure it grabs this opportunity and continues to be a world leader.

Kulveer S Ranger
Mayor's Director
of Environment

EXECUTIVE SUMMARY

Key headline messages

- London is already vulnerable to extreme weather, in the form of floods, droughts, heatwaves and very cold weather. Without action, further climate change, London's population growth, and other changes (eg changes to make-up of London's population and land cover) will increase the risk of severe impacts.
- London has already experienced some changes to its climate and we should expect warmer wetter winters and hotter, drier summers in the future. Extreme weather, such as heatwaves and very heavy rainfall is expected to become more frequent and intense. Very cold winters will still occur, though they will become less frequent. Sea levels will rise for centuries.
- Preparing for extreme weather and further climate change is about managing risks and increasing our resilience to them - it is therefore as much about the economy, quality of life and social equality, as about the environment.
- Early action today will not only manage current and future risks, but save Londoners money and create jobs.
- Many of our vulnerabilities to climate impacts stem from London's 'urbanisation'. Restoring greenspaces and building community capacity will increase our resilience and improve our quality of life.
- The Mayor does not have the power or the budgets to adapt London on his own. However through this strategy he can provide a framework for collective action, identifying where he is uniquely placed to act and where other organisations, and even Londoners themselves, can lead or facilitate action.

Key messages by chapter are:

Introduction
There is clear evidence that our climate is already changing. It is widely accepted that without significant and global action to reduce our greenhouse gas emissions, we run the risk of experiencing significant changes to our climate that will dramatically impact on our quality of life and the economy.

'Adaptation' is a process of identifying climate risks and opportunities, assessing the options to manage these risks and opportunities, and implementing the most sustainable actions to sustain and even improve our quality of life. Because the climate will keep changing through the century, and our responses change with it, adaptation should be seen as a 'journey', rather than a 'destination'.

Chapter 1: London's future climate
The UK currently has the most advanced climate projections in the world. They project that the southeast of the UK will experience warmer, wetter winters and hotter, drier summers in the future. Extreme weather, such as heatwaves and very heavy rainfall will become more frequent and intense. Very cold winters will still occur, though they will become less frequent. Sea levels are expected to continue to rise for centuries to come.

Chapter 2: Mapping adaptation
No single authority is individually responsible, or capable, of increasing our resilience to climate risks. To effectively sustain and even increase our resilience, we need the climate to be routinely considered in all significant decisions and more joint working across the public, private and voluntary sectors. This chapter attempts to map where responsibility for adaptation lies and identify where gaps exist in enabling adaptation.

Chapter 3: Flooding
London is vulnerable to flooding from a variety of sources, key of which are 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 principally managed by a system of flood defences (walls, gates and the Thames Barrier) and drainage networks.

London is currently very well protected against tidal flooding, but has a lower and much more variable standard of protection against fluvial flooding and a relatively low standard of protection against surface water flooding. The probability of all forms of flooding is projected to increase as sea levels rise and heavy rainfall events become more frequent and intense. The cumulative impact of paving over of front and back gardens has increased the pressure on our drainage system, also increasing the likelihood of flooding.

The impact of a major flood in London would be significant because it is heavily urbanised and 15 per cent of the city's surface area lies on the floodplains of London's rivers. Currently 1.25 million people, 481,180 properties, and a substantial proportion of the capital's schools, transport network, and emergency services are at tidal and fluvial flood risk, though most are well protected. More than 800,000 properties lie at risk of surface water flooding. The consequences of flooding will increase as London's population grows and more property and infrastructure is located in areas of flood risk. There are also a large number of flood-vulnerable communities at risk. Advance warning times for fluvial and surface water flooding are short and public awareness of flood risk and capacity to act is low.

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 from, flooding. 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 identify areas at greatest current and future risk
- supporting collaborative working to enable a coherent cost-effective approach
- 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.

Chapter 4: Drought
The likelihood of a drought having a significant impact on London is currently low, as in most years there is sufficient water to meet demand. However, this 'security of supply' is only met by withdrawing more water from the environment than can be sustained. In the future, less summer rainfall, greater demand for water and greater restrictions on the volume of water we can remove from the environment will threaten our security of supply.

Without action, London will experience an increasing frequency of drought management measures (such as restrictions on water use, for example hosepipe and non-essential uses bans). Frequent and prolonged droughts would affect water-dependent businesses, London's green spaces and biodiversity – particularly wetlands and watercourses. Reducing our water use could improve our drought resilience, safeguard our environment and save Londoners money through reduced utility bills.

Response

The Mayor believes that London should have a secure supply of water that is affordable and safeguards the environment. 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:

- promoting an integrated package of measures to enable and sustain a long-term improvement in water efficiency
- lobbying government to integrate water efficiency into housing retrofitting programmes
- promoting capturing and using rainwater for non-consumptive purposes
- improving our response to drought.

In response to the 2006 drought, Londoners' water use fell by ten litres per person per day, but has now increased back to its original level. This shows we can, and have, made significant water savings, but that without ongoing support and incentives, consumption increases. The Mayor will work with partners to deliver a 'six point plan' of integrated actions:

a Improve the water efficiency of existing buildings
b Ensure all new development is super water efficient
c Raise Londoners awareness of the financial benefits of increased water efficiency
d Increase the number of homes with a water meter
e Change the way Londoners pay for their water
f Continue to tackle leakage.

As part of its strategy to reduce CO2 emissions by 80 per cent by 2050, government has made a commitment to offer an energy efficiency retrofit to every home in the UK by 2030. The Mayor believes that improving the water efficiency of London's 3.2 million homes is essential to balancing supply and demand for water in the long-term and meeting our carbon reduction targets. As such, water efficiency improvements should to be integrated into energy efficiency retrofitting programmes to ensure cost effective delivery and increased public awareness.

The Mayor is keen to promote capturing and using rainwater for non-consumptive purposes (such as flushing toilets). This approach, known as 'rainwater harvesting' can be a 'win-win-win' solution, though reducing the use of treated mains water for uses that do no require highly-treated water, reducing flood risk and reducing the volume of rain-diluted sewage at sewage treatment works.

Chapter 5: Overheating

Overheating is a term used in this strategy to describe when temperatures are hot enough to affect Londoners' health and comfort, or affect the capital's infrastructure. As we have already experienced two major heatwaves in the last decade (2003 and 2006), overheating is a real and present risk to London. Without action, the risk of overheating is expected to increase in the future as average summers get hotter, heatwaves increase in intensity and frequency and as London grows. In addition, urban landscapes can amplify summer night-time temperatures, maintaining high temperatures in the city at night, an effect known as the urban heat island effect.

Londoners are more resilient to rising temperatures than the rest of the UK, but once temperatures exceed 24.7ºC, Londoners seem to be more vulnerable, with a higher rate of deaths and ill effects. The reasons for this vulnerability are that London is located in the warmest part of the UK and therefore our thermally poor homes are more likely to overheat. Poor air quality also thought to compound the impact of high temperatures. High temperatures also affect the transport network, electricity supply and water use.

The Mayor will work with partners to reduce and manage the impact of hot weather on Londoners through:

- mapping overheating risk to prioritise actions to target the worst affected areas and most vulnerable people
- managing rising temperatures by increasing the amount of green space and vegetation in the city
- reducing the risk of overheating and the need for mechanical cooling in new and existing development and infrastructure
- ensuring London has a robust heatwave plan.

Chapter 6: Health

The impact of climate change on the health of Londoners is a complex issue as the benefits or threats to health may be direct (for example, heatstroke), or indirect (for example, a hospital having to be closed due to flooding). On balance, for the early decades of this century, the changing climate is expected to present more health benefits than challenges, such as a predicted reduction in hospitalisation and cold-related deaths. It is also expected that without targeted action, existing health inequalities will increase, particularly for vulnerable populations. Managing these impacts is the responsibility of a wide range of agencies, both within the health sector and beyond.

To date, the health sector has largely focused on actions to reduce carbon emissions. It is critical that the health and social care services are resilient to extreme weather. The health sector is an emergency service and therefore needs to be capable during emergencies.

The Mayor will work with the health and social care sector to provide climate information, assist with assessing climate risks and opportunities to the sector and developing best practice demonstration projects.

Chapter 7: London's environment

London is the greenest big city in the world and the quality and abundance of its greenspaces provides the opportunity for Londoners and visitors to have access to wildlife in an urban setting. London's greenspaces also perform a range of functions, known as 'ecosystem services', such as reducing flood risk by absorbing rainwater, and cooling the city through shading and evaporation. These ecosystem services are essential to the wellbeing of Londoners and London's resilience to climate change.

The Mayor plans to increase London's resilience to climate impacts through using ecosystem services to complement London's 'grey' infrastructure (floodwalls, drains and sewers). The Mayor will work with partners to deliver a major Londonwide 'urban greening' campaign, increasing the quality, quantity, function and connectivity of London's greenspaces, targeting projects where they are most needed and where they will have greatest impact.

Chapter 8: Economy

All cities are vulnerable to climate change because of the concentration of people and development in a relatively small area, and their reliance on importing people, food, water, energy and products for them 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. In particular, London must 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.

The Mayor will work with London's business-to-business organisations and Business Improvement Districts to help businesses identify and respond to the risks and opportunities presented by climate change and extreme weather.

Chapter 9: Infrastructure

A city is a system of systems. The resilience of the city is therefore not just dependent on how resilient its systems (transport, utilities etc) are individually, but also the resilience between these systems. This chapter looks at London's transport, energy and waste infrastructure.

London's transport network is the lifeblood that supports the city. The diversity of London's transport modes (Underground, bus, train, taxi etc) provides greater resilience to climate impacts as it is very unlikely that all modes would be affected by an extreme weather event. However some modes are more vulnerable than others. The Underground is the most vulnerable to flooding and overheating as water will naturally flow to the lowest point and cooling the deep level Underground lines is very challenging. Buses on the other hand are very flexible as their routes can be easily changed and the buses themselves are relatively easy to retrofit or replace.

Transport for London has undertaken a climate risk assessment across all its modes using the UKCP09 climate projections and is confident that it has the mechanisms to manage an extreme weather event and replace operational critical assets as required.

The energy system is vulnerable to both direct climates impacts and changes in demand for energy. It is expected that winter heating demand will decrease through the century and summer cooling increase. This will provide challenges as currently most heating is gas powered and almost all cooling electrically generated.

More than a third of the energy industry processes – generation and distribution – are sensitive to climate variability, especially temperature, rainfall, wind, sea levels and soil moisture. The energy generation and distribution companies need to ensure that their systems are climate resilient and that they can meet changes in seasonal energy demand.

Climate change will affect waste management through potential changes in the types and volume of waste produced and direct impacts on the waste management process (from collection through to treatment and final disposal). New facilities will need to be flexible to changes in waste production and be resilient to climate impacts.

INTRODUCTION

What is 'adaptation'?

In this strategy, 'adaptation' is used to define actions to a) understand the risk and opportunities we face from extreme weather today and further changes to our climate in the future; b) to identify, assess and prioritise the options to manage the risks and opportunities, and c) to develop, deliver and monitor actions to manage these risks and realise these opportunities.

Why adapt?

The Mayor believes that there are many good reasons we should adapt.

1 **The UK is not very well adapted to our current climate.** If we look at the last decade alone, the UK has experienced significant flooding in 2002, 04, 05, 07, 08, 09 and 10, heatwaves in 2003 and 2006, a severe drought in 2006 and unusually cold winters in 2009 and 2010. Each of these events have affected the health and quality of life of UK residents and had a negative impact on the UK economy. Taking action to prepare London today for changes in our climate will help to protect us from extreme weather today and put us on the road to greater resilience against future challenges.

2 **Our climate is already changing and further changes are now unavoidable.** We are already experiencing changes to our climate that typify what we are projected to experience in the future. Summers today are now on average 2ºC warmer than they were 30 years ago and heavy rainfall events are five times more frequent. Even if we stopped all our emissions today, the legacy of our previous emissions means that we are still likely to experience changes that may be beyond our current capacity to cope.

Climate change is likely to mean that the South East of England will experience a trend of increasingly warmer, wetter winters and hotter, drier summers. Within this average trend, we will also experience an increase in the frequency and intensity of extreme weather – particularly heatwaves and heavy rainfall events. In fact, what may be considered an extreme event today – for example a heatwave - is likely to become the average weather by the middle of the century and a new, higher, intensity will define a future extreme event. Sea levels are projected to rise by one metre by the end of the century. This means that the existing risks (floods, droughts and heatwaves) will increase throughout the century unless we take action.

3 **Urban areas are particularly vulnerable to climate impacts.** The density of people and assets within a relatively small geographic area means that there is a lot more at risk than rural areas. London is also reliant on areas outside the city to provide a large percentage of its workforce, its food, water, energy and other consumables. The capital is the economic engine of the UK and an integral part of the world economy, and therefore any impact on London will have repercussions across the country and internationally. London's communities are also more diverse, more mobile and more fragmented than other parts of the UK, meaning that communicating risk management measures is more difficult. Lastly, the urban landscape itself can reinforce climate impacts, for example by preventing the city from cooling off on hot summer nights and increasing the rate of run off of rainfall leading to flash flooding.

4 **Proactive action is always cheaper and more effective than reaction**. As frequently demonstrated by examples from all over the world – from Hurricane Katrina in New Orleans, to the 2007 floods in the UK – investing in preventing, or limiting, the impacts of extreme events is much cheaper and has less social impact than recovering afterwards. Not all risks can be prevented, but pre-emptive action to reduce the impact of an extreme event and a swift, effective response to the event can reduce the health and financial impact of an event and speed up recovery.

5 **Adaptation actions can provide wider benefits.** Measures to adapt to warmer, wetter winters and hotter, drier summers can have a wider beneficial effect. Many of the actions proposed in this strategy have been shaped to improve London in a number of ways beyond buffering us from the potential impacts of our climate. For example, increasing the amount of greenery in our city to absorb floodwater and cool the city will also improve the quality of Londoners' lives, reduce energy use, improve water and energy security, tackle social inequality and boost the 'green' economy.

Not all climate impacts will be negative. 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 and will require co-ordinated action to maximise the opportunities they present.

6 **Some adaptation actions are complex and require a number of partners at a range of scales to manage an impact.** The strategy provides a framework to enable partners to work together more effectively and efficiently to deliver key adaptation actions. Some actions will take decades to implement (for example increasing our urban forest so that it is mature when summers are routinely hot), so we need to start now to ensure that we will receive the benefits when we need them. Responses to some challenges may require a phased approach, implementing relatively small actions today, but planning and preparing for potentially significant interventions in the future (for example, building a second Thames Barrier).

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[2] to reduce GHG emissions in London. Under the duty, the Mayor must ensure that all GLA plans and strategies consider adapting to, and mitigating further, climate change.

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 Identify and prioritise the climate risks and opportunities facing London and understand how these will change through the century
2 Identify and prioritise the key actions required to prepare London, and to define where

responsibility for delivering and facilitating these actions lies
3 Promote and facilitate new development and infrastructure that is located, designed and constructed for the climate it will experience over its design life
4 Improve the resilience of London's existing development and infrastructure to the impacts of climate change
5 Ensure that tried and tested emergency management plans exist for the key risks and that they are regularly reviewed and tested
6 Encourage and help business, public sector organisations and other institutions prepare for the challenges and opportunities presented by climate change
7 Promote and facilitate the adaptation of the natural environment
8 Raise general awareness and understanding of climate change with Londoners and improve their capacity to respond to changing climate risks
9 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.

Scope of the strategy

The Climate Change Adaptation Strategy undertakes seven tasks:

1 Analyses how London is vulnerable to weather-related risks today (and so establishes a baseline to assess how these risks change).
2 Uses projections from climate models to identify how climate change may accentuate existing risks and create new risks or opportunities in the future.
3 Prioritises the key climate risks and opportunities for London.
4 Provides a framework that:
   a identifies the scale, or scales at which to tackle the risks
   b identifies actions where the GLA is uniquely placed to act
   c identifies where other stakeholders need to act
   d facilitates action by highlighting where collaborative working will increase the efficiency and effectiveness of any action
   e identifies and prioritises where further work is required to understand the climate and its impacts before actions can be defined.
5 Establishes a strategic process by which London can put in place the measures necessary to adapt to future climate change.
6 Recommends how London should capitalise on the opportunities presented by climate change.
7 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 Climate Change Adaptation Strategy is organised into four parts:

PART ONE
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 TWO
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 discussed in Chapters 6-9.

PART THREE
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 FOUR
Implementing the strategy
Chapter 10 Providing a 'roadmap to resilience', with a summary of the key actions, and an action plan.

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'.

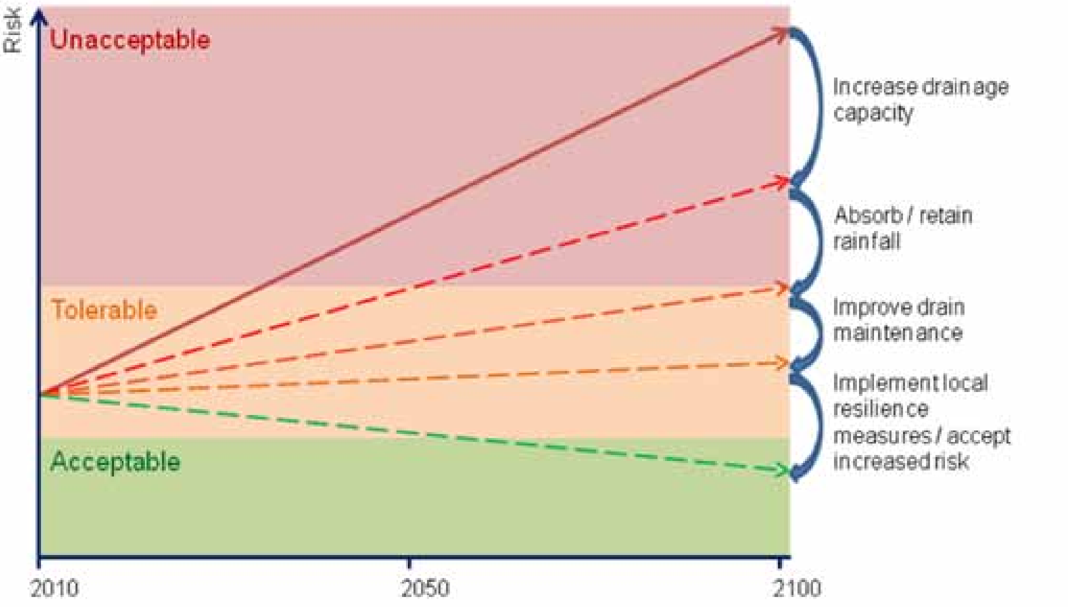
Adapting to climate change is not about drafting lots of new policies. It is about understanding how climate change may affect the world around us and then routinely integrating that understanding into our decision-making processes to make better choices. Decisions about spatial planning, engineering 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.

Adaptation is about managing risk and 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 and manage risk, it is necessary to understand the components of risk. These are:

- **Probability** of an event (for example, a tidal surge) or change that exceeds our ability to cope with it and therefore has an impact
- **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 *adaptive capacity* (for example, what ability do people at risk have to prepare and respond to climate risks).

As our climate changes and the frequency and intensity of extreme events increases, it is important to understand the sensitivity to these changes. A key step is 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.

Figure A. Diagrammatic representation of risk management



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.

When to adapt and how much to adapt to?

A key challenge is to understand the 'adaptation gap' we face – that is the gap between what society is able, or prepared, to cope with and the increased risk of a future impact. Figure A diagrammatically represents an increasing risk (in this example, surface water flooding) and the steps that can be taken to manage the risk and bring it down to an 'acceptable' level. Some of the measures can be achieved at little, or no, cost and can be implemented with minor amendments to a 'business as usual' approach (such as improving the maintenance programme of drains). Other interventions may be much more intensive, and require significant planning and funding to implement (for example increasing the drainage capacity in London).

This strategy is the first step in determining the 'adaptation gap' for each climate impact in London and exploring the adaptation options to close the gap. The Mayor will work with partners to identify the risk management options, assess the 'true' value of these options (including social, environmental and economic benefits) and then develop flexible adaptations pathways (see Fig 3.6) for each climate risk.

