CROSSRAIL

CLIMATE CHANGE ADAPTATION REPORT

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1. Introduction

This report provides a summary of Crossrail's work to date (December 2010) on assessing and responding to current and future climate change risks to Crossrail. The structure of the report is based on the 11 questions contained within Box 2 of the Defra Statutory Guidance on Climate Change Adaptation Reporting, therefore the order of information follows this structure. In order to avoid repetition cross referencing between Sections, Figure and Tables is used where appropriate.

The Climate Change Act 2008 makes the UK the first country in the world to have a legally binding long-term framework to cut carbon emissions. It also creates a framework for building the UK's ability to adapt to climate change. The Act gives the Secretary of State for the Environment the power to direct reporting authorities (organisations with functions of a public nature and statutory undertakers) to produce reports on:

- the current and future predicted impacts of climate change on their organisation; and
- proposals for adapting to climate change.

The Greater London Authority (GLA) is one of these reporting authorities, and has requested that its constituent bodies contribute to the GLA Climate Change Adaptation Report. Transport for London (TfL) is one of the GLA's constituent bodies and has requested that all TfL transport modes, including Crossrail, London Underground, Rail for London and the Docklands Light Railway, produce their own climate change impacts risk register and adaptation report as inputs to the TfL report. Other organisations required to produce climate change adaptation reports to Government include Network Rail, the Environment Agency, National Grid and Electricite de France (EDF). These are all Crossrail stakeholders as listed in **Table 1** below.

Table 1. Crossrail's key stakeholders and interfaces as at December 2010

NB. Stakeholders who are also reporting authorities under the Climate Change Act 2008 are starred.

Crossrail Project Partners	
Department for Transport*	Sponsor
Transport for London* (reporting as part of the GLA)	Sponsor and owner of Crossrail
Industry Partners	
Network Rail*	Duty Holder, Infrastructure Manager and Industry Partner for surface sections
London Underground*	Duty Holder, Infrastructure Manager and Industry Partner for underground sections
Rail for London* (reporting as part of TfL)	Service Franchisor. Infrastructure Manager for the Crossrail Stations at Paddington, Isle of Dogs, Custom House and Woolwich
Canary Wharf Ltd	Industry Partner responsible for the Isle of Dogs Crossrail station
Berkeley Homes Ltd	Industry Partner responsible for the Woolwich Crossrail station.
Docklands Light Railway* (reporting as part of TfL)	Industry Partner
National Grid Plc (Gas and Electricity)*	Gas and Electricity Provider
EDF Energy*	Energy Provider
British Telecom*	ITC Provider
Thames Water Utilities Ltd*	Water Provider
Other significant organisations in London and the South-East	
Olympic Delivery Authority (ODA)	Interfaces at south end of Olympic Park
Royal Society for the Protection of Birds (RSPB)	Interfaces regarding Wallasea Island project
British Waterways Board* (reporting voluntarily)	Navigation Authority
Other reporting authorities with interfaces to Crossrail project	
Environment Agency*	Interfaces re: Environmental Statement and Flood Risk Assessment
Office of Rail Regulation*	Interfaces re: rail industry standards
Port of London Authority*	Interfaces at Isle of Dogs Station and transportation logistics
Natural England* (reporting voluntarily)	Interfaces re: environmental and ecological considerations
Highways Agency* (reporting voluntarily)	Interfaces re: traffic liaison during construction and surface water flood risk
Maritime and Coastguard Agency* (reporting voluntarily)	Interfaces re: tidal flood risk and transportation of excavated material to Wallasea Island

Crossrail differs from the other TfL transport modes in one key respect in that it does not yet exist as a piece of transport infrastructure and future ownership arrangements for the railway generally result in a greater complexity of risk transfer. This means that extreme weather events due to climate change are not currently affecting an operational Crossrail railway system, as they are other operational transport modes in London. However, Crossrail Ltd is designing, procuring and constructing the Crossrail project to meet all Sponsor requirements, and to ensure all that appropriate industry standards and legal requirements are fulfilled in order to ameliorate the future risk posed to an Operational Crossrail from climate change.

Like any major infrastructure project Crossrail has a considerable number of stakeholders, interfaces and interdependencies, any one of which could either ameliorate or exacerbate climate change risks to the Crossrail project during the three project phases of design and procurement (2010-2012), construction (2010-2017) and operation (2017 -2137) (see **Table 2** below). From 2017 Network Rail will be the infrastructure manager for the tunnels and surface sections, London Underground will be the infrastructure manager for the sub-surface stations, Rail for London will be the railway owner and a separate as yet unidentified company will be the railway operator. Whilst Crossrail knows what the interfaces and interdependencies between itself, its key stakeholders and other reporting authorities are, we expect these interfaces and interdependencies as they relate to climate change risks to be clarified throughout this reporting process.