Review of the strategy

The strategy will be regularly appraised and reviewed to ensure that it is providing the optimum framework to increase London's resilience to extreme weather and climate change. When the Localism Bill becomes law, a new London Environment Strategy will replace this strategy and amalgamate it with the other statutory strategies and plans concerning the environment that the Mayor is required to publish under the GLA Act (1999).

PART ONE

UNDERSTANDING THE CLIMATE OF THE FUTURE

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 278ppm. However, 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[3] 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 this 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. 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.

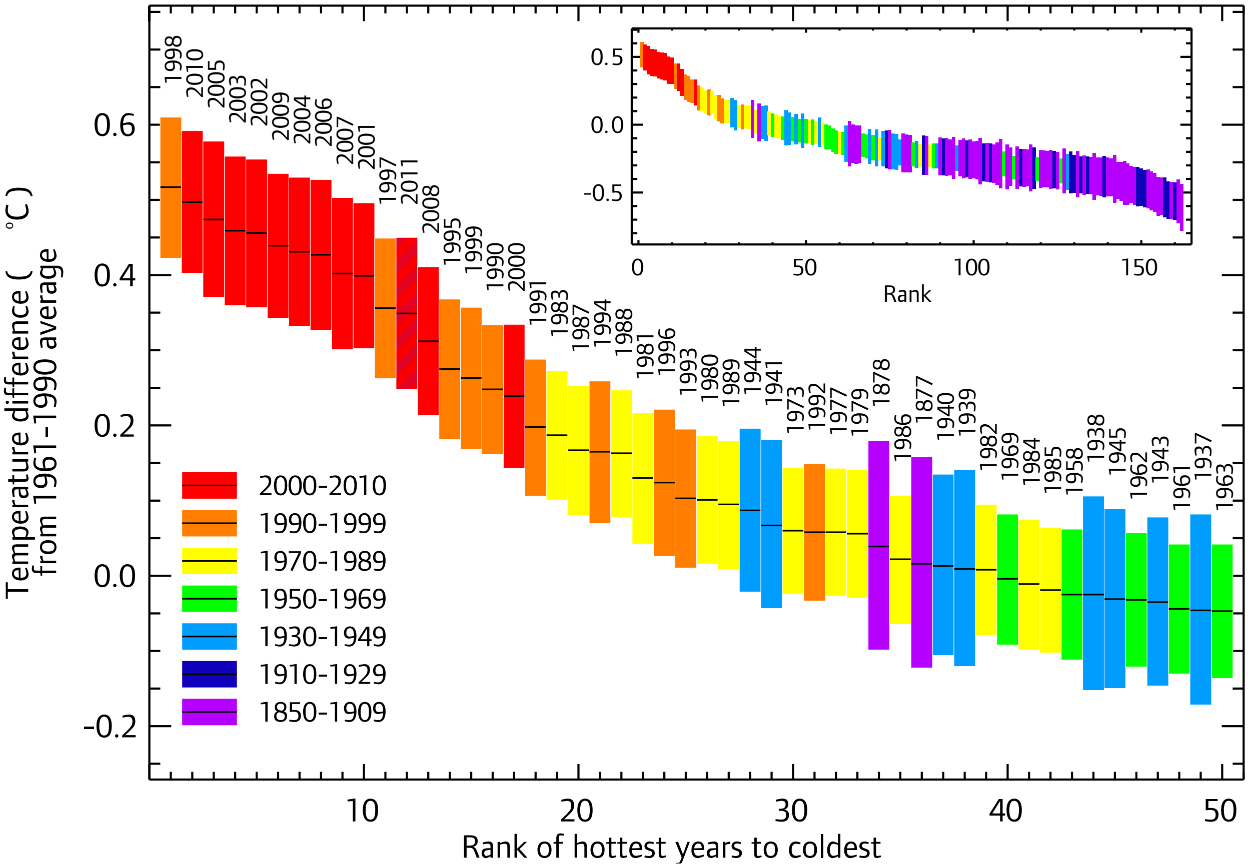
Catastrophic climate change

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 losing the Amazon rainforest, or the rapid melting of the polar ice sheets).

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, 450ppm. 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.

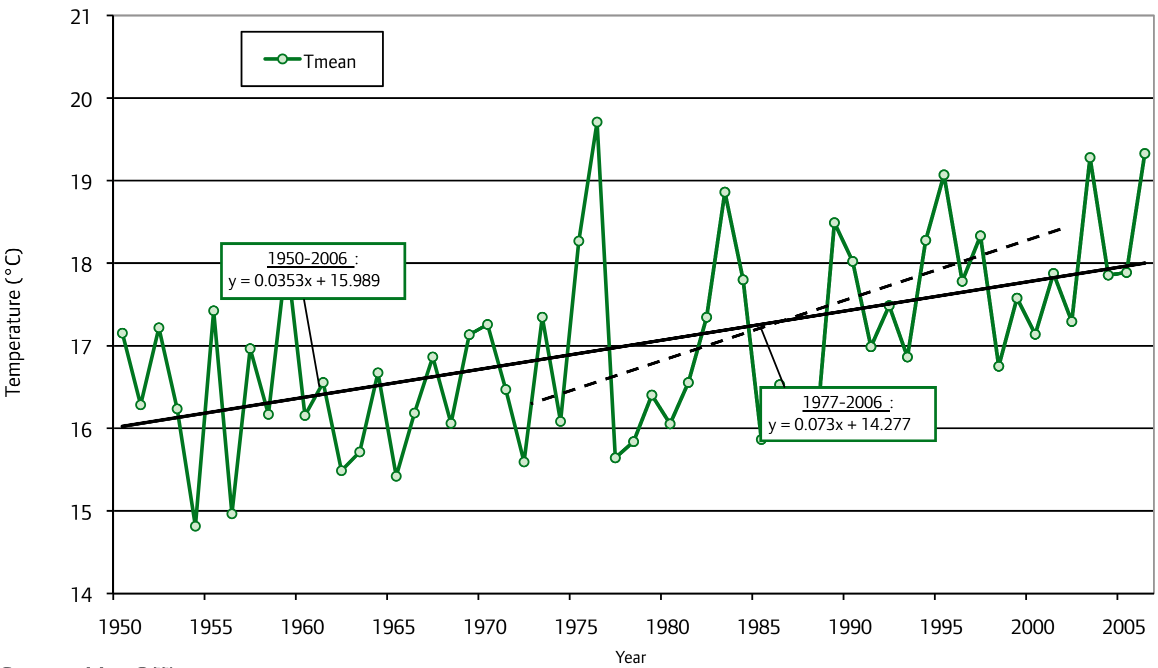
The Mayor is committed to reducing London's carbon dioxide emissions by 60 per cent by 2025 through action involving all levels of government, as well as individuals and the private sector. In the Mayor's Climate Change Mitigation and Energy Strategy[2], the Mayor sets out the steps on how this will be achieved.

Figure 1.1 Global annual average temperatures, ranked hottest to coldest



Source: Meteorological Office, Hadley Centre

Figure 1.2 Average summer temperatures in London 1950-2006



Source: Met Office

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 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.

The same trend can be seen in heavy rainfall events, where the frequency of heavy rainfall days (defined as more than 45mm of rainfall in a day) occurred, on average, once every thirty years before 1960 and once every six years after 1960[4].

Projections of London's future climate

Climate models are computer models used to project our future climate. 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[5] and provide probabilistic projections for a number of atmospheric variables (such as temperature, rainfall and humidity) at a number of different time and geographic scales and emissions scenarios.

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[6]. Both sets of projections allow for a slight weakening of the Gulf Stream, so are cooler than would otherwise be projected[7].

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'[8], 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[9].

Climate versus weather

'Climate is what you expect – weather is what you get'.
Robert A. Heinlein

'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, or localised weather events (for example the cold winters of 2009 and 2010), with long-term trends (for example, winters warming by over 2ºC by the mid-century). There will be years when summers are wetter, or winters are colder than the predicted trend. This does not mean that the climate change projections 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.

2010 was the second warmest year globally on record, but the coldest year in the UK since 1986[10].

The following section shows information from the UKCPO9 projections for London in two 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 and 1.4 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. 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 time slices).

Figure 1.5, 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

Table 1.1 UK Climate Projections 2009 for London (2050s and 2080s medium emissions scenario)

Rising temperatures	Summers will be hotter. By the middle of the century, the average summer day[11] is projected to be 2.7°C warmer and very hot days 6.5°C warmer than the baseline average. By the end of the century the average summer day is likely to be 3.9° warmer and the hottest day of the year could be 10°C hotter than the hottest day today. Winters will be warmer, with the average, mid-century winter's day being 2.2°C warmer and a very warm winter day 3.5°C above the baseline. Very cold winters will still occur, but will occur less frequently.
More seasonal rainfall	Summers will be drier. By the middle of the century, the average summer is projected to be 19 per cent drier and the driest summer 39 per cent drier than the baseline average. By the end of century average summers could be 23 per cent drier. Winters will be wetter. By the middle of the century, the average winter is projected to be 15 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 or height, except under an extreme scenario, where a 70cm increase has been projected.
Sea level rise	Sea levels are projected to rise by up to 96cms 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 Average monthly maximum temperatures (°C) in London over the century, under a medium emissions scenario, compared to baseline period

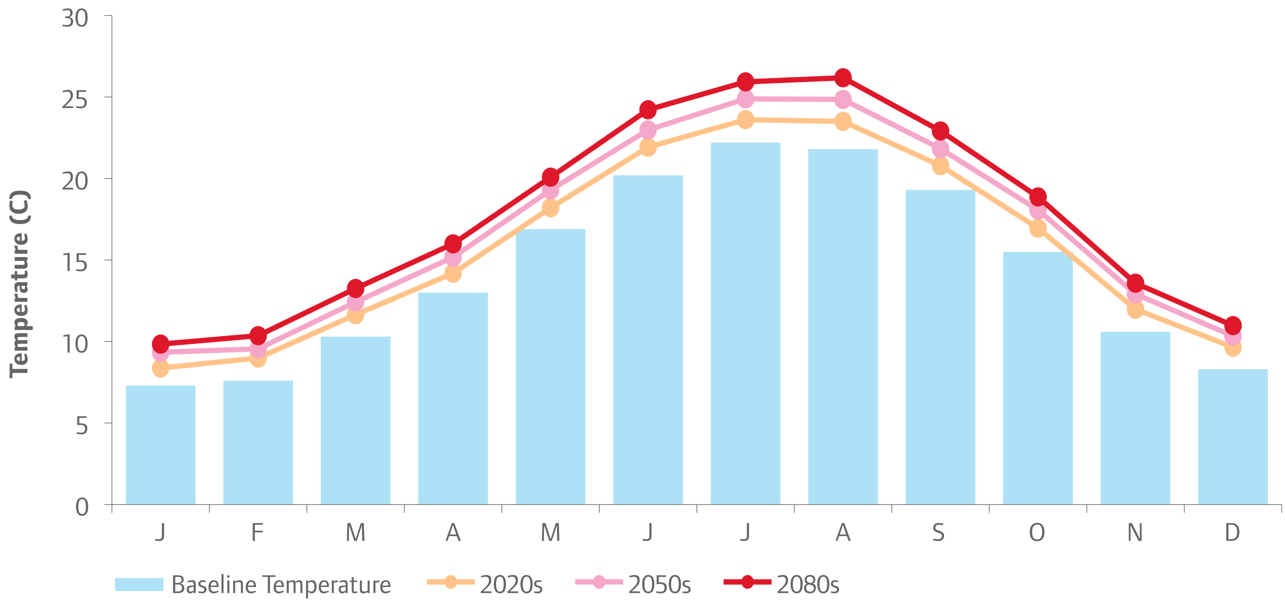
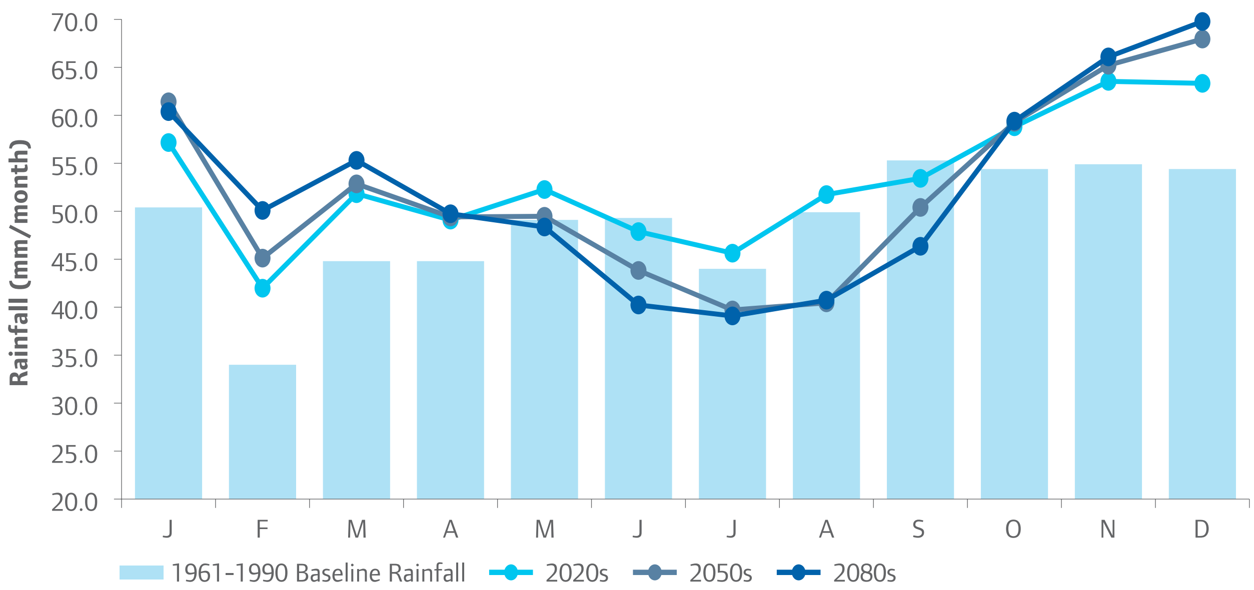


Figure 1.4 Average monthly rainfall (mm of rainfall per month) in London over the century, under a medium emissions scenario, compared to baseline period



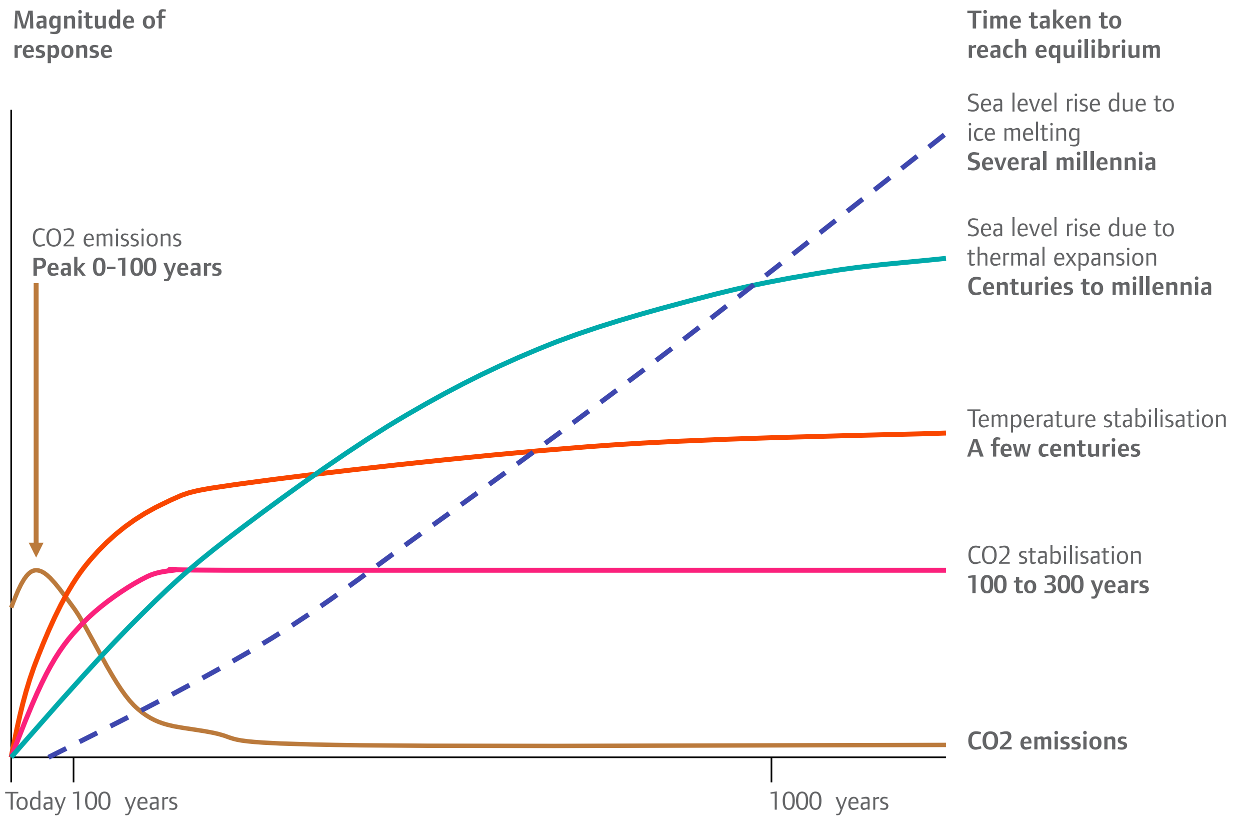
global temperatures to stabilise, but thousands of years for sea levels to reach equilibrium.

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

Figure 1.5 Climate system responses to reducing carbon dioxide emissions



Source: IPCC Third Assessment Report

standards for wind resistance in England, this 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.

CHAPTER 2
MAPPING ADAPTATION – WHO IS RESPONSIBLE FOR WHAT, AND WHERE ARE THE GAPS?

As highlighted in the introduction, there is no 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, maps out who is responsible for enabling adaptation for London's three key climate risks (flooding, drought and overheating) under four headings (Prevent, Prepare, Respond, Recover). It also highlights where there are critical gaps and signposts the relevant actions in the strategy.

Flooding

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

Spatial planning – This involves avoiding locating 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 in the future. However, the pressure for development in urban areas means that it is sometimes necessary to develop in flood-risk areas. The GLA and boroughs are responsible for using the planning process to reduce flood risk. The government's forthcoming review of the planning system must ensure that spatial planning remains the first step in flood risk management.

Flood defences and drainage systems – A significant proportion of London is protected by flood defences. The Environment Agency has responsibility for maintaining most of the tidal and fluvial 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 boroughs, TfL, the Highways Agency and private landowners also have responsibility for some drains. Most drains are designed to manage up to a 1 in 30 year storm, but maintenance is often poor, so the standard of service provided by parts of the network is often well below the original design standards. Under the Flood and Water Management Act[12] (FWMA), local authorities have been designated 'Sustainable drainage systems approval bodies' and are required to promote and manage sustainable drainage systems (SuDS – see chapter 3) to tackle flood risk.

Using the public, or private, realm to store, or redirect floodwater – This involves designing areas to deliberately flood (such as parkland, sports fields, public squares, road spaces, or below ground spaces) so that flooding of more vulnerable land uses can be avoided, or reduced. 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 London Regional Flood Risk Appraisal[13] (RFRA). This identifies many of the regionally important assets at risk of flooding 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 risk of flooding.

The Environment Agency has produced Catchment Flood Management Plans (CFMPs) which identify the flood risk management strategies for each of London's rivers. The Thames Estuary 2100 Project sets out options for managing tidal flood risk through this century. These plans operate at a strategic scale and identify areas at flood risk today, as well as using climate projections to assess how risk will change in these areas. All boroughs have produced Strategic Flood Risk Assessments (SFRAs). These provide a good starting point for understanding local flood risk, though most do not consider surface water flood risk.

Under the FWMA, Local Authorities (boroughs in London), have been designated as 'Lead Local Flood Authorities' (LLFAs), with the responsibility for mapping and managing surface water flood risk. There is significant concern that most boroughs do not have the skills to meet this challenge. Government has provided some funding to boroughs to help take on this responsibility, but in some cases this funding has been used for other priorities. Through Drain London, the GLA has been working with the boroughs to support them in performing their LLFA role in mapping flood risk and developing Surface Water Management Plan (SWMPs).

Boroughs also have to produce Flood Risk Management Plans under the Flood Risk Regulations (2009) and Local Flood Risk Management Strategies under the FWMA. The Mayor believes that boroughs should produce a single flood risk management plan for all flood sources and that this should draw information from the draft SWMPs, SFRAs and CFMPs.

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. It is important that they take account of surface water flood risk and that the utility financial regulators (Ofwat and Ofgem) support utility companies in investing in the flood resilience of these assets. It is also important that the interdependencies between critical infrastructure are understood to maintain and increase resilience.

Communities and individuals in areas of known flood 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), having a flood plan and emergency kit and developing a Community Flood Plan. Currently there is a low uptake of the Floodline Warnings Direct scheme in some areas of London 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. Flood risk is recognised as a priority risk, and the LRP has published the London Strategic Flood Framework[14] 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. 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 borough has produced a generic emergency plan or a bespoke multi-agency flood plan on behalf of their borough resilience forum. These set out how responders will work together to manage the response to flooding. The Environment Agency is working with boroughs to ensure that their plans meet a satisfactory standard in accordance with Defra's guidance. Where relevant, these plans now need to be updated to take into account the improved surface water flood risk data available through Drain London.

Homeowners, businesses and landlords can fit flood resilient or resistant measures to their properties to reduce the impact of flooding. The government has published advice on flood resilience measures and has funded two rounds of grants to help toward the costs[15]. 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[16] 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 fixtures and fittings with more flood resilient designs, thereby continuing instead of reducing future risks.

Current gaps in adapting to flood risk	Action
Flood risk management needs to be more joined up, both within and between flood risk management partners, particularly boroughs.	3.6
Critical infrastructure at flood risk needs to be identified interdependencies between key infrastructure understood and ensure appropriate resilience	3.8, 9.2
There is a lack of community awareness and capacity to respond in high-risk areas	3.11
Poor sign-up to Floodline Warnings Direct in some areas of London and lack of individual preparedness for flooding	3.10
Like-for-like insurance replacement fails to improve the resilience of property at risk from flooding	8.1

Drought

Prevent
A drought is caused by a 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 propose 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 five-year business plan detailing 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, assesses the water companies' business plans. In the current five-year business plans, Ofwat did not support water companies seeking investment in adapting their infrastructure to risks based on the UKCIP02 projections. The water industry is now using UKCP09 to model impacts on water resources and drainage requirements, so it expected that water companies will invest in adaptation in the next round of planning.

In the face of declining supplies and increasing demands, it makes sense to use the water we have more wisely. Reducing our demand for water by increasing our water efficiency can not only help reduce the need for drought restrictions, but save money and safeguard the environment.

The government has committed to reducing the UK's CO2 emissions by 80 per cent by 2050. A key action in achieving this target is to offer every home an energy efficiency retrofit package by 2030. There is no similar programme for improving water efficiency, despite that fact that the major challenges to implementing retrofit programmes are getting access to peoples' homes and the cost of implementing the measures (not the actual cost of the measures themselves).

Respond
As a drought becomes more likely or prolonged, water companies can implement demand-reduction and supply-optimisation actions in their drought plans. These plans take a risk-based approach and are designed to avoid having to implement area-based cuts. These actions start with asking customers to voluntarily 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.

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 currently no requirement for any government body, or agency, to produce a drought recovery plan.

Current gaps in adapting to drought risk	Action
Water efficiency programmes are not integrated into energy efficiency programmes, making them more difficult and expensive to deliver	4.1, 4.2
Each of London's four water companies has a drought plans but there is no London-specific drought plan	4.3

Overheating

Prevent
It is not possible to prevent hot weather from occurring, but it is possible to limit how much the urban realm intensifies hot weather, our exposure to heat and how we look after vulnerable Londoners.

It is also possible to design new buildings and infrastructure and retrofit existing development to minimise overheating in hot weather and therefore minimise all but essential mechanical cooling, which would otherwise increase the urban heat island. 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 and design green spaces and breeze pathways to cool the city.

The risk of overheating has only recently been recognised and is therefore relatively 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 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 hospitals) often do not take the forthcoming climate into account in their design or construction, and may overheat. Energy efficiency measures can increase the risk of overheating by absorbing too much solar energy or preventing heat from escaping a building.

Overheating is one of the risks assessed in Housing Health and Safety Assessments. These are usually carried out by borough environmental health officers, but these are not routinely carried out and many vulnerable Londoners live at overheating risk.

Prepare

Mapping overheating risk is more difficult than flood risk, as vulnerability varies from location–to-location, building-to-building and person-to person. This makes targeting the most vulnerable in society and making the case for funding difficult to achieve.

Following the 2003 heatwave, the Health Protection Agency published and annually revised a national Heatwave Plan. 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 challenged.

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 identify and inform to their vulnerable communities and individuals during a heatwave, but there are questions regarding how effective this works at present. This especially applies to those who are not aware that they are vulnerable to high temperatures.

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 for vulnerable patients.

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 managing overheating risk	Action
New and refurbished development is often not designed for the climate it will experience over its design life. Energy efficiency measures can increase the risk of overheating.	5.1, 5.7, 5.8,
Many heat vulnerable Londoners are unaware of overheating risk and may be oblivious to passive means of awareness raising.	5.11

PART TWO

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 identify areas at greatest current and future risk
- supporting collaborative working to enable a coherent cost-effective approach
- reducing flood risk to the most critical developments 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, and an improving understanding of current surface water flood risk. **To improve our ability to predict and manage future flood risk, further work is required to disseminate this knowledge and understand how climate change will increase all forms of flood risk.**

Action 3.1. 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 3.2. The Drain London Forum will develop a surface water management plan for London which identifies and prioritises areas at risk and develops more detailed plans for priority areas.

Action 3.3. The Drain London Forum will create an online data portal to allow flood risk management partners to more effectively share information.

Action 3.4. The Drain London Forum will create a flood incident reporting system and encourage its adoption across London.

Effective flood risk management requires co-ordinated working across different geographic scales, organisations and departments within organisations. **To enable coherent, cost-effective collaborative working:**

Action 3.5. The Mayor will maintain the Drain London Forum as a mechanism to facilitate information exchange, project identification and development.

Action 3.6. The Mayor will encourage each borough to form a cross-departmental flood group.

Action 3.7. The Mayor will work with Thames Water, the Environment Agency and the boroughs to trial an intensive urban greening retrofitting pilot project to manage surface-water flood risk.

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

Action 3.8. The Mayor will work with the London Resilience Partnership and the London Climate Change Partnership to identify and prioritise critical infrastructure and vulnerable communities at flood risk.

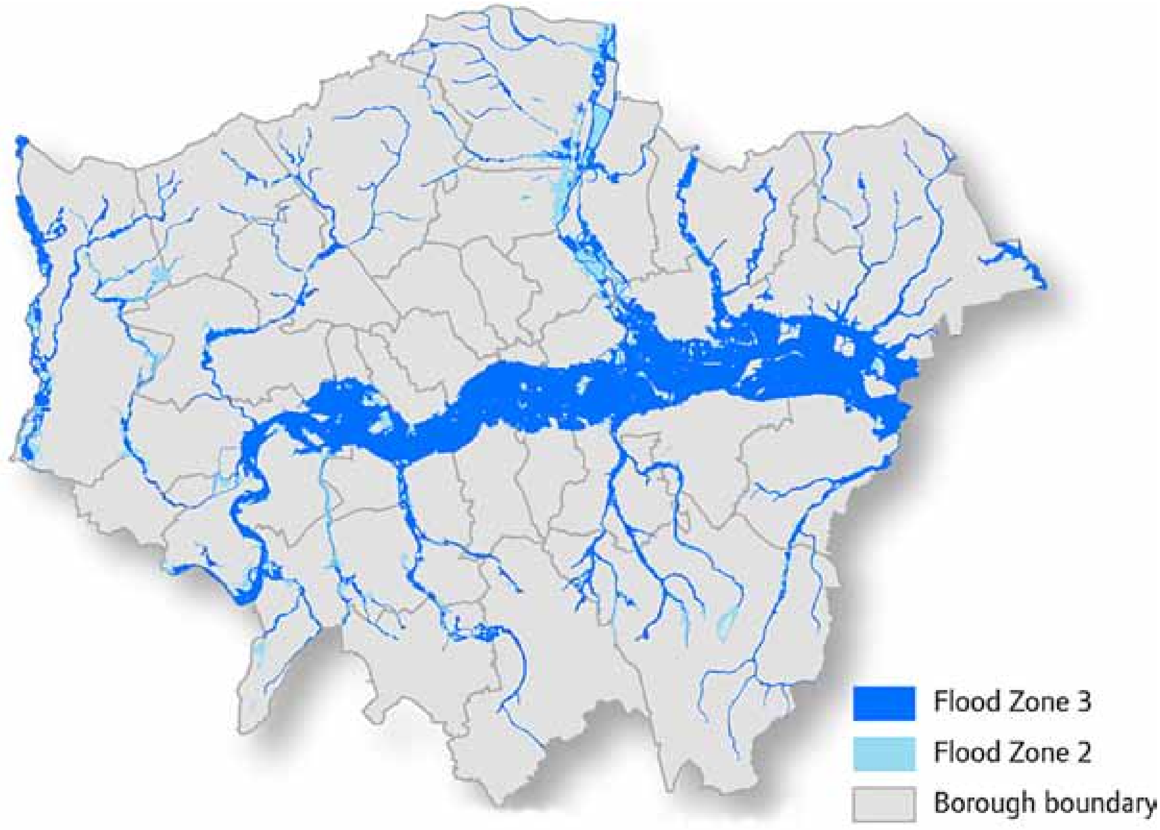
Action 3.9. To reduce the risk of local surface water flooding, the Mayor will work with TfL, the London boroughs and Thames Water to review their drain and gully maintenance programme, particularly in high-risk areas.

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

Action 3.10. 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 3.11. 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. The Mayor will then encourage the boroughs and communities to roll this approach out to areas at high flood risk.

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



Increasing and enhancing London's greenspaces is an effective mechanism to manage both flooding and overheating. Actions that increase greenspace cover are also covered in Chapters 5 and 7.

Background

London is prone to flooding from six 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
- from rising groundwater
- from reservoirs.

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 practice 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 Netherlands having higher standards of flood protection.

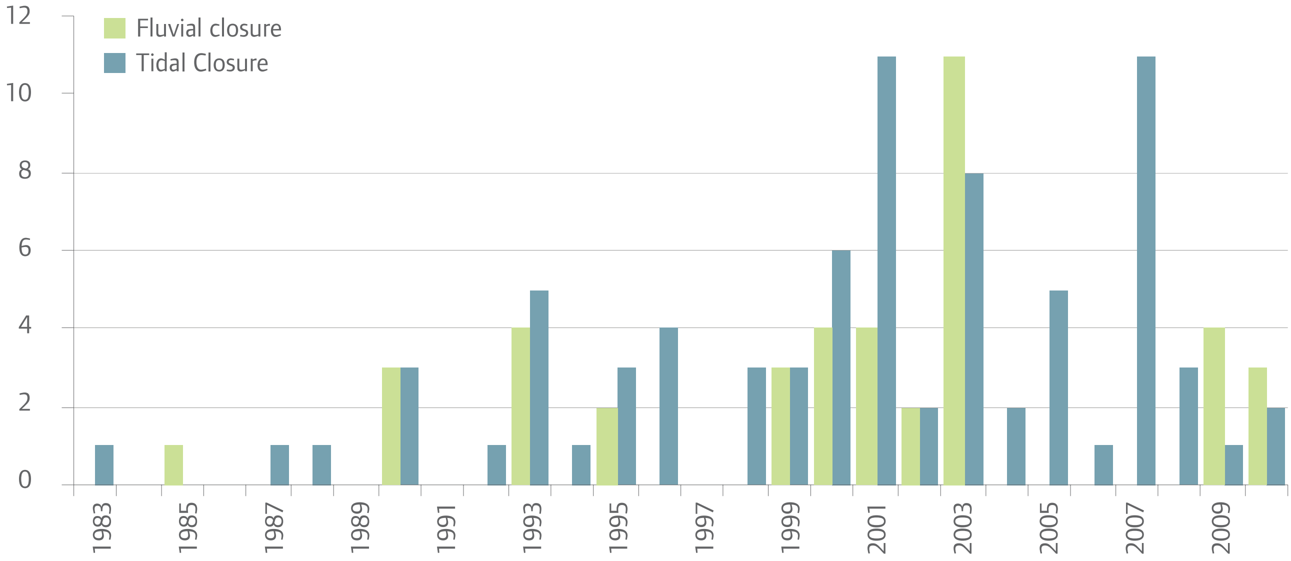
The flow in the Thames is affected by the tide as far as Teddington Weir in west London. A significant proportion of London lies within the Thames tidal floodplain and without the protection afforded by the tidal flood defences, much of that area would flood twice a day, every day on each high tide (the 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, London narrowly escaped damage when a tidal surge inundated large parts of Kent and Essex, killing over 300 people. 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 a meteorological phenomenon known as a tidal surge. Tidal surges occur when an intense low-pressure weather system (depression) forms over the Atlantic, 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 2009-10. 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 fluvial flows after heavy rainfall in the upper Thames catchment to the west of London. These closures protect riverside development in west London from fluvial flooding and are known as 'fluvially dominated' closures.

Figure 3.2 Thames Barrier closures 1982-83 to 2009-10



Source: Environment Agency

Table 3.1

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

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 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 increase the flood risk along the tributaries.

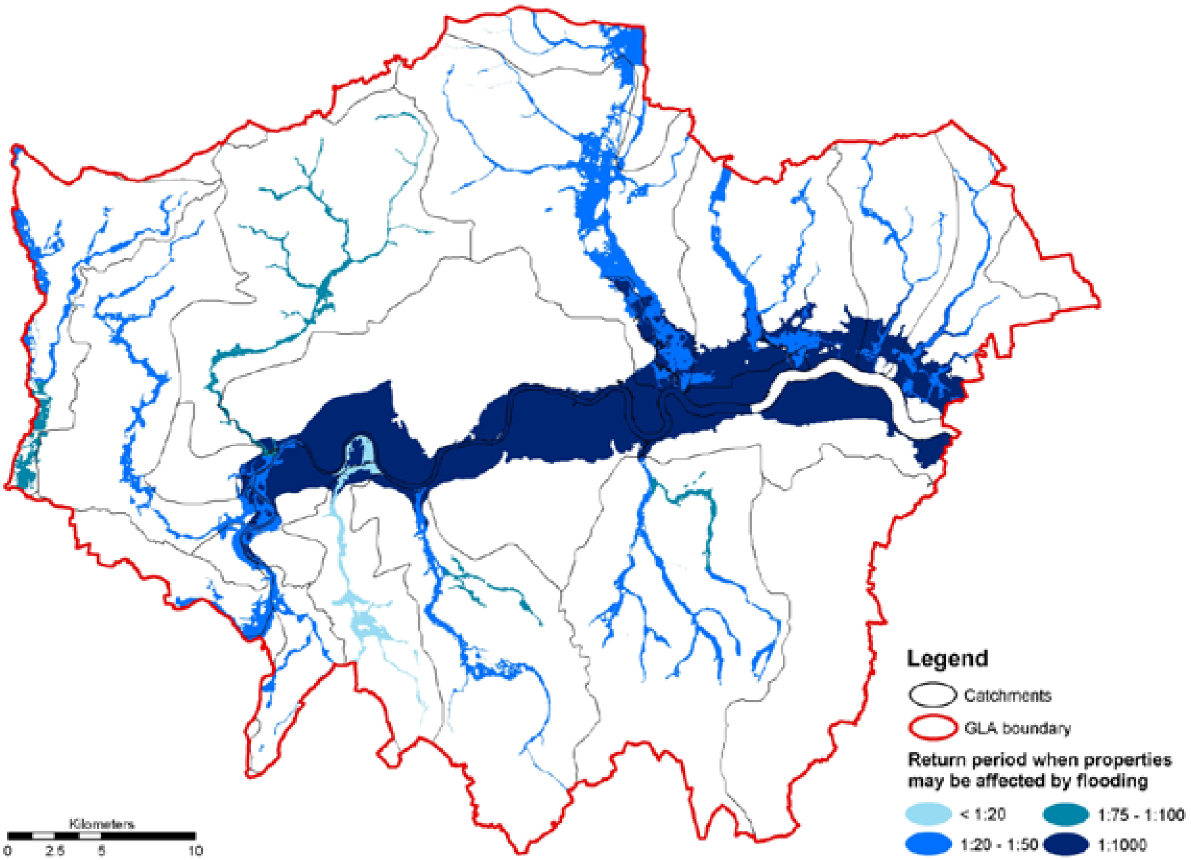
The Thames tidal defences were designed to provide protection against a tidal surge that might statistically occur only once in every 1,000 years by 2030. The sort of tidal flood event that could seriously affect central London is expected to occur in less than once in 2,000 years. This is because the 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.

Understanding today's flood risk

Probability

The probability of being flooded depends upon the standard of protection provided by London's flood defences and drainage systems. The standard of protection provided by London's fluvial and tidal flood defences is known and hence can be mapped. The probability is usually expressed as a 'return period' or as an annual percentage[17]. Table 3.1 sets out the risk categories used to describe the probability of being flooded from a river or the sea.

Figure 3.3 Area of London at risk of flooding, showing the different levels of probability, expressed as a return period



Source: Environment Agency

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 affordable flood insurance as part of usual insurance cover[18]. The Environment Agency's 'What's in my backyard?' website[19] provides an online flood risk map that shows the areas that could be flooded.

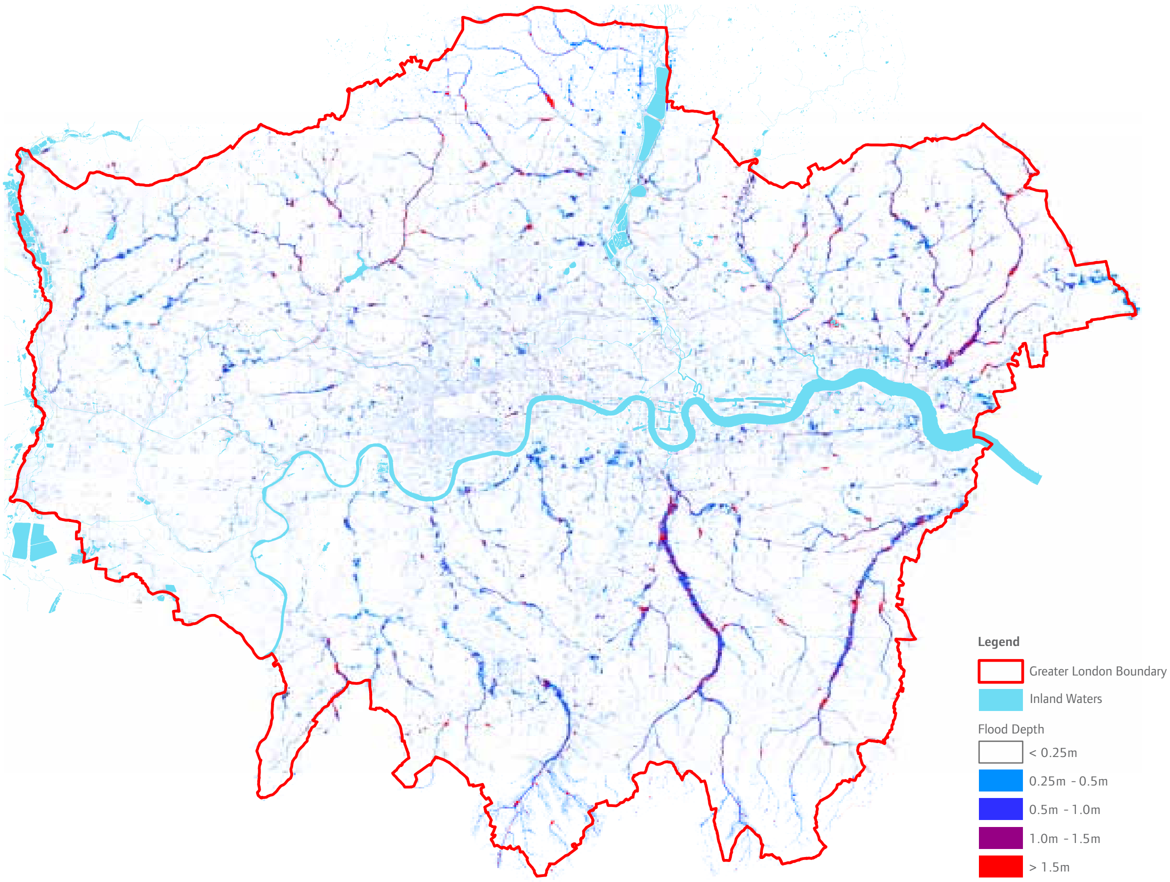
It is more difficult to predict areas at risk of surface water flooding than tidal or fluvial flooding, as the capacity of the drainage network is less well understood than the river network and the storms that are usually responsible for heavy rainfall (for example, summer convective storms) tend to be extremely localised and most unpredictable. The drainage network is designed to carry away rainfall levels up to a one in 30 year event. However, historic sections of the drainage system were designed to lower standards, and in practice the drainage system is often not maintained to the design standard. This means that in parts of London the standard of protection is probably less than 1 in 10 year. Figure 3.4 shows the area that would be flooded by a 1 in 100 year rainfall event.