Table 2. The three main phases of Crossrail

1. Design/procurement **(2010-2012)**	• Enabling works • Rolling stock procurement
2. Construction **(2010-2017)**	• Construction of tunnels stations and systems (including testing, commissioning and delivery)
3. Operation **(2017-2137)**	• Operation and maintenance of assets and infrastructure in the West (including Heathrow Spur), Central (including South-East spur) and East sections • Operation and maintenance of the rolling stock

Source: Crossrail, 2010.

This report summarises the main climate change risks to Crossrail focusing on those risks most relevant to the design and procurement and construction phases, rather than the operation phase. This is because Crossrail has direct responsibility and control over these two phases, whereas Network Rail, London Underground and Rail for London will have responsibility and control over climate change risks during operation. A summary climate change risk register providing an assessment of risks for Crossrail has also been produced and is included as **Appendix A.**

As part of the preparation of this report, all existing work that has been undertaken by Crossrail and its stakeholders to address these risks, whether explicitly or implicitly, has been collated and recorded in a document register which is included as **Appendix B**.

2. Definitions, acronyms and abbreviations

1 in 1000 year return period	An event with a 0.1% (1 in 1000) chance of happening each year
1 in 200 year return period	An event with a 0.5% (1 in 200) chance of happening each year
Adaptive capacity	The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of potential opportunities, or to cope with the consequences of climate change
ARM	Active Risk Management system
CEDS 10	Civil Engineering Design Standard Part 10
Climate change adaptation	Adaptation means taking action to deal with the consequences of a changing climate, resulting from increased levels of greenhouse gas emissions.
Climate change mitigation	Mitigation means taking action to tackle the causes of climate change, by reducing concentrations of greenhouse gases in the atmosphere.
CMS	Crossrail Management System
CPFR	Crossrail Programme Functional Requirements
FDC	Framework Design Consultant
Fluvial flood risk	Risk of flooding from rivers
maOD	Metres above Ordnance Datum
maTD	Metres above Tunnel Datum
PDP	Project Delivery Partner
Pluvial flood risk	Risk of flooding as a result of surface water run-off from heavy rain
Resilience	The ability of a system to modify or change to cope with the impacts of climate change with minimum disruption or change to buildings, organisations and the natural environment.
Risk	The probability that a situation will produce harm under specified conditions. A combination of two factors: the probability that an adverse event will occur; and the consequences of the adverse event. Risk encompasses impacts on systems, and arises from exposure and hazard.
Tidal flood risk	Risk of flooding from the sea
UKCP09	UK Climate Projections 2009
Vulnerability	A function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. The extent to which a system is unable to cope with the negative impacts of climate change, variability, and extremes. It depends on changes in climate as well as the sensitivity and adaptive capacity of the system or society.

3. Information on organisation

Organisation's functions, mission, aims, and objectives affected by the impacts of climate change. A summary of your organisational purpose and key strategic priorities which are or will be affected by climate change is important when identifying risks to your organisation.

Crossrail Ltd is the company charged with delivering Crossrail. It was first created as Cross London Rail Links Ltd in 2001 to promote and develop new railway lines that would meet the needs of people and businesses throughout the South East, as well as to ensure that London continues in its role as Europe's leading financial and business centre.

Crossrail Ltd's sponsors are the Mayor of London, through Transport for London (TfL), and the Secretary of State for Transport, through the Department for Transport (DfT). The Crossrail Act (given royal assent in July 2008) gave the legal authority for the railway to be built. In December 2008 the Government and the Mayor of London signed the key funding agreements for Crossrail. Initially established as a joint venture company between TfL and the DfT, Crossrail Ltd became a wholly owned subsidiary of TfL on 5 December 2008. Preliminary works on the Crossrail project commenced in early 2009 with main construction starting in 2010. From here on in Crossrail Ltd will be referred to as Crossrail, and a distinction will be made between the company and the project where necessary.