Consequence

The impacts of flooding include:

- loss of life and personal injury
- direct damage to property, infrastructure and utilities

Figure 3.4 Areas at risk of surface water flooding from a 1 in 100yr (plus an allowance for climate change)



Source: GLA (Drain London) © Crown copyright. All rights reserved (LA100032379) (2009)

- contamination and disease from flood and sewer water
- loss of income and delayed economic development
- break-up of communities and social networks
- poor mental (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).

Vulnerability and adaptive capacity

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[20] (RFRA) to map assets 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 nearly half a million 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[21] of these properties are at 'low' flood risk, but that there are over 83,000 properties at 'moderate' risk or 'significant' risk[22] (see Table 3.1 for definition). Seven London boroughs are within the top 20 local authorities in England with the highest number of properties at risk of flooding. These are Southwark, Hammersmith and Fulham, Newham, Wandsworth, Tower Hamlets, Westminster and Greenwich.

It is estimated that nearly 80,000 properties would be flooded to a depth in excess of 0.5

metres by a severe rainfall event, though the probability of this occurring is low.

People
The consequence of flooding to people is determined by factors that include:
- vulnerability – for example, living on the ground or lower-ground floor, having limited advance warning of a flood
- adaptive capacity – being able to receive and respond to information or help (for example: age, health, disability, proficiency of spoken English, living alone or not having a support network) and financial security (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 their flood risk
- 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.

Socioeconomic 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[23] 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 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 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.

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 forecast 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.

Part of the Environment Agency's operational role is to issue flood warnings. Flood warnings are sent out to public and professional partners when a fluvial or tidal flood is predicted using Floodline Warnings Direct (FWD). This is a free service that people can register for. Flood warnings are sent out via telephone, text message, e-mail and fax. Following recommendations in the Pitt Review the Environment Agency (in February 2010) rolled a new 'opt out' service called Extended Direct

Table 3.2 Advance warning times for flood sources.

Flood source	Advance warning	Comments
Fluvial*	Up to 1-2 days on the Thames but as less than 2 hours on some tributaries.	Suitable advance warnings are not possible on all London's rivers as some of them react much more quickly to heavy rainfall.
Surface water	Little or no warning for specific areas, but a general area warning 24 hours in advance.	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, can 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.

Warnings (EDW). Fifty per cent of Londoners at flood risk are covered under the extended service, though coverage does not imply that they are aware of the flood risk they live at, or know what action to take if a warning was given. The Environment Agency has recently revised its flood codes and flood warnings, and the Mayor will work with the Environment Agency to increase the number of people signing up to Floodline Warning Direct (see Action 3.10), particularly in areas of high-risk and low take-up.

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. Public awareness of fluvial flood risk is variable, but improving under the Environment Agency's Floodline Warning Direct programme.

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 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 identifies the key social and civil infrastructure at flood risk in London.

Table 3.3 Key social and civil infrastructure at tidal and fluvial flood risk

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 cent per annum tidal flood risk or >1 per cent per annum fluvial flood risk)
Source: GLA Regional Flood Risk Appraisal

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 generally 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).
- 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 be required 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.

Emergency planning and response

The efficiency of the response to a flood and the recovery after a flood can be crucial in 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[27] 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[28] has prepared the *London Strategic Flood Framework*[29] to replace the outdated London Flood Plan. The main objective of the Framework 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 framework responds to tidal, fluvial and surface water flooding and also identifies the thresholds at which the response escalates from a local response to a regional response (managed by a Regional Civil Contingencies Committee[30]).

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 Multi-Agency Flood Plan and the command and control protocols agreed by the London Emergency Services Liaison Panel (LESLP)[31].

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[32] contains details for the coordination 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 has been 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 businesses 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 land, 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.

How will climate change increase the risk?

Even without climate change, flood risk is increasing in London as the flood defence and drainage systems age, more people and assets are located in areas at flood risk and more of London's surface area is covered in concrete (known as 'urban creep'), increasing the rate and volume of rainwater run-off.

Climate change is expected to further increase flood risk through:

- Wetter winters will mean that rain will fall on ground that is already saturated and unable to absorb any more water, creating greater runoff to rivers, causing river levels to rise more quickly and higher river flows.

- More frequent and intense extreme rainfall events: what is a one in 100 year rainfall event today may increase in frequency to one in 30 year event by the end of the century[33].
- Rising sea levels and higher tidal surges: sea levels are projected to rise by up to 1m by the end of the century, with an extreme scenario projecting up to 2m. Tidal surges are not expected to increase in frequency or height, but an extreme scenario a 0.7m increase in tidal surge height by 2100 has been projected.
- More seasonal rainfall will cause greater fluctuations in soil moisture content, leading to greater amounts of soil movement, placing greater stresses on flood defences, the mains water network and the drainage network.

Managing the risk

Tidal

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. The finalised plan[34] been submitted to Defra and work has begun on preparing an implementation plan and a business case for Treasury. The plan proposes a range of actions over the short (2010-2035), medium (2035-2070) and long (2070-2100) terms.

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 25 years and that under the current projections, it is very unlikely that a new Thames Barrier would be required before 2070. The following actions are proposed for the next 25 years:

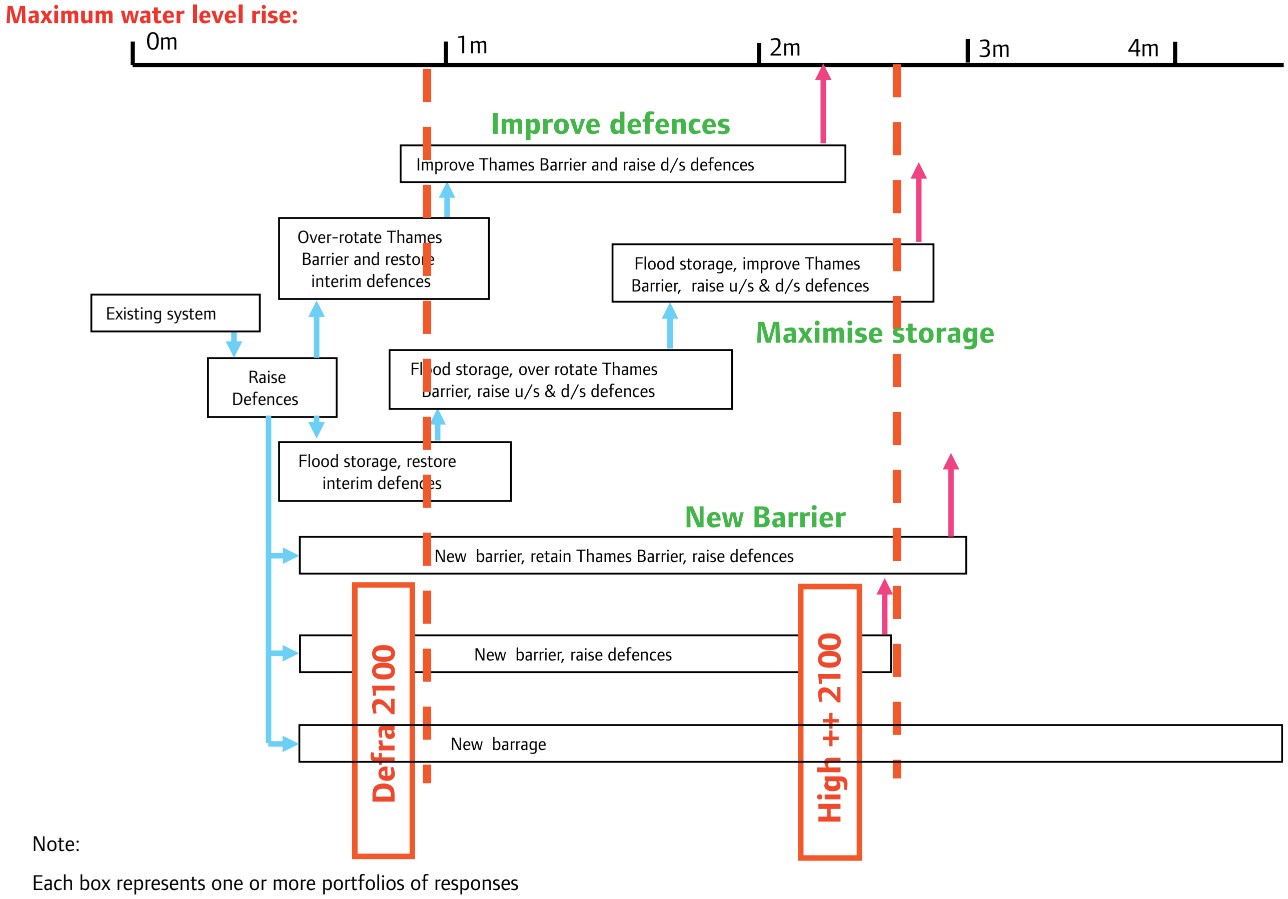
- Maintain the existing defences and stop the removal of temporary additions to the defences in central and west London
- Work with the GLA and boroughs to manage and reduce the consequences of flooding through spatial and emergency planning
- Safeguard space for enhancement of the existing defences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

The TE2100 project also 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 higher sea level rise projections (for example when to switch from raising flood defences to planning for a second barrier). This approach has received international recognition as a proactive approach to planning for and managing uncertainty.

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 improved protection over the existing system, but if water levels rise by more than three metres, that only a new barrage will provide protection.

The Thames Barrier was designed to manage extreme events and is therefore not designed to be operated too frequently. Climate change (rising sea levels, higher tidal surges and higher river levels) will increase the number of times the

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.

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 flood defences on the non-tidal Thames will decrease the number of times the Thames Barrier needs to close, but it will also 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 could 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.

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[35].

Tributaries to the Thames

The Environment Agency has published the Thames Catchment Flood Management Plan[36] (Thames CFMP) which identifies the scale of current and future fluvial flood risk for the Thames and the tributaries in London and the proposed flood risk management strategy for each river. The Thames CFMP seeks to inform the planning and decision-making of a range of stakeholders, including the Environment Agency's investment decisions, the Mayoral and borough spatial and emergency plans and to influence other parties, including landowners, businesses and the public.

The Thames CFMP uses a 20 per cent increase in peak flows due to climate change, (based on UKCIP02) to model future flood risk. The modelling projects that, without action, the probability of a flood will increase, but 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 EA has published guidance[37] to help all flood risk management authorities take a risk-based approach to managing future peak river flows. Table 3.4 summarises the projected changes for peak flows in the Thames District. It can be seen that the central estimate has risen to 25 per cent (as compared to 20 per cent used the Thames CFMP) with an upper scenario of 70 per cent increase in peak flows by the end of the century. The Environment Agency will use these projections in reviewing the Thames CFMP.

The Environment Agency is working with the boroughs to agree the local actions necessary to implement the strategies identified in the Thames CFMP. Progress towards delivering these agreed actions was being monitored by government through the National Indicators[38]. Since the reporting on National Indicators has been abolished, the Mayor is concerned that boroughs may deprioritise this important work.

All local authorities (boroughs in London) have to produce a Local Flood Risk Management Strategy that covers flood risk from all sources (FWMA). The Mayor recommends that these are produced in collaboration with boroughs in the same catchment to ensure a coherent and cost effective approach. Furthermore, the Mayor recommends that boroughs form cross-departmental flood groups, with representation from all the relevant departments (including spatial planning, emergency planning, development control, highways etc) to ensure that flood risk is managed effectively (see Action 3.6).

Fig 3.7 right maps where the Environment Agency plans to prioritise investment to manage flood risk over the next five years. The Mayor will work with the Environment Agency to identify synergies to enhance the impact of these projects.

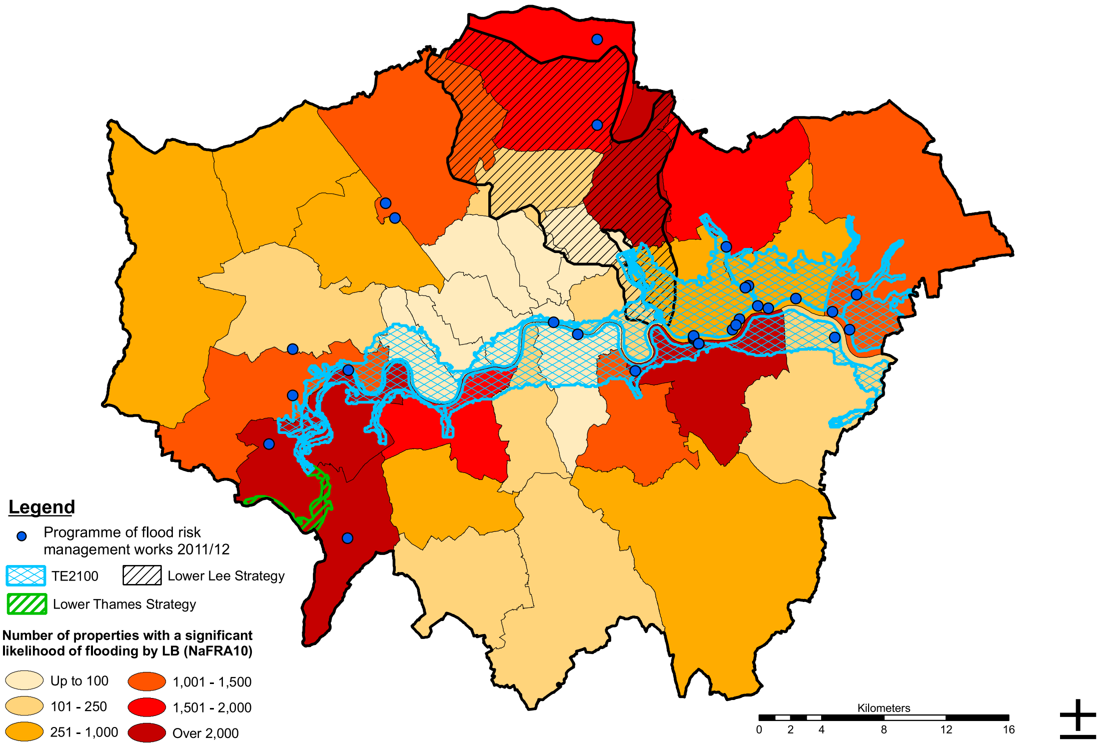
Surface water

Surface water flooding is probably the greatest short-term climate risk to London. 14 of the top 15 areas at risk of surface water flooding in

Table 3.4. Projected changes in peak fluvial flow. Source: Environment Agency.

Change factor	Total potential change anticipated for the 2020s	Total potential change anticipated for the 2050s	Total potential change anticipated for the 2080s
Upper estimate	30%	40%	70%
Central estimate	10%	15%	25%
Lower estimate	-15%	-10%	-5%

Figure 3.7 FCRM investment and significant likelihood of flooding (NaFRA09)



Source: Environment Agency

the UK are London boroughs. London is reliant on a network of drains, rivers and greenspaces to manage surface water flood risk. Managing surface water flooding in London is complex because the drainage network is owned and maintained by many partners, and until recently, no single authority had overall responsibility for managing surface water flood risk. This confusion over responsibilities led the Mayor to create the Drain London Forum (DLF), a partnership of all the agencies responsible for surface water flooding. Subsequently, government has designated London boroughs as 'Lead Local Flood Authorities' (LLFA), with responsibility for managing surface water flooding in their areas.

The DLF has developed high-resolution surface water flood risk maps and draft Surface Water Management Plans for every borough. The Mayor will continue to support the boroughs and other partners in managing surface water flood risk through:

- developing an online portal to facilitate the sharing of information between flood risk management partners (see Action 3.3)
- developing a single, simple flood reporting system and encouraging all partners to use it (see Action 3.4)
- maintaining support for the DLF as a mechanism to facilitate information exchange and project development (see Action 3.5).

The DLF has identified over 300 surface water flood risk 'hotspots' and will analyse these to identify those which are of strategic importance to London. The DLF will then work with partners to determine who should lead on managing flood risk in these areas and provide funding to develop detailed flood risk management measures in at least three of the priority areas (see Action 3.2).

The London Water Strategy proposes a more creative approach to managing rainwater, seeking opportunities to use it for non-consumptive purposes, or at least slow its progress to give our drainage system a chance to manage the projected increase in volume. The London Plan encourages sustainable drainage through a 'sustainable drainage hierarchy' policy (5.13). 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 Wildlife Trust[39] estimates that an area equivalent more than double that of Hyde Park of vegetated garden space is being converted into impermeable surfaces every year. This is largely as a result of changes to front and back gardens (patios and hard paving for off-street parking). The Mayor believes that the cumulative loss of permeability, in combination with climate change will present significant challenges to managing flood risk in London.

The Mayor will work with the Environment Agency, Thames Water and other partners to develop a number of pilot projects demonstrating how permeability can be retrofitted back into existing high-density urban areas, using sustainable drainage systems. The pilots will be developed with local communities to highlight the cumulative impact of small incremental changes and ensure local ownership of the solutions (see Action 3.7).

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. However, these gains may have been offset by a relaxation on planning requirements for extensions at the rear of a property.

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 boroughs to review the maintenance of culverts and drainage systems in high flood risk areas (see Action 3.9).

It may not be possible to reduce flood risk to all communities at high flood risk. The Mayor is keen to work with Londoners to develop a 'Community Flood Plan' for every community at high flood risk. To initiate this programme the DLF will work with local communities and their boroughs to develop two pilot Community Flood Plans and promote a programme to roll out this approach across London (see Action 3.11).

Box 3.1 – Understanding the surface water 'adaptation gap'

Surface water drains are generally designed to cope with high-frequency, low-intensity rainfall. The current design standard is one in 30 years. Research by Ofwat[33] predicts that rainfall intensity is likely to significantly increase through the century, such that what is a one in 30 year event today will double in frequency by 2040, and that what is a 1 in 100yr event today will become a one in 30 year event by the 2080s. This means that if we wish to maintain the current standard of protection, we will need to adapt to a one in 100 year rainfall intensity by the end of the century. There is therefore a 'gap' between what we can cope with today and what we may need to cope with in the future.

There are three principal options to managing this gap:

a accept more frequent and intensive flooding
b increase our drainage capacity
c reduce the amount of rainwater entering the drainage through reducing run-off (for example Sustainable Drainage Systems) and storing rainwater (for example rainwater harvesting systems).

The GLA is working with Thames Water and the Environment Agency to understand these options in greater detail, to identify the relative cost-benefits of these options, the delivery mechanisms, the barriers to implementation, and to develop flexible adaptation pathways to maintain an acceptable level of risk through the century.

It is anticipated that in order to maintain anything like the current standard of protection, a mix of measures will be required, with 'green infrastructure' (see chapter 7) being used to complement the 'grey' infrastructure of the drainage network. Action 3.7 is a key step in understanding how significantly urban greening measures can play in managing this risk.

CHAPTER 4
DROUGHT

Vision
To achieve a sustainable balance of supply and demand for water in London 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:

- promoting an integrated package of measures to enable and sustain a long-term water efficiency
- lobbying government to integrate water efficiency into housing retrofitting programmes
- promoting capturing and using rainwater for non-consumptive purposes
- improving our response to drought.

From policy to action
In an average year, London has enough water for its needs, but only by taking more water from the environment that it can sustain. Climate change and London's growth will put further pressure on London's water supplies. In order to safeguard our environment, increase our water security and limit the frequency of drought restrictions, it makes sense to use the water we have more wisely.

Promoting an integrated package of measures to enable and sustain long-term water efficiency:
Action 4.1. The Mayor will work with partners to implement a six point plan to improve water efficiency:

a Improve the water efficiency of existing buildings
b Ensure all new development is super water efficient
c Raise Londoners awareness of the financial benefits of increased water efficiency
d Increase the number of homes with a water meter
e Change the way Londoners pay for their water
f Continue to tackle leakage.

As part of its strategy to reduce CO^2 emissions by 80 per cent by 2050, government has made a commitment to offer an energy efficiency retrofit to every home in the UK by 2030. The Mayor believes that improving water efficiency in London's 3.2 million homes is essential to balancing supply and demand for water in the long-term. Therefore **water efficiency improvements should to be integrated into energy efficiency retrofitting programmes to ensure cost effective delivery and increased public awareness.**

Action 4.2. The Mayor will lobby government to integrate water efficiency into housing retrofitting programmes.

Over two feet of rain falls on London every year, yet very little of this is captured and used. Instead, it runs off our roads and roofs and enters the drainage system. The Mayor will promote capturing and using rainwater for non-consumptive purposes to reduce the demand for treated mains water and reduce flood risk.

Action 4.3 The Mayor will work with London Sustainable Schools Forum to promote rainwater harvesting, including delivering at least two demonstration projects to retrofit schools with rainwater harvesting systems and developing a business model to enable their widespread uptake.

The Environment Agency and water companies have published drought plans, but there is no London-specific drought plan. We need to improve our response to droughts.

Action 4.4. 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, how 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 restrictions on water use.

Eighty per cent of London's water comes from the Thames and the River Lee and is stored in reservoirs around London. Most of the remaining 20 per cent is groundwater, pumped 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.

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[40], leaving approximately 45 per cent of the 'effective' rainfall to feed our rivers and wetlands (see Figure 4.1). This means that only 18 per cent of the original rainfall actually forms part of our water supply. The large population in the South East of 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.

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

Figure 4.1. What happens to rainfall in the Thames catchment?

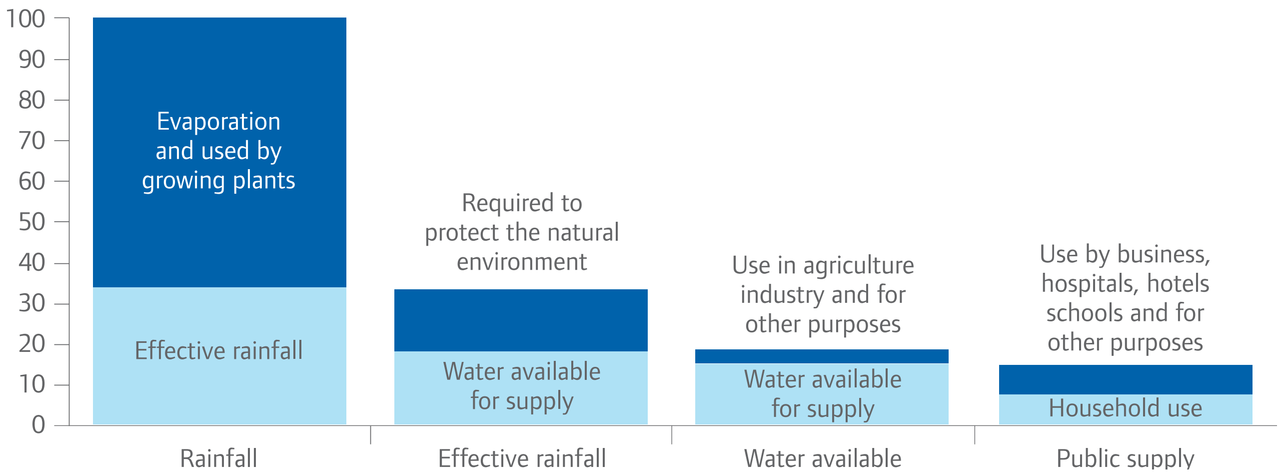
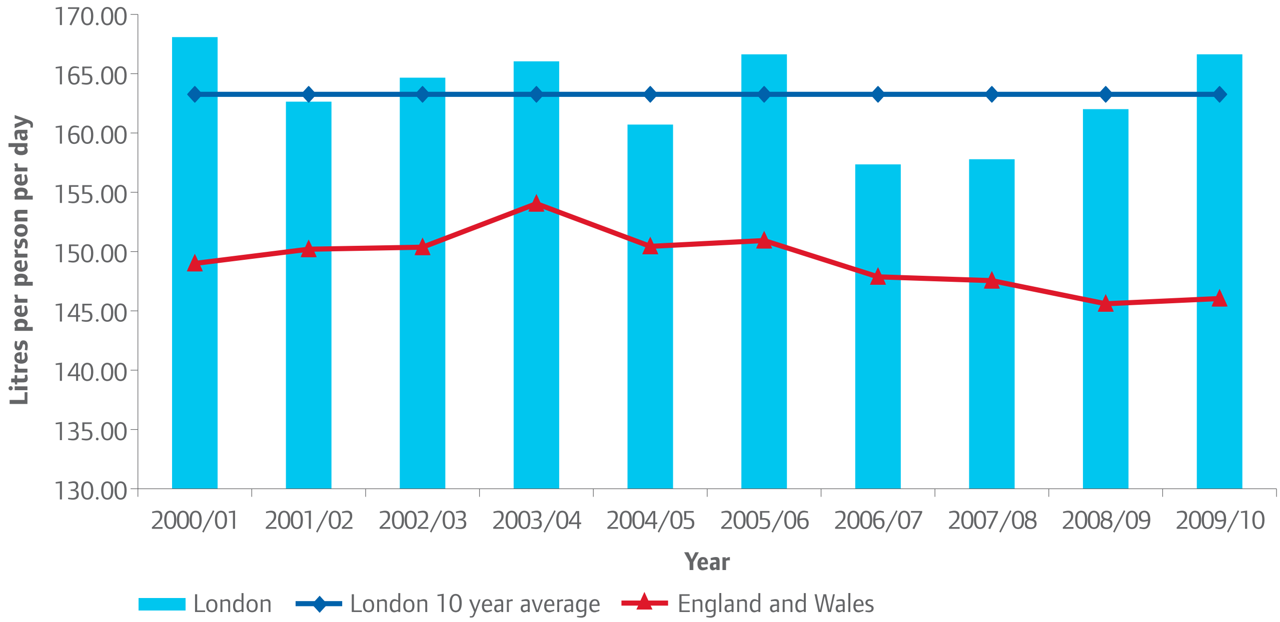


Table 4.1 Water company supply statistics for London

Water company	Proportion of London's population served (%)	Overall water supplied (million litres/day)
Thames Water Ltd	76.9	1,875
Veolia Water Central	11.8	277
Essex and Suffolk	5.8	136
Sutton and East Surrey	2.9	68
		Total 2,356

Source: OfWat 2009-10 June Returns

Figure 4.2 Domestic water use in London and England and Wales 2000-2009



Water demand

Domestic water use in London has increased by about 50 litres per person per day since the 1970s. Fig 4.2 shows the annual and ten-year average per capita consumption of water for London compared to the England and Wales ten-year average. It can be seen that Londoners now consume an average of 167 litres per day, compared to the national average of less than 150 litres per person per day[41]. 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).

The graph also shows that domestic water use fell in response to the 2005-06 drought but in London has now risen to back to pre-drought levels. This shows that Londoners can, and have, made significant water savings, but that without ongoing support and incentives, consumption increases.

Only one in four households in London has a water meter[42]. The remaining 80 per cent of households pay a flat rate for their water, largely based on the historic taxable value of their property, and thus have no incentive to save water and no opportunity to save money on their water bills.

Nearly 600 million litres a day, a quarter of all the water distributed to London customers, is lost in leakage. This is the equivalent to 177 litres per property per day (or the equivalent of an additional person's demand in every home in London). This is due to three reasons:

- Much of London's mains water network dates back to the Victorian era. Thames Water estimates that nearly a third of the water pipes making up its network are over 150 years old, and about half of them are over 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 water than the environment can sustainably provide, it is important to balance the supply of, and the demand for, water. Water companies must produce Water Resources Management Plans (WRMP) detailing how they intend to provide sufficient water to meet demands and protect the environment over the next 25 years. These WRMPs are approved by the Environment Agency and are reviewed every year and updated every five years. In a parallel process water companies must submit their business plans on how the WRMPs will be funded to their financial regulator, OfWat.

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 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 projected demands plus headroom will exceed supply, its WRMP 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 (CAMPs) to determine how much water the environment needs to retain and therefore how much water is available for abstraction. The London Catchment Abstraction Management Strategy[43] 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[44], 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 4.2 provides examples of Thames Water's drought management measures[45] (Thames Water's plans are cited as they supply over three-quarters of Londoners).

Table 4.2 Examples of drought management measures

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

Source: Thames Water

Table 4.3. Thames Water Planned Levels of Service.

Restriction Level	Frequency of occurrence	Water use restrictions
Level 1	1 year in 5 on average	Intensive media campaign
Level 2	1 year in 10 on average	Sprinkler ban, enhanced media campaign
Level 3	1 year in 20 on average	Hosepipe ban, non-essential uses bans requiring the granting of an Ordinary Drought Order
Level 4	Never	If extreme measures such as rota cuts in supply and the installation of standpipes were necessary, their implementation would require the granting of an Emergency Drought Order.

Source: Thames Water final drought plan (2010)

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.

Water companies have planned 'Levels of Service' that determine how frequently they can implement water restrictions. Thames Water's Levels of Service are set out in Table 4.3 and are similar to other water companies. The effectiveness of a water company's WRMP and its drought plans will determine its performance against these Levels of Service.

Understanding today's drought risk

In most years, there is sufficient water to meet London's current demands. The Thames basin is the largest river basin in southeast England and benefits from the combined groundwater discharge into rivers from the extensive aquifer systems of the Chilterns, Berkshire Downs and Cotswolds. It generally takes two consecutive dry winters to cause a serious risk to London's water supply. In contrast to London, the upper Thames is vulnerable to a one-year drought, as is the rest of the southeast.

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. The key aim of a drought plan is to provide a risk-based approach for making decisions on the timing of the implementation of drought management measures. Thames Water have tested their drought plan against an extreme version of the 1976 drought (the worst drought on record) and claim that it performed well enough to avoid the need to initiate emergency 'Level 4' measures despite modelling a one-in 108 year event.

In June 2010, Thames Water opened its desalination plant at Beckton. Desalination is the process of removing salt from seawater to create drinking water. The Beckton plant is capable of supplying 150 million litres of water per day. This capacity means that Thames Water is able to balance supply and demand in a dry year. However, deslination is an energy intensive process and the plant is intended only as an emergency drought management measure and is not intended to be routinely used to balance supply and demand in average years.

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 their toxicity, or the rate of eutrophication and stagnation. There is no record of impacts upon the environment, but wetlands and rivers will have been affected by these dry periods.

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.

London already faces limited water resources and is 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 emergency drought management measures, such as rota cuts and standpipe delivery, would be very difficult to implement and have damaging consequences for the city. It is therefore of great importance that London's water supply-demand balance is made resilient to climate change.

How will climate change affect the risk of drought?

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.

Reducing river flows

Climate change is not projected to alter the total 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, leaving less 'effective rainfall'.

Increasing losses 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 frozen ground.

Increased demand for water from people and plants
In hot weather, 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)[46].

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 and infrastructure. Warmer winters will lengthen the growing season, increasing the demand for water from vegetation, and also reduce the winter recharge period for aquifers.

The EU Water Framework Directive requires member states to undertake actions to improve the ecological potential of their water bodies. As noted previously, one of the main impacts on rivers in the Southeast is low summer flows, accentuated by abstractions. The Environment Agency is currently using UKCP09 to assess how climate change may affect future summer river flows and whether to impose 'sustainability reductions' on water companies and other water abstractors to protect these watercourses and comply with the EU Directive. These reductions are expected to be significant in the Southeast and are likely to dramatically affect the next round of water company resource planning.

Managing the risk
As can be seen above, the existing threat of drought can be managed by emergency measures such as drought plans and desalination, but these are not practical as every day measures.

The Mayor believes that to improve our water security, increase our resilience to drought and safeguard our water environment, we should use the water we have more wisely. The London Water Strategy sets out a six point action plan for increasing and sustaining water efficiency:
1 Improve the water efficiency of existing buildings
2 Ensure all new development is super water efficient
3 Raise Londoners awareness of the financial benefits of increased water efficiency
4 Increase the number of homes with a water meter
5 Change the way Londoners pay for their water
6 Continue to tackle leakage.

Increasing water efficiency in existing buildings
The Mayor has developed a Londonwide programme with the boroughs, London Councils and the Energy Saving Trust to improve the water and energy efficiency of Londoners' homes. The programme, known as RE:NEW, involves installing a free package of measures, such as loft insulation and aerator showerheads, into people's homes. 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 save energy as well as water, reducing both energy and water bills (in metered homes). On average the RE:NEW package saves an estimated 98.5 litres of water per household per day and £30 on annual energy bills and £60 on annual water bills.

Improving the water efficiency of London's existing homes though retrofitting water efficiency measures would allow London to grow without increasing its demand for water. Based on the savings demonstrated through the RE:NEW project, three homes[47] would need to be retrofitted for every new super water efficient home built. The *Housing Strategy* sets a target for the construction of a minimum of 32,210 new homes to be built every year, increasing London's demand for water by 9.2 million litres per day. If fully supported by government, the boroughs and London's water companies, the RE:NEW programme (and its successor) aims to retrofit 55,000 homes by the end of 2011-12, and 1.2m homes by 2015, thus offsetting the new development.

The Mayor will lobby government to ensure that water efficiency measures are included in the Green Deal programme.

The Environment Agency estimates[48] that 89 per cent of all the carbon emissions from water use are generated in homes. This is greater than the level of emissions from aviation in the UK[49]. Improving the water efficiency of homes is therefore critical to reaching the 60 per cent carbon reduction targets set out in the CCMES.

Improving the water efficiency of new workplaces
In London, workplace (non-domestic) water use accounts for 29 per cent of total consumption. Building regulations do not set a water use standard for workplaces, which has led to the development of a number of best practice standards. In the next review of the London Plan, the Mayor will draft a new policy requiring all new workplaces to achieve an improved water efficiency standard such as WRAP's 'highly

efficient practice'[50] or AECB's 'best practice' levels[51].

Improving the water efficiency of existing workplaces
The Mayor will work with partners through a number of programmes to improve the water efficiency of workplaces, including through the RE:FIT programme, which focuses on reducing the carbon emissions from public sector buildings (offices, schools, hospitals etc) and the Better Buildings Partnership, which involves the 14 largest workplace landlords in London.

Super water-efficient new homes
The London Plan requires that all new homes in London should be built to Code for Sustainable Homes[52] Level 3. This means that new homes should be built to enable the inhabitants to use, on average, 105 litres of water per person per day (l/p/d). This is a substantial reduction (37 per cent) from the 167 l/p/d that Londoners currently use on average.

Increasing metering and supportive tariffs
As noted previously, three-in-four London households do not pay for the water they use on the basis of how much they use. This means that they have no opportunity to reduce their water bills and no incentive not to waste water. The low level of metering in London is partly due to the high number of flats in London (nearly a third of all properties in London are flats). It is more difficult to install meters in flats because of the complexity of their plumbing systems and the difficulty in gaining access to flats to rearrange the plumbing system.

Paying for the volume of water consumed has been shown to reduce wastage, cutting water use by 10–15 per cent[53]. The Mayor believes that all London's households should have a water meter and will work with London's water companies to install water meters in all houses by 2020 and all flats by 2025. Research[54] has shown that most Londoners would save money by having a water meter, though some households will be worse off. The Mayor will work to minimise water affordability issues through aligning the RE:NEW programme with the water metering programme and lobbying the government to change the way we pay for water to tariffs that incentivise and reward water efficiency and support vulnerable households.

More informative bills
Most UK water bills currently provide very little information on how households can save water and how their consumption compares against similar households. The Mayor believes that this information would be helpful to water company customers and will lobby the government to encourage water companies to provide this additional information when billing customers.

The Mayor will work with the London Water Group[55] to achieve water neutrality. In the longer term, the Mayor believes that London should go 'beyond' water neutrality and seek to reduce demand year on year to provide a buffer against the impacts of climate change. To do this, we will need to look at measures to increase supply as well as further reduce water wastage and improve water efficiency.

Continue to tackle leakage
Currently a quarter of the water that has been treated and pumped into the distribution system is lost in leakage. The London 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 167 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, 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 the need for water efficiency more difficult.

Develop new resources

As previously discussed, abstracting more water from the environment is not a sustainable option in the Southeast. 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 further damage to the environment. The options to increase supply are therefore fivefold:

- desalination
- effluent reuse
- increase in reservoir capacity
- artificial groundwater recharge
- raw water transfers and import
- small scale rainwater harvesting.

Desalination

Thames Water already has one desalination plant in London, which it operates as an emergency back-up supply in case of hard droughts. Desalination is a very energy intensive means of increasing supply, so is at odds with efforts to reduce emissions.

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 per day supply of water 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 the Upper Thames Reservoir in Oxfordshire. The cost of building this reservoir is in excess of £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.

Raw water transfers and import
'Raw' water is untreated water from a river, reservoir or aquifer. Raw water transfers are transfers of untreated water between neighbouring water companies. One extreme solution is importing raw water from another country. This is obviously very expensive, has a massive carbon footprint and is therefore only an extreme drought management measure.

Small-scale rainwater harvesting
Over two feet of rain falls on London every year. Most of it runs off our roofs and roads and is discharged to rivers or sewage treatment works through the drainage system. About a third of our domestic water use does not require highly treated, drinking-quality water, for example flushing the toilet and outdoor uses, such as watering the garden and washing the car. Capturing and using rainwater for non-consumptive purposes is therefore a win-win-win solution: it reduces the demand for treated water, it reduces the strain on the drainage network (and hence flood risk) and it reduces the volume of dilute effluent to be pumped to, and treated, at a sewage treatment works.

The Mayor is working with the London Sustainable Schools Forum (LSSF) to test the application of 'rainwater harvesting' technologies in London (see Action 4.3), including retrofitting two schools with a system that uses rainwater to flush the toilets. The Mayor is keen to develop a business model where the capital costs of installing the system and the revenue costs of maintaining it are recovered by the savings on the water bill, and full pay-back secured within 4 years.

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.

Subsequently, the Environment Agency and the water companies have produced drought plans. The Mayor believes that because most of the water companies in the South East are reliant on rainfall, and that they trade water between themselves to balance supply and demand that there are interdependency issues that may need to further explored. The Mayor therefore 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 levels rise. 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, the solutions to soil movement are insurance and remedial work (such as underpinning) 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).

In hot weather, 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)[56].

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 and infrastructure. Warmer winters will lengthen the growing season, increasing the demand for water from vegetation, and also reduce the winter recharge period for aquifers.

CHAPTER 5 OVERHEATING

Vision

To make London a more comfortable and healthy 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 work with partners to reduce and manage the impact of hot weather on Londoners through:

- mapping overheating risk to prioritise actions to target the worst affected areas and most vulnerable people
- managing rising temperatures by increasing the amount of green space and vegetation in the city
- reducing the risk of overheating and the need for mechanical cooling in new and existing development and infrastructure
- ensuring London has a robust heatwave plan.

From policy to action

We have an improving 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 will continue to work on refining our understanding to be able to prioritise actions to target the worst affected areas and the most vulnerable people:**

Action 5.1. The Mayor will work with partners 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.

Action 5.2. The London Climate Change Partnership 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.

Vegetation and greenspaces are effective at cooling the city. **The Mayor will work with partners to manage rising temperatures by increasing green space and vegetation cover in the city:**

Action 5.3. 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 5.4. 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 5.5. 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 5.6. The Mayor will work with partners to enable the delivery of 100,000m2 of new green roofs by 2012 (from 2008/09 baseline).

To reduce the risk of overheating and the demand for mechanical cooling in new and existing development and infrastructure:

Action 5.7. The Mayor and the Chartered Institution of Building Services Engineers will publish design guidance for architects and developers to reduce the risk of overheating in new development, and encourage its use through the London Plan.

Action 5.8. The Mayor will work with social housing providers to encourage the use of passive measures to manage overheating and test the relative benefits of cavity wall insulation in managing overheating.

Action 5.9. The Mayor will continue to work with the boroughs to map opportunities for decentralised energy. This will identify opportunities for combined cooling, heat and power and other forms of low-carbon cooling.

Action 5.10. 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.

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 5.11. 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.

Summers are already getting warmer in London. An analysis[57] 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.

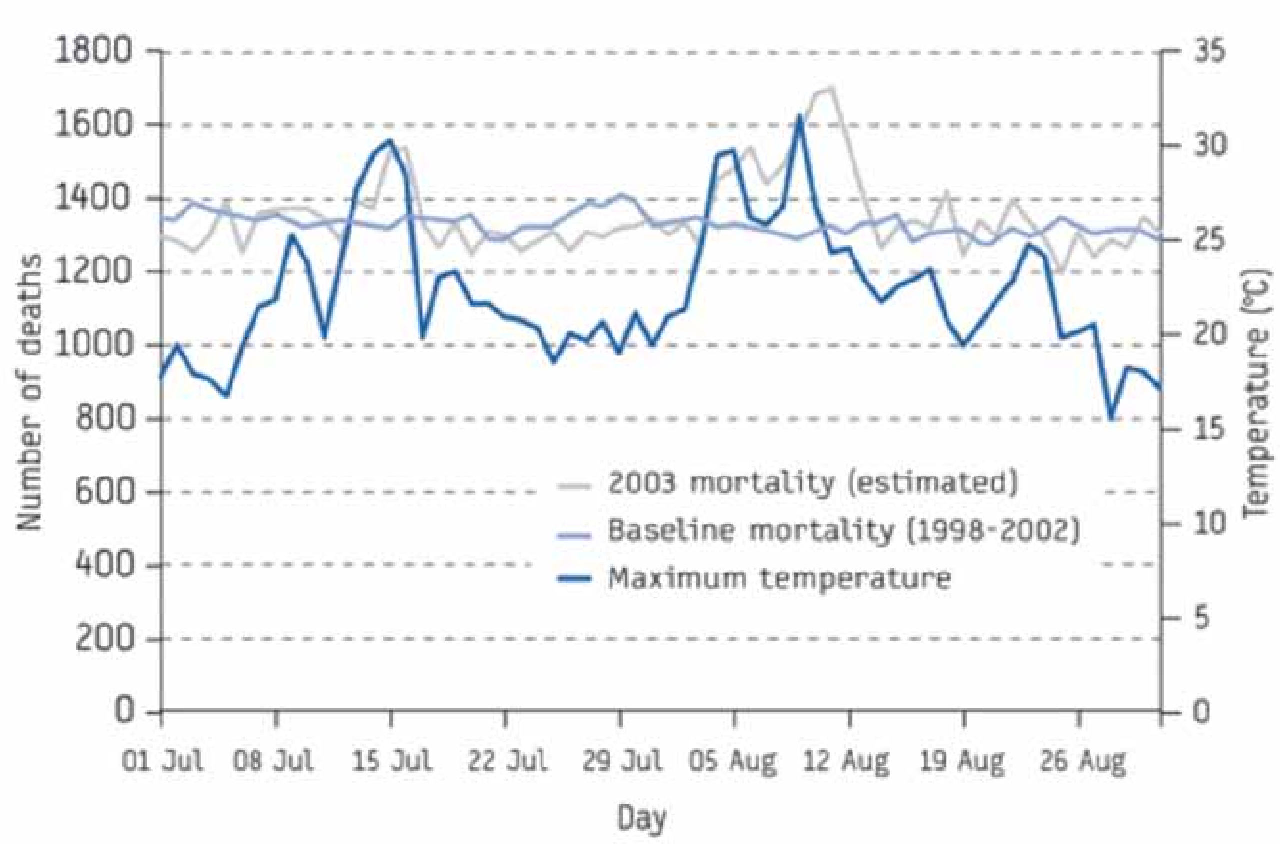
Extreme weather events

In England and Wales, there were 2,139 excess deaths during the August 2003 heatwave. Figure 5.1 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.

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[58] because of the heatwave. The impact of the 2003 heatwave on Londoners appears to have been greater than anywhere else in the UK[59]. An analysis of the excess deaths during the August 2003 heatwave for each UK government region shows that whilst London did not experience the highest temperatures nationally, London had the highest number of excess deaths for any region, even allowing for the size of its population.

Further research[60] suggests that the number of deaths in response to rising temperatures in London increases above 24.7°C (which is a higher threshold than in other UK regions) and that above this threshold, there is a greater increase in the number of deaths per degree Celsius rise in temperatures than in other regions with lower thresholds. The reasons for this vulnerability are that London is in the warmest

Figure 5.1 Number of deaths during summer 2003



Source: London School of Hygiene and Tropical Medicine

part of the UK and therefore our thermally poor homes are more likely to overheat. Poor air quality also thought to compound the impact of high temperatures (see chapter 6). It should be noted that most Londoners will acclimatise to warmer summer temperatures.

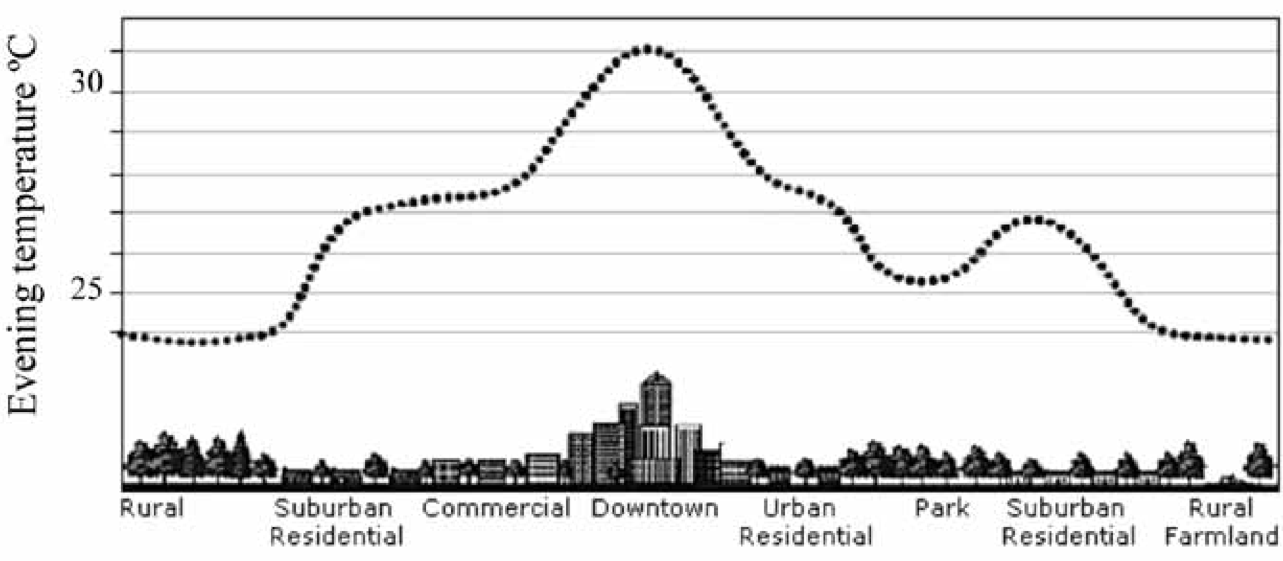
The urban heat island

The 'urban heat island' (UHI) 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 morning, the centre of London is slightly cooler than rural areas, as the urban fabric absorbs solar energy. During the day rural and urban areas are approximately the same temperature. After sun set, rural areas quickly cool off, whereas in urban areas the greater amount of absorbed heat escapes less quickly, trapped in the urban atmosphere and in street canyons. This relative slower rate of cooling off compared to rural areas is known as the 'urban heat island effect'.

Figure 5.2 provides a simplified diagram of an UHI. It shows how the UHI varies across a typical city, highlighting how temperatures generally 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

Figure 5.2 Simplified temperature profile of a typical urban heat island



areas are hotter still. It should be noted that even moderate wind speeds can shift this temperatures pattern downwind.

The UHI effect varies from day-to-day in London, but in general, peaks after sunset, when air temperatures in the warmest parts of the city can typically be 3-4°C warmer than outlying rural areas. During the heatwave of 2003, the centre of London was up to 11°C warmer than the surrounding greenbelt.

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

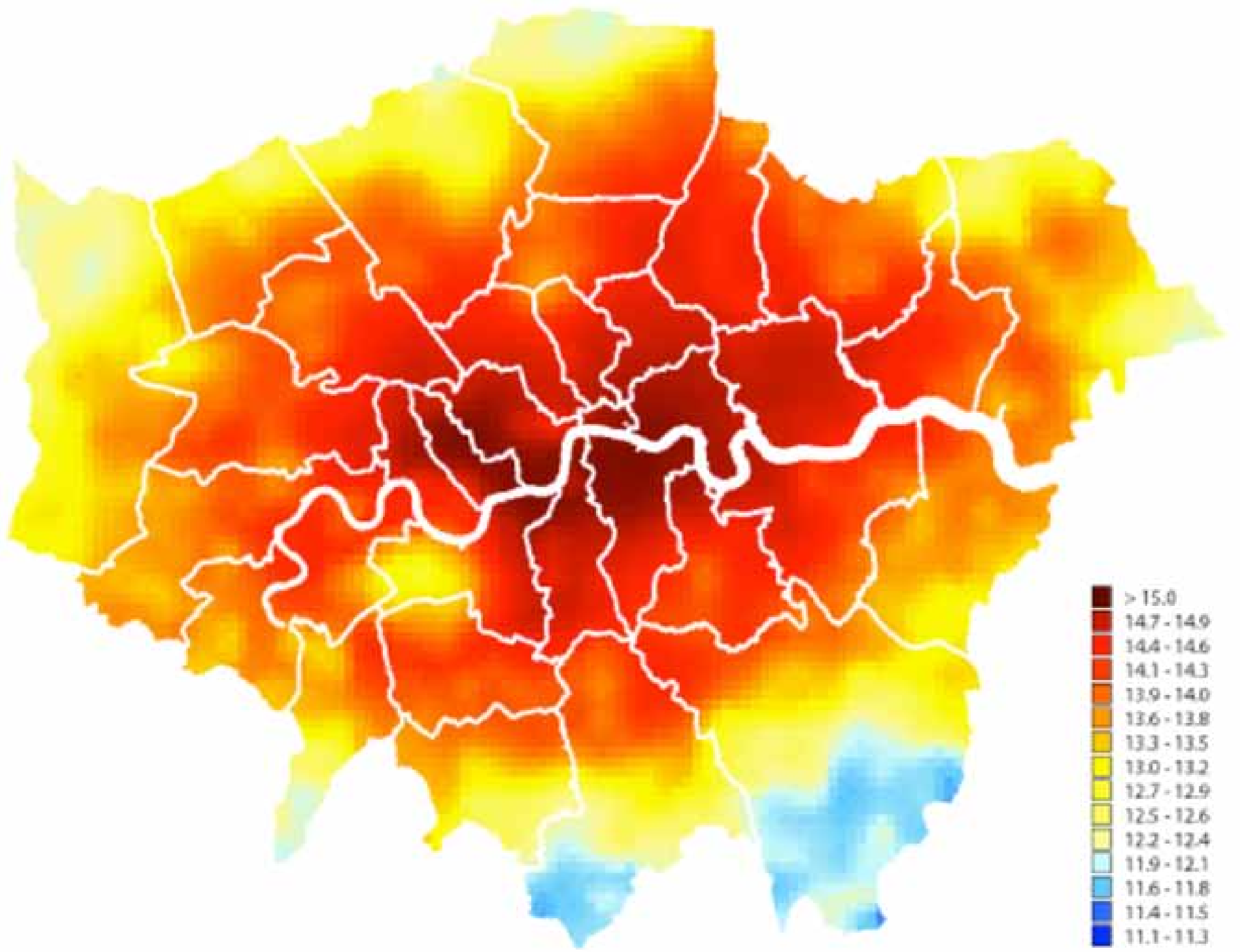
The heat generated in the city by traffic, air conditioning systems and other energy uses also acts to raise temperatures. This 'anthropogenic' (man-made) contribution to the UHI can have significant local impact in high-density areas, raising summer air temperatures by a further 2ºC[61]. If the use of air conditioning were to become more 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 limit recuperation and may contribute to deaths associated with prolonged hot weather (especially for the ill and the elderly).
- Hot nights prevent the city from cooling off and so reduce the amount of natural night-time cooling in buildings. This increases the demand for cooling the following day (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, education and quality of life.

Figure 5.3 shows the average daily minimum temperature (ºC) for London for the period 26 May to 19 July 2006. This is, in effect, a 'map' of London's UHI. This image was generated using a computer model that represents the energy exchanges between the sun, the city's surfaces and the atmosphere to predict air temperatures[62]. The model's outputs were then compared against real measurements to verify its accuracy.

Figure 5.3 Modelled average daily minimum temperature (ºC) for period 26 May – 19 July 2006.



Source: LUCID (LondUM model).

Box 5.1 : Understanding London's urban heat island and overheating risk

The GLA has been working with a consortium of universities on a project, known as LUCID[63], to improve the understanding of London's urban heat island. The project has developed a number of computer models of London that represent how the city absorbs and radiates heat from city-wide to individual building scales. These models provide an improved understanding of 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. www.lucid-project.org.uk/

Despite the millions of pounds being spent on climate models, there are currently only two MetOffice recognised weather stations in London (St James's Park and the Olympic Park), so the observational record of London's climate is poor. This means that we are currently reliant on computer models and satellite data to define how London's climate varies across the city and we have no capability to measure the actual impacts of any interventions. There are however, a wide range of 'unofficial' sites – rain gauges, school weather stations and privately owned weather stations, monitored by dedicated amateur meteorologists. The LCCP will undertake a feasibility study to assess whether these information sources would be sufficient to create a Londonwide weather station network and what additional info would be required (see Action 5.2).

Understanding today's overheating risk

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 gardens and 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) on over-stretched or overheated systems
- an increase in fire-risk of greenspaces.

Mapping the risk

Mapping overheating risk to identify high and low risk areas is more complex than flood risk. The following factors need to be combined to determine variations in risk:

a the likelihood of the external environment overheating due to:
  - the 'background' climate
  - the location within the UHI
  - specific local microclimate

b the exposure of the population to high temperatures (ie the amount of time spent indoors)

c the vulnerability to heat (see Box 5.2) of:
  - the development (does it overheat and by how much)
  - the occupants.

The LUCID project partners (see Box 5.1) have developed methods to use the above factors to address overheating risk. It may be possible to combine these factors to produce a Heatwave Vulnerability Index to facilitate both the identification of risk 'hotspots' and the type of actions necessary to manage the risk[64].

Box. 5.2 Overheating vulnerability factors

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

- housing (building type and design, condition and insulation, glazed area, which floor, aspect, the presence and use of air conditioning or good ventilation)
- place of work (working outside, or if indoors the above characteristics)
- level of physical activity (overexertion or inactivity).
- 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[65])
- 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).

Research by the GLA 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.

How will the risk change ?

London will experience an increasing risk of overheating due to:

- climate change
- the intensification of the 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.

Even allowing for some acclimatisation and improvements to our buildings stock, it is expected that rising temperatures and an ageing population[66] will increase the risk of overheating in the future.

Climate change

By mid-century, the projected increases in average summer temperatures will mean that most summers will be the equivalent of 'heatwave' temperatures today. Heatwaves that currently occur one-to-two times per decade are projected to occur five years per decade by the 2040s in urban areas[67]. The UKCP09 project that by the end of the century a heatwave could be 10ºC hotter than a heatwave today (the 2003 heatwave was 3.4ºC above the existing average maximum temperature), potentially requiring us to review the definition of 'a heatwave'. Only urgent and sustained global action to reduce carbon emissions can slow future climate change and therefore reduce the risk of large increases in temperature in the second half of the century.

Heatwaves are usually caused by high-pressure weather systems known as anticyclonic weather systems, or 'blocking highs'[68]. Blocking highs also prevent air pollution from being dispersed from the city, leading to higher levels of air pollution.

Intensification of the urban heat island effect

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

Intensification due to climate change

Research indicates that the intensity of the UHI effect in urban areas around the world is similar for similar-sized cities and not significantly affected by absolute temperatures. Hence any increase in the UHI intensity due to hotter summers is expected to be small.

However, climate change is expected to increase the number of cloud-free days. As the UHI is predominantly 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 heat island creation, thereby producing longer and more intense heat island periods.

Intensification due to increasing density

There is a strong relationship between the ratio of greenspace to buildings and the intensity of the UHI. Modelling simulations from the LUCID project suggests that UHI intensity increases as the relative fraction of greenspace to non-green cover decreases, at a rate of 0.5ºC per 10 per cent increase in non-green cover. Removing greenspace will increase temperatures by 2-3ºC.

Intensification due to anthropogenic contributions
As noted earlier, the anthropogenic contribution in London is currently most significant in high-density areas. However, experience from cities such as Hong Kong and Tokyo shows that anthropogenic contributions, particularly the widespread use of air conditioning, can make a significant contribution to the UHI and create a self-reinforcing problem. Hotter summers will encourage the more widespread uptake of air-conditioning and London's growth will also increase the amount of energy used in the city and so generate more heat. An analysis[69] 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[70]. Increased anthropogenic heat emissions will increase both the intensity of the overall UHI and the area where temperatures are highest.

Intensification due to drier summers
The increasing frequency of drier summers and drought periods (see Chapter 4) will mean that the evaporative cooling benefit from vegetation is likely to 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 lose much of their cooling potential (though they are still cooler than concrete or tarmac).

Managing the risk

It is not possible to prevent hot weather from occurring, but it is possible to limit how much the urban realm intensifies hot weather, our exposure to heat and how we look after vulnerable Londoners. It is also possible to design new buildings and infrastructure, and retrofit existing development, to reduce overheating in hot weather and therefore minimise all but essential mechanical cooling, which would otherwise contribute to the urban heat island.

This section of the strategy will therefore focus on achieving four inter-related aims:
1 limiting the intensification of hot weather by London's UHI
2 designing new, and adapting existing buildings and infrastructure to minimise the need for cooling as far as possible
3 ensuring that where cooling is still required, that low-carbon, energy-efficient methods are used
4 enhancing the emergency response to heatwaves.

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 geographic scales, the ky factor in determining the intensity of the urban heat island is the proportion of greenspace to urban land cover. This is not surprising, given the fact that the UHI is caused by replacing green space with urban materials that store 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', or materials that mimic urban greening.

The GLA has been working with scientists to understand whether it is possible to keep London cool in the future by increasing the amount of greenspace in the city. Initial findings from the LUCID project have shown that to completely offset the UHI effect, we would need to cover 60-70 per cent of the city with greenspace. Obviously, this is not practical. However, we are now working to understand what combinations of measures can cumulatively act to moderate temperatures throughout the century, so that temperatures that are high enough to cause a significant impact remain infrequent.

The direction we will pursue is to:

a protect existing green spaces to ensure we maintain a 'mosaic' of greenspaces across the city (frequent greenspaces and trees provide more widespread cooling than larger, more infrequent greenspaces[71])
b Increase the quantity of greenspace and vegetation in London, particularly in central and East London (during hot weather the prevailing winds are easterly, so the air warms up as it passes over the city. Keeping East London as green as possible therefore helps keep Central and West London cooler)
c Minimise the amount of energy wasted in London, with a particular focus on waste heat from air-conditioning in high-density areas.

These ambitions will be achieved through:

- defining the Central Activity Zone as an 'urban heat island action area' where the Mayor will work with the boroughs, developers and Business Improvement Districts to increase the green space and vegetation cover by 10 per cent by 2050.
- Major new developments would be required to:
  - minimise the need for cooling using the cooling hierarchy (see London Plan policy 5.9)
  - have a green roof (and where this is not technically feasible a cool roof[72])
  - vent any waste heat from a mechanical ventilation or cooling system above the roof level
  - contribute to the planting and maintenance of additional street trees, soft landscaping and pocket parks.
- initiating a Londonwide urban greening campaign (see Chapter 7) identifying, prioritising and implementing opportunities to increase greenspace cover, particularly in east London
- integrating the UHI map (figure 5.3) into the planning of the All London Green Grid (see Chapter 7) and encouraging the boroughs to use their Open Space Strategies to manage the UHI by protecting local green spaces and identifying opportunities for further green infrastructure.

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 and buildings to provide shade in summer and passive solar gain in winter.
- punctuate new development with green spaces
- optimise the street width to allow for appropriate scale deciduous street trees
- use high-albedo (pale and reflective) and permeable paving materials.

The Mayor is working with researchers through the BRIDGE[75] programme to understand how to optimise the balance between managing the urban heat island through urban greening and the parallel needs to reduce air pollution, water use and carbon emissions. The programme focuses on central London and seeks to provide guidance on how and where to maximise urban greening measures whilst minimising the negative impacts, such as increasing water demand to maintain the vegetation and trapping air pollutants in street canyons. The programme concludes in 2012.

Figure 5.4. Illustrative example of the mapping of the housing component of overheating risk (red – higher risk, blue – lower risk)

As noted previously, there is a complex cocktail of factors that define overheating risk and the relative importance of these factors varies from location-to-location, building-to-building and individual-to-individual[74, 75, 76]. The Mayor will work with the LUCID and AWESOME[77] research teams to map overheating risk and identify 'triple jeopardy' areas where UHI intensity, poor thermal performance of the housing and high personal vulnerability combine to create a high risk hotspot. For example, Figure 5.4 shows an illustrative example of the mapping of the housing component of overheating risk.

The Mayor will then work with partners to define who (eg a Registered Social Landlord) is best placed to manage the risk (for example by local urban greening, or building retrofitting measures).

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, green walls and climbing plants.
- 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, 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

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 % 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

(It should be noted that this definition of overheating is under review and is likely to be replaced by a new, more flexible definition, that takes account of acclimatisation and the increasing health impact of rising temperatures.)

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

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

overheating. The criterion has two temperature thresholds, demonstrated in Table 5.1 below.

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 by the LCCP[78] 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.

The CREW project[79] as developed an online toolkit[80] that can predict overheating in four different house types (detached, semi-detached, terraced and purpose-built flats). The toolkit can also be used to assess the impact of a range of 'passive' (non-powered) measures in managing overheating, the associated impact on space heating energy use and the relative cost-benefits of individual and combined measures. This will allow landlords to identify an optimum mix of measures to manage overheating in their housing stock. The Mayor will encourage London's Registered Social Landlords to utilise this toolkit.

The CREW modelling also reveals that external wall insulation is more effective than internal wall insulation for reducing overheating and that in some cases. For example for west-facing walls in houses, internal wall insulation has the potential to increase the maximum daytime temperature (by retaining heat gains and removing the cooling benefit of existing exposed thermal mass in the walls). This is an

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 shutters, blinds and awnings Vegetated walls	
Albedo	High albedo value	
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	
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)	

important issue where such houses are inhabited by older people, who are more likely to be at home for longer periods during the daytime when temperatures are highest. The elderly are also more likely to be vulnerable to high temperatures. The Mayor will work with partners to test this issue to determine whether the projected increased risk of overheating exceeds the benefits of reducing cold weather health impacts (see Action 5.8).

Under the Housing Act 2004[81], the quality of housing must be assessed[82] for a number of risks, one of which is overheating. This assessment is usually undertaken by borough environmental health officers. Depending on the severity of the risk, boroughs can require the landlord to take action to manage the risk, or alternatively, the assessment can be used as a basis for housing renewal assistance, eg grants or loans. For serious risks, there is a duty on the borough to take action. In London, this often results in vulnerable people being given portable air-conditioners, as this is seen as the most cost-effective approach. The Mayor believes that private and social landlords should consider passive measures and will promote such approaches.

New development
It is important that efforts to make new development ever more energy efficient do not increase the risk of the development overheating. 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'.

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, schools and hospitals) 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 only operate once passive measures have reached their limits. 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 is developing a bespoke set of Design Summer Years (DSYs) with CIBSE for London[83] 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[84]. The GLA will encourage the use of these DSYs through the London Plan (see Action 5.7).

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[85]. This is of particular concern for the construction of new, and renovation of existing, health and social care buildings. 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.

Single aspect developments (buildings with external openings on only one side, such as flats in a tower block) and buildings where the floor plate is more than three times the ceiling height, can be difficult, or impossible to passively ventilate (such as cross-ventilation) making them often entirely reliant upon mechanised ventilation to cool the building. Such buildings increase London's summer energy demand, reducing our energy security and potentially leaving mechanically ventilated buildings un-cooled during power shortages.

As part of the Mayor's plans to reduce London's CO2 emissions by 60 per cent by 2025, the Mayor has set a target of 25 per cent of London's energy being generated through 'decentralised energy'[86] by 2025. The Mayor is working with partners to assess the opportunities for combined cooling, heat and power (CCHP) to supply low-carbon cooling to new and existing development (see Action 5.9).

Emergency 'heatwave plan'

Following the August 2003 heatwave, the Department of Health produced a National Heatwave Plan (see box), which was first published in 2004 and has been revised annually[87]. The plan spells out the responsibilities at national and local level for preparing for hot weather over the summer, preventing heat-related illnesses and alerting individuals and organisations once a heatwave has been forecast. It further advises on what to do during a heatwave. The London Resilience Partnership has adapted the national plan and has produced a London-specific Heatwave Plan[88].

Box 5.3. National Heatwave Plan. Source: Health Protection Agency (2011).

LEVEL 1	Long-term planning	Summer preparedness
Long-term planning - All year Summer preparedness - 01 June – 15 Sept	Increase trees and green spaces External shading Reflective paint Loft and wall insulation Water features Reduce internal energy and heat	Identify high-risk individuals Include risk in Common Assessment Framework and Care Programme Approach Install thermometers Identify cool areas Increase awareness in staff

LEVEL 2	Alert & readiness in community	Alert & readiness in care homes & hospitals
60 per cent risk of heatwave in 2-3 days	Public media messages Increase advice to health & social care workers Check high-risk people have visitor/phone call arrangements in place	Monitor indoor temperatures four times a day Prepare cool areas Ensure sufficient staffing Identify high-risk individuals Sufficient cold water & ice

LEVEL 3	Heatwave action in community	Heatwave action in care homes & hospitals
Heatwave temperature reached in one or more regions	Media alerts about keeping cool Visit/phone high risk people Look out for neighbours Reduce unnecessary travel Review safety of public events	Monitor indoor temperatures four times a day Maximise external shading and night-time ventilation Ensure cool areas do not exceed 26°C Provide regular cool drinks

LEVEL 4	EMERGENCY
Heatwave for four or more days in two or more regions	If severe or prolonged heatwave affecting sectors other than health

The Heatwave Plan operates all summer and Levels 1 and 2 are designed to reduce the impact of hot weather at temperatures below the ‘heatwave threshold’ (in London a heatwave is declared when daytime temperatures exceed 32ºC for two consecutive days and the intervening night-time temperature remain at or above 18ºC). At Level 2, advice and weather alerts are communicated by radio, TV and papers.

Heat can very quickly affect vulnerable people. It is therefore important that health and social care services are well prepared for warm weather and are able to act quickly. 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. Maintaining this register is obviously difficult, but provides an opportunity to target the most vulnerable (though it is recognised that vulnerability is not static and can change from day-to-day).

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 5.11).

PART THREE

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 to 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.

Action 6.1. The Mayor will work with the London Climate Change Partnership, GP and other commissioners, London boroughs, London Councils and Public Health England to ensure that climate risks are addressed in the commissioning and provision of health and social care services; and the refurbishment programmes of the health and social care estates.

Action 6.2. The Mayor will work with the shadow London Health Improvement Board to facilitate the provision of climate risk information to borough Health and Well Being Boards.

Action 6.3. The LCCP will work with local healthcare providers and communities to provide scalable examples of practical adaptation measures. This will include supporting a bid to the Technology Strategy Board for funding to retrofit a health building to improve its resilience to the impacts of extreme weather and climate change.

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'[89]. 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[90].

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 and social care sectors, and beyond[91].

Climate change will affect the quality of life of all Londoners both positively and negatively; in addition there exists currently inequalities in the health of Londoners[92] and climate change is likely to increase these. This is both because the negative impacts will disproportionately affect those already experiencing health inequalities and inequalities in the wider determinants of health; and these same groups are less likely to have the capacity 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 looked at under three headings:

1. Direct impacts on health and health inequalities (positive and negative)
2. Indirect impacts on health, affecting the wider determinants of health (positive and negative) and health inequalities
3. Direct effects on the delivery of health and social care 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

Table 6.1 below identifies the principal effects of weather on health outcomes[93].

Table 6.1

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	Risk of bacterial pathogens increases with rising temperature. Increases in drought conditions may affect water availability and water quality 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.

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 hospitalisations, particularly amongst the elderly, and the predicted reduction in snow and ice may lead to fewer 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, for example, heatstroke.

Warmer winters
There is a strong link between external temperature and excess winter mortality[94]. Despite having a relatively mild climate, the excess winter mortality ratio is high in Britain, compared with countries with similar or colder climates[95] (this is largely because a large proportion of our homes are thermally poor - difficult to keep warm or cool). In London 3,300 pensioners died of cold-related illnesses in the winter of 2008-09[96]. 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, though for some buildings it can increase the risk overheating[97].

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. Over 24.7ºC, the health response becomes increasingly negative. External factors such as the housing thermal 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 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 Air Quality Strategy[98] 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 than for other impacts. 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[99].

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[100]. 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[101].

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[101] 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[101].

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[102]. Over the last 25 years, the incidence of malignant melanoma has increased more than any other major cancer in the UK[103].

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[104]. Research indicates that a 1°C increase in temperature might result in a 4.5 per cent increase in food poisoning[101]. 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[105].

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 diverse array of wider social and environmental determinants of health such as education, housing and employment. It is likely that climate change will increase health inequalities because the negative impacts will disproportionately affect those already experiencing health inequalities and inequalities in the wider determinants of health. In contrast, climate change will potentially benefit the health of those groups that 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 increase 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. The capital 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[106] 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[107]. Black, Asian and minority ethnic households were disproportionately likely to live in housing in a state of disrepair[108].

Overcrowding is one of the London's most pressing housing problems. Estimates suggest about 150,000 households are overcrowded, and 61,000 severely overcrowded[109]. Over a quarter of a million children in London live in such conditions. Overcrowding both increases vulnerability to climate change (more people at risk) and residents of overcrowded households are more likely to struggle to adapt[110].

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. They are also more likely to suffer long-term mental health problems.

The Mayor has a statutory duty to produce a Health Inequalities Strategy for London. The London Health Inequalities Strategy[111] 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.

The Secretary of State for Health has invited the Mayor, borough leaders and health sector to convene a London Health Improvement Board (LHIB) to improve partnership working to secure good health outcomes for Londoners. The 'shadow' HIB will focus on four priority areas – childhood obesity, alcohol misuse, cancer, and data availability. It is vital that climate risks are incorporated into the evidence base that individual borough Health and Well Being Boards use to determine local priorities and actions through their Joint Strategic Needs Assessment. As chair, the Mayor will work with the shadow LHIB and London Councils to facilitate the provision of climate risk information to health and wellbeing boards (see Action 6.2).

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
- damage to health facilities (partial or total closure of health premises).

Most social care and health facilities have emergency staffing plans, which should include a range of impacts from extreme weather events. International evidence shows 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 areas of tidal and fluvial flood risk. Further work is required to identify where additional primary and secondary health and social 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 healthcare 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[112] and are therefore reliant on using portable air conditioners to cool priority areas only (operating theatres and intensive care wards)[113]. Examples of temperatures in wards exceeding 35°C have been reported in hospitals in London[114]. 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.

CHAPTER 7
LONDON'S ENVIRONMENT

Actions
As this is a cross-cutting issue, actions proposed in Chapters 3-5 apply to this chapter, particularly Actions 5.3 to 5.6 and the following action.

Action 7.1. 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, rivers and wetlands) perform a range of functions known as 'ecosystem services' that improve the quality of life in London. These include:

- 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 wind speeds
- supporting biodiversity
- 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 create a 'green infrastructure'. This 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 infrastructure.

The All London Green Grid (see box) provides the strategic framework for promoting and creating green infrastructure in London, identifying where it should be located and how it should be designed to maximise ecosystem services.

Table 7.1 Ecosystem services provided by green infrastructure.

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	✓		✓	✓✓	✓✓✓	✓✓✓

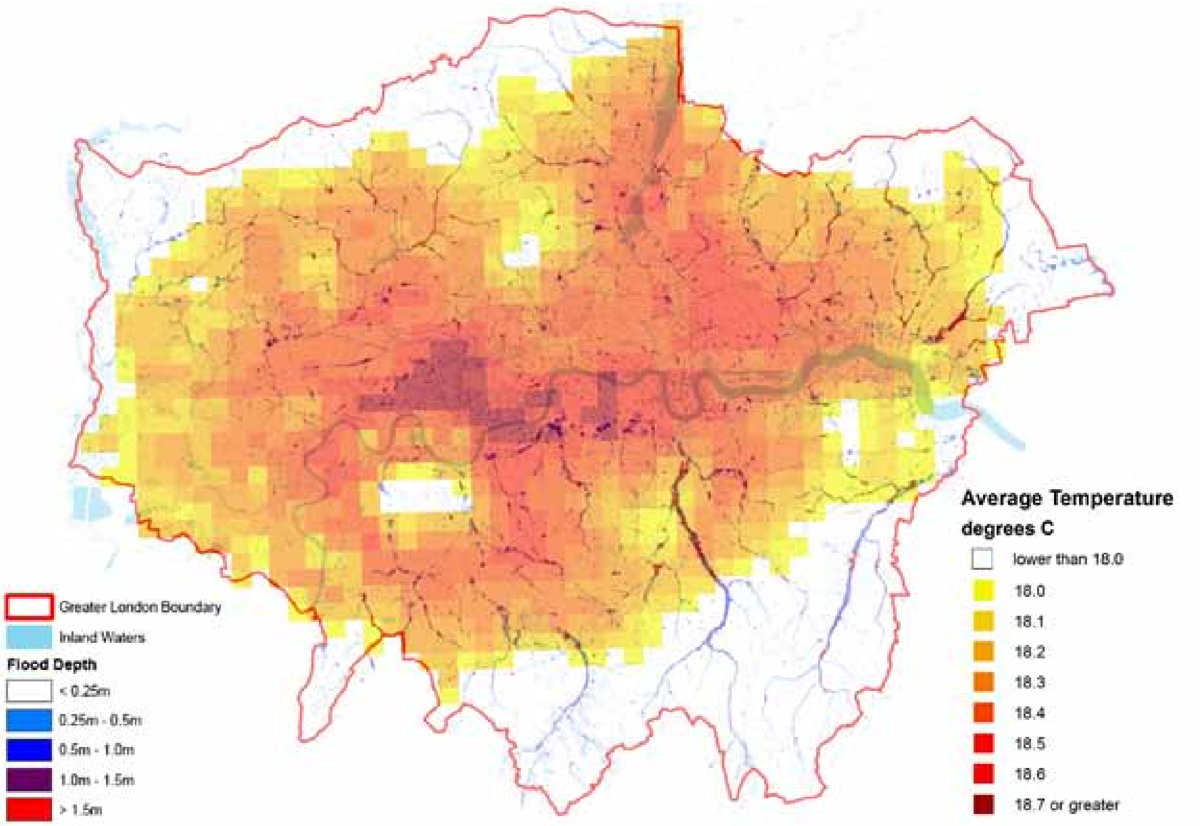
All London Green Grid

The vision for the All London Green Grid (ALGG) is to create a network of interlinked, multi-purpose open spaces to support the regeneration and development of London. The ALGG will be 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 has already been delivered in east London where the Green grid was piloted. The Mayor will publish the ALGG Supplementary Planning Guidance to update the existing East London Green Grid Supplementary Planning Guidance[115] to enable the implementation of green infrastructure through borough and sub-regional planning.

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

- Quality: improve the resilience of London's green spaces 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 cooling or flood storage). Identify and pursue opportunities to enhance the function of existing green spaces (for example, SUDS and flood storage in riverside parks).
- Connectivity: Many of the ecosystem services provided by green spaces would be enhanced

Figure 7.1. Map showing the combined flood and overheating risk in London



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.

Figure 7.1 depicts the flood risk hotspots (fluvial and surface water - see Chapter 3) and the urban heat island hotspots (see Chapter 5) to highlight opportunities where the ALGG can be used to deliver green infrastructure to manage flood risk and cool the city. This information will be included in the ALGG Supplementary Planning Guidance to focus the design and delivery of greenspace projects to maximise ecosystem services where they are most needed.

Climate opportunities and impacts on London's biodiversity

Climate, particularly temperature and rainfall, is one of the main factors that affect the distribution of plants and animals. London is predicted to experience the same changes to the climate as the rest of South East England. However, 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.

As the climate changes, so will the conditions suitable for certain habitats and species – their so-called 'climate space'. For example, the geographical area that has the appropriate climate-dependent ecological conditions for a 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. This fragmentation may impair the ability of plants and animals to adapt to climate change by moving within their climate space.

The projected changes 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.

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.

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, over 1,400 sites, covering almost one-fifth of London's land area, have been identified as non-statutory sites of importance for nature conservation. These are of metropolitan, borough or local importance, depending on the habitats and/or species they support.

Without appropriate action, the adverse impacts of climate change on London's biodiversity could be severe, while the benefits will be difficult to predict 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. The LCCP report[117] provides fuller details.

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 salt marsh.

The London Rivers Action Plan[118] 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 (see Action 7.1). 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[119]. This pollution can be reduced by fixing sewer misconnections and reducing contamination from urban runoff, thereby increasing the resilience of aquatic environments. The Thames River Basin Management Plan (2009) provides the first assessment of London's waterways under the EU Water Framework Directive. It reveals that only one out of London's 47 water bodies is classified as being of 'good ecological status', with 30 being classified as 'moderate' and 16 as 'poor'.

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 London Plan 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 a variety of biologically rich grassland habitats including: acid grassland, found mostly in Richmond Park; the chalk grassland found on the Downs on the southern edge of London; ancient herb-rich meadows in north-west London; 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 butterfly species 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 desiccated and hard-baked, providing limited amenity value and further reduced biodiversity interest. Furthermore, amenity grassland in this condition absorbs less rainfall and loses much of its cooling effect. 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[120] 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 limits 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[121] 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[122] 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 through the RE:LEAF London campaign. As a first step, the Mayor has funded the planting of 10,000 new street trees by 2012, 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[123] 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 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.

CHAPTER 8
LONDON'S ECONOMY

Actions

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

Action 8.1. 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 8.2. The LCCP will work with London's business improvement districts (BIDs) to identify climate risks to the districts and develop appropriate communication and risk management measures.

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. In particular, the capital must 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[124] on a risk register of natural hazards for the worlds' 50 megacities[125]. Figure 8.1 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 therefore likely to increase as the climate changes.

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. The capital 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 Carbon Disclosure Project[126] proposes that a city that addresses its climate risks (principally through publishing and implementing a forward-thinking adaptation strategy) could reinforce the value of municipal bonds, reduce insurance premiums, increase investor confidence and positively influence corporate real estate location decisions. The preparation of this strategy is therefore an important step in ensuring that the capital is prepared for the impacts of climate change and reinforcing London's position as a world city.

Figure 8.1 Megacities ranked by their exposure to natural hazards

Rank	City	Earthquake	Volcanic eruption	Tropical storm	Winter storm	T'storm/ hail/tornado	Flood	Tsunami	Storm surge	City GDP as 1 per cent of country's GDP[1]	Risk Index
1	Tokyo – Japan	High	Low	Medium	Low	Medium	Low	Low	Medium	40	710
2	San Francisco Bay – USA	High	None	None	Low	Low	Low	None	None	<5	167
3	Los Angeles – USA	High	None	None	Low	Medium	Medium	None	None	<10	100
4	Osaka, Kobe, Kyoto – Japan	High	None	Medium	None	Medium	Medium	Low	Medium	20	92
5	Miami – USA	None	None	High	None	Medium	Low	None	High	5	45
6	New York – USA	Low	None	Medium	Medium	Medium	Low	None	Low	<10	42
7	Hong Kong – China	Medium	None	High	None	Medium	Medium	Low	Medium	10	41
8	Manila, Quezon – Phillipines	High	Medium	High	None	Medium	Medium	Medium	Low	30	31
9	**London – UK**	None	None	None	High	Medium	Medium	None	Medium	**15**	**30**
10	Paris – France	None	None	None	High	Medium	Medium	None	None	30	25

Natural Hazards[3]

Risk key: High, Medium, Low, None

Sources:
[1]Statistical authorities,
[2]Munich Re 2004,
[3]Munich Re Topics 2002

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

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 policymakers highlight the indirect risk to all financial services posed by climate change[127].

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. However, for the majority of the financial services sector, the impacts of climate change are considered 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 climate 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. Insurance transfers some of the risks from policy-holders to their insurance companies. 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[128] 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[129]: for example, insurance companies are the largest domestic owners of UK shares - owning 17 per cent of UK shares[130].

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 increase premiums and so make them uncompetitive, or 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 at the Copenhagen Climate Summit. It stated 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 extreme weather and climate change – this will be especially true of advice or services with a long-term impact, such as that from architects and engineers.

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[132] (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.

Victoria Business Improvement District (BID) is currently investigating the opportunity to manage flood risk through intensive urban greening. The LCCP will work with London's BIDS to identify the climate risks to the BIDs and develop appropriate communication and risk management measures.

Business Continuity Management (BCM)

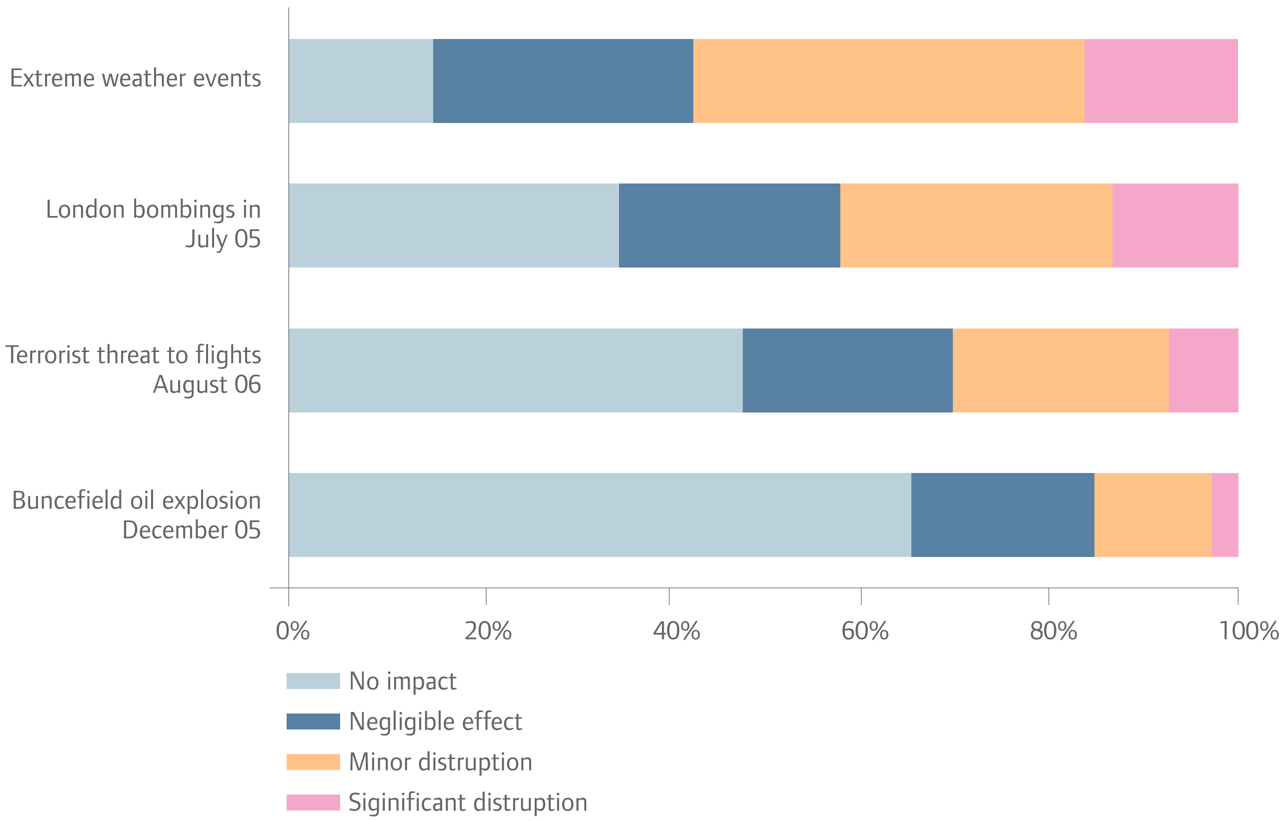
The Chartered Management Institute (CMI) defines BCM as *'a holistic management* *process that identifies potential threats to an organisation and the impacts to business operations that those threats, if realised, might cause, and which provides a framework for building organisational resilience with 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[133] 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 came 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.

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[134]. 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, or how frequently the plans that are made are tested and reviewed.

Figure 8.2 Business disruption due to external impacts



Source: CMI

CHAPTER 9
INFRASTRUCTURE

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

Action 9.1. TfL should regularly review and revise the risk assessments of their assets and operations and develop prioritised action plans for key climate risks.

Action 9.2. The Mayor will work with the London Resilience Partnership to assess the resilience of London's critical infrastructure to climate risks, including interdependencies between infrastructure.

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

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

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

Mode	Flooding	Drought	Overheating
London Underground, London Overground, Docklands Light Railway, 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 places vulnerable people at increased risk of heat illness. Increased risk of rail buckling, power line sagging and trackside fires, leading to speed restrictions and line closures. 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. Increased risk of burst water mains leading to diversions and delays.	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

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, the Highways Agency and private hire companies. TfL is one of the GLA's agencies and is chaired by the Mayor.

TfL has published a review of its risk assessments and plans for each business area using the UKCP09 climate projections. It is confident that it has the mechanisms to manage an 'extreme' weather event and will use the lessons it has learnt from the recent heavy snowfalls to improve communication and collaboration with other partners (eg boroughs). TfL is also working to review maintenance and procurement contracts to identify opportunities to replace operational critical assets with more climate resilient measures.

Background

Flooding

As described in Chapter 3, London is at risk of flooding from six different flood sources, but only three – tidal, fluvial, surface water are considered in detail here.

Water will naturally flow to the lowest point, thus low-lying transport infrastructure such as the London Underground network, lower-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, 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, concourses and ticket halls.

London Underground maintains and audits 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[135]. 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. Bus drivers will also accept tickets for other modes, e.g. the Tube, if one is affected by the weather.

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, cycling or driving
- thermal expansion of rails, overhead power lines 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 may affect the wellbeing of vulnerable passengers.

Temperatures on the Underground
The main sources of heat on the London Underground are from the movement of the trains, passengers' body heat and heat absorbed by the trains from the sun. 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[136] of body 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[137].
- 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 40ºC[138].

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 just enough room for the trains, cooling the London Underground network is a highly complex engineering problem. In addition, London Underground is preparing to meet the rising demand by increasing 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. London Underground is attempting to minimise this warming but some increase can still be anticipated, 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 external temperatures caused by climate change[139]

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[140]
- Improved ventilation shafts on the Victoria Line
- Replacing and upgrading out-of-service ventilation fans across the network
- Placing industrial fans or chiller units on the concourses of key interchange stations.
- Plans for cooling systems in certain key stations delivered as part of future major station upgrades.

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 operating 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 upstairs on double-decker buses, 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, 25 per cent of the bus fleet is equipped with upper deck ventilation and 82 per cent of the fleet is fitted with automatic heating systems which cut off the heating when a certain temperature is reached. As of March 2011, the proportion of buses with white roofs was 79 per cent. All other buses with non-white roofs will be converted as part of bus refurbishment programme, which are usually determined by the bus operator. The specifications of the cooling requirements will be reviewed and updated as technology and manufacturing capability develops.

Thermal expansion of rails and overhead power lines

High temperatures cause railway tracks and overhead power lines to expand, increasing the risk of failure. London Underground and Network Rail therefore restrict train speed or even close lines in hot weather[141]. The imposition of speed restrictions inevitably leads to passenger delays and congestion on rail networks. Seasonal track stretching[142] and rail replacement programmes will have to consider projected future peak temperatures and address rail and power line 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 when leaves 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 recent years, very cold weather 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's Climate Change Mitigation and Energy Strategy covers 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. GLA research estimates that within London there has been a decrease of 156 heating degree days[143] 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[144].

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 renewable energy

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 are likely to become more economical as the number of cloud-free days increases. High temperatures can reduce the efficiency of photovoltaic arrays, but when combined with green roofs, this problem is significantly reduced.

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[145] 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 have limitless cooling water, but are vulnerable to tidal flooding. Any future build of new nuclear power stations is expected 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-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 increasing demand for cooling provides opportunities for decentralised energy, specifically combined cooling heating and power (CCHP). The Mayor has set a target of 25 per cent of London's energy being supplied by decentralised energy (see Action 5.9). In most cases, absorption chillers are chosen as a less environmentally damaging alternative to other cooling technologies, as they make use of heat that would otherwise be wasted in summer, which can help improve the business case for decentralised energy schemes.

The move towards greater 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 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 recycling municipal waste (27 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 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, Business Waste 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 FOUR

IMPLEMENTING THE STRATEGY

CHAPTER 10
ROADMAP TO RESILIENCE

Action	Lead	Partners	Delivered by
To improve our ability to predict and manage flood risk			
3.1. 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.	GLA	EA, boroughs, LRP, TfL, MPS,	Ongoing
3.2. The Drain London Forum will develop a surface water management plan for London which identifies and prioritises areas at risk and develops more detailed plans for priority areas.	Drain London	Boroughs	Winter 2011
3.3. The Drain London Forum will create an online data portal to allow flood risk management partners to more effectively share information.	Drain London		Winter 2011
3.4. The Drain London Forum will create a flood incident reporting system and encourage its adoption across London.	Drain London		Winter 2011
To enable coherent cost-effective working			
3.5. The Mayor will maintain the Drain London Forum as a mechanism to facilitate information exchange, project identification and development.	GLA	Drain London Forum	ongoing
3.6. The Mayor will encourage each borough to form a cross-departmental flood group	GLA	Boroughs	ongoing
3.7. The Mayor will work with Thames Water, the Environment Agency and the boroughs to trial an intensive urban greening retrofitting pilot project to manage surface water flood risk.	GLA	TW, EA, Boroughs	Summer 2013
To prioritise flood risk management actions we need to identify the most vulnerable communities and critical assets			
3.8. The Mayor will work with the London Resilience Partnership and the London Climate Change Partnership to identify and prioritise critical infrastructure and vulnerable communities at flood risk.	GLA	LCCP, LRP	Spring 2012
3.9. 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.	GLA	TfL, TW, boroughs	Autumn 2012
To raise individual and community-level awareness and capacity to cope and recover			
3.10. 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.	EA	GLA, boroughs	ongoing
3.11. 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. The Mayor will then encourage the boroughs and communities to roll this approach out to areas at high flood risk.	Drain London	Boroughs	Spring 2012

Action	Lead	Partners	Delivered by
To promote an integrated package of measures to enable and sustain a long-term water efficiency			
4.1. The Mayor will work with partners to implement a six point plan to improve water efficiency	GLA	London Water Group	Ongoing
To integrate water efficiency into energy efficiency retrofit programmes			
4.2. The Mayor will lobby Government to integrate water efficiency into housing retrofitting programmes.	GLA	Defra, DECC, CLG	Ongoing
To promote capturing and using rainwater for non-consumptive purposes to reduce the demand for water and reduce flood risk			
4.3 The Mayor will work with London Sustainable Schools Forum to promote rainwater harvesting, including delivering at least two demonstration projects to retrofit schools with rainwater harvesting systems and developing a business model to enable their widespread uptake.	GLA	LSSF, boroughs	Summer 2012
To improve our response to droughts			
4.4. The Mayor recommends that the London Resilience Partnership should review the need for a London-specific Drought Plan.	LRT	GLA	Ongoing
To priotitise actions to target the worst affected areas and most vulnerable communities			
5.1. The Mayor will work with partners 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.	LUCID & AWESOME research teams	GLA	Ongoing
5.2. The London Climate Change Partnership 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.	LCCP	Boroughs	Ongoing
To manage temperatures by increasing green space in the city			
5.3. 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.	GLA	Boroughs, private sector, voluntary sector	Winter 2012
5.4. 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.	GLA	Boroughs, private sector, voluntary sector	2050
5.5. The Mayor will work with partners to increase tree cover across London by 5 per cent (from 20 to 25 per cent) by 2025.	GLA	Boroughs, private sector, voluntary sector	2025
5.6. The Mayor will work with partners to enable the delivery of 100,000m2 of new green roofs by 2012 (from 2008/09 baseline).	GLA	Boroughs, private sector, voluntary sector	Winter 2012

Action	Lead	Partners	Delivered by
To reduce the risk of overheating and the need for mechanical cooling			
5.7. The Mayor and the Chartered Institution of Building Services Engineers will publish design guidance for architects and developers to reduce the risk of overheating in new development, and encourage its use through the London Plan.	CIBSE	GLA	Winter 2012
5.8. The Mayor will work with social housing providers to encourage the use of passive measures to manage overheating and test the relative benefits of cavity wall insulation in managing overheating.	GLA	Sustainable Homes Index for Tomorrow, social housing providers	Spring 2012
5.9. The Mayor will continue to work with the boroughs to map opportunities for decentralised energy. This will identify opportunities for combined cooling, heat and power and other forms of low-carbon cooling.	GLA	Boroughs	Spring 2012
5.10. 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.	GLA	European Cool Roof Council	Ongoing
To ensure that London has a robust heatwave plan			
5.11. 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.	GLA	Boroughs and communities	Summer 2013
Health			
6.1. The Mayor will work with the London Climate Change Partnership, GP and other commissioners, the boroughs, London Councils and Public Health England to ensure that climate risks are addressed in the commissioning and provision of health and social care services; and the refurbishment programmes of the health and social care estates.	GLA	LCCP, London Councils, Public Health England, GPs & other commissioners	Ongoing
6.2. The Mayor will work with the shadow London Health Improvement Board to facilitate the provision of climate risk information to borough Health and Well Being Boards.	GLA	Shadow LHIB	Spring 2012
6.3. The LCCP will work with local healthcare providers and communities to provide scalable examples of practical adaptation measures. This will include supporting a bid to the Technology Strategy Board for funding to retrofit a health building to improve its resilience to the impacts of extreme weather and climate change.	LCCP	Health and social care providers, Technology Strategy Board	Summer 2012
London's economy			
8.1. 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.	Insurance sector (Climatwise)	GLA	Ongoing
8.2. The LCCP will work with London's Business Improvement Districts to identify climate risks to the Business Improvement Districts and develop appropriate communication and risk management measures.	LCCP	BIDS	Summer 2012

Action	Lead	Partners	Delivered by
London's infrastructure			
9.1. TfL should regularly review and revise the risk assessments of their assets and operations and develop prioritised action plans for key climate risks.	TfL		Ongoing
9.2. The Mayor will work with the London Resilience Partnership to assess the resilience of London's critical infrastructure to climate risks, including interdependencies between infrastructure.	LRP	GLA	Spring 2012

APPENDIX ONE

ACRONYMS AND ABBREVIATIONS

ABI	Association of British Insurers
BACLIAT	Business Areas Climate Impacts Assessment Tool
BCM	Business Continuity Management
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
FWMA	Flood and Water Management Act
GHG	Greenhouse gas
GLA	Greater London Authority
IPCC	Intergovernmental Panel on Climate Change
LCCP	London Climate Change Partnership
LESLP	London Emergency Services Liaison Panel
LRP	London Resilience Partnership
LRT	London Resilience Team
LU	London Underground
LUCID	Local Urban Climate model and its application to the Intelligent Design of cities
MO	Meteorological Office
NHS	National Health Service
NLARS	North London Aquifer Recharge Scheme
Ofgem	Office of the Gas and Electricity Markets
Ofwat	Office of Water Services (UK government)
PFI	Private Finance Initiative
PM10	Particulate matter (smaller than 10 micrometres)
PR09	Price Review 2009 (Water company business plans)
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 TWO

NOTES AND REFERENCES

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3. Intergovernmental Panel on Climate Change (2007), Working Group 1, Fourth Assessment Report
4. Lloyds (2010) East London Extreme Rainfall. Importance of granular data. www.lloyds.com/~/media/Lloyds/Reports/Emerging%20Risk%20Reports/East%20London%20Extreme%20Rainfall_Finalv2.pdf
5. http://ukclimateprojections-ui.defra.gov.uk
6. 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 (°C) to the 2080s under the medium emissions scenario and at the 50 per cent probability interval is 0.2°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 (°C) to the 2080s under the medium emissions scenario and at the 50 per cent probability interval is 3.9°C for London, whereas the increase in mean winter temperatures is 3°C.
7. 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.
8. Further information on probabilistic projections is available at http://ukclimateprojections.defra.gov.uk/content/view/1119/9/
9. 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.
10. The 2010 annual CET average, at 8.83°C, was the coldest year since 1986 in the CET record and nominally the 97th coldest in the whole CET record (1659-2010). There are uncertainties in the CET record so its ranking is approximately 97th. The 1961-1990 average annual CET is 9.47°C, so 2010 was 0.64°C below normal.
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15. www.defra.gov.uk/environment/flooding/documents/manage/floodgrantguidance.pdf
16. London Resilience (2008). London recovery management protocol. www.londonprepared.gov.uk/downloads/rmprotocol_august2008.pdf
17. 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.
18. 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 per cent 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 buildings built after 1 Jan 2009.
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132. UCKIP (2005) *A changing climate for business*
133. Chartered Management Institute (2007) *Business Continuity Management*
134. National Flood Forum, personal communication
135. London Borough of Camden (2003) *Floods in Camden: Report of the Floods Scrutiny Panel*
136. The equivalent of 63,925 hundred-watt light bulbs burning continuously.
137. 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.
138. BRE (2004) *Understanding thermal comfort on London Underground trains and stations – summer survey*. Report No 211739
139. 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.
140. 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.
141. Railtrack Company Specification, 2002
142. 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.
143. 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.
144. H. Graves and M. Phillipson (2000) *Potential implications of climate change in the built environment,* BRE
145. Met Office (2006) *Climate change and energy management.*

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Chinese

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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 چاهتے هیں، تو براہ کرم نیچے دئے گئے نمبر پر فون کریں یا دیئے گئے پتے پر رابطه 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 સાઘો.