Crossrail's vision is to 'deliver a world-class affordable railway safely through effective partnerships'. Crossrail's objectives are to:

1. Deliver the project safely
2. Deliver a quality railway
3. Deliver to schedule
4. Maintain financial control (deliver within budget, manage risk, value and cost)
5. Procure the railway effectively and efficiently
6. Establish and maintain good stakeholder relationships
7. Manage the development

Crossrail will be the largest addition to the transport network in the region for more than 50 years, with a high frequency, convenient and accessible train service across the capital from 2017. The Crossrail route (see **Figure 1**) will run 118km from Maidenhead and Heathrow in the west, through new 21km twin-bore tunnels under Central London out to Shenfield and Abbey

Wood in the east, joining the Great Western and Great Eastern railway networks. The Central section route runs from Paddington Station to Pudding Mill Lane Portal, incorporating 6 stations, and includes the South-East Spur route which comprises 4 stations, Canary Wharf, Custom House, Woolwich and Abbey Wood. The West section route runs from Maidenhead and Heathrow Spur to Royal Oak Portal, incorporating 14 stations) and a train depot at Old Oak Common. The North East section route runs from Pudding Mill Lane Portal to Shenfield, incorporating 13 stations and a mini-train depot at Ilford. There is a clear distinction between those stations which are existing or ‘on-network’ and therefore only require minimal refurbishment work to become Crossrail stations, and those stations which are being completely newly built in the Central section.

Figure 1. Crossrail route

Source: Crossrail, 2010.

Once completed, Crossrail will make travelling in London and the South-East region quicker and easier, reducing crowding on London's existing transport network. It will operate with mainline size trains, which can carry more than 1,500 passengers. The project will add 10 per cent to London’s tube and rail capacity, handling around 500,000 passenger journeys on week days with a footfall at its main central London interchange stations of between 50,000 and 100,000 people each week day. It will deliver substantial economic benefits in London and the South-East and across the UK, linking Heathrow Airport, the West End, City and Canary Wharf via direct services. The estimated benefit of Crossrail to the UK economy is at least £36 billion.

Crossrail comprises ten main systems and their sub-systems which together form the integrated railway system (see **Table 3** below).

Table 3. Crossrail route-wide and station systems and sub-systems

1. Civil works
2. Stations
3. Track
4. Rolling stock
5. HV Power Distribution (also known as Bulk Power Supply)
6. Traction Power
7. Signalling
8. Communications and Control
9. Tunnel Ventilation
10. Mechanical and Electrical Services

Source: Crossrail, 2010.

The three key impacts of climate change for London and the South-East are flooding, high temperatures and water scarcity (see **Table 4** below). All systems and sub-systems of the Crossrail project will be affected by these impacts to some extent. Some systems will be more or less vulnerable and resilient to these impacts than others, resulting in a higher or lower risk to Crossrail. There are inter-relations between these impacts and risks across the three main stages of the project.

Table 4. Key climate change impacts for London and South-East and potential risks to Crossrail

Impact for London and South-East	Risk to Crossrail
1. Increased flooding (fluvial, tidal and pluvial or surface water)	- Inundation of construction sites, equipment and excavated material - Inundation of network, stations, tunnel portals, shafts during construction - Inundation of network, stations, tunnel portals, shafts during operation
2 Higher temperatures	- Impact on health and safety of construction workers on site and on efficiency of equipment during construction - Overheating of stations, tunnels, trains during operation
3. Increased water scarcity	- Water restrictions during construction, drying out of excavated material - Water restrictions during operation

Source: Adapted from the Greater London Authority, 2010.

Although the trend is for a warmer average climate in London and the South-East with more extreme hot weather events, when cold or snow events do occur they are projected to be more extreme, for example the snow events experienced in the UK during the winters of 2009 and 2010. For the purposes of this report however the focus is on the three key climate change impacts of flooding, high temperatures and water scarcity, and the associated risks to Crossrail.

These impacts and risks are summarised for each project phase and system of Crossrail in a separate risk assessment matrix in **Appendix A**

4. Business preparedness before Direction to report was issued

Has your organisation previously assessed the risks from climate change?
Have you a baseline assessment of the risks of climate change to your business currently? The requirements of the Direction can build upon any existing risk assessment you have in place. Please include a summary of findings from your previous risk assessment(s) in your report.
If so, how were these risks and any mitigating action incorporated into the operation of your organisation? It is useful to understand whether, and to what extent climate change risks are already incorporated into your business risk management processes at the strategic level.

The UKCP09 projections are the latest climate change projections for the UK. Crossrail has not explicitly assessed all climate change risks to the project based on these projections however a number of key assessments have been undertaken, particularly in relation to flood risk to tunnel portals and shafts, and overheating of tunnels, stations and rolling stock. These assessments have considered future climate change impacts.

As a result of this existing body of work, strategies have been developed and design standards specified. These documents support this climate change risk assessment and adaptation report and the most relevant documents have been collated and summarised in a document register in **Appendix B.**

Of the three climate change impacts for London and the South-East summarised in **Table 4**, the most significant two in terms of the risk they pose to Crossrail are increased flooding and higher temperatures, although increased water scarcity is still an important consideration. Crossrail has undertaken the following measures to deal with these three impacts and better mitigate the associated risks.

4.1 Flooding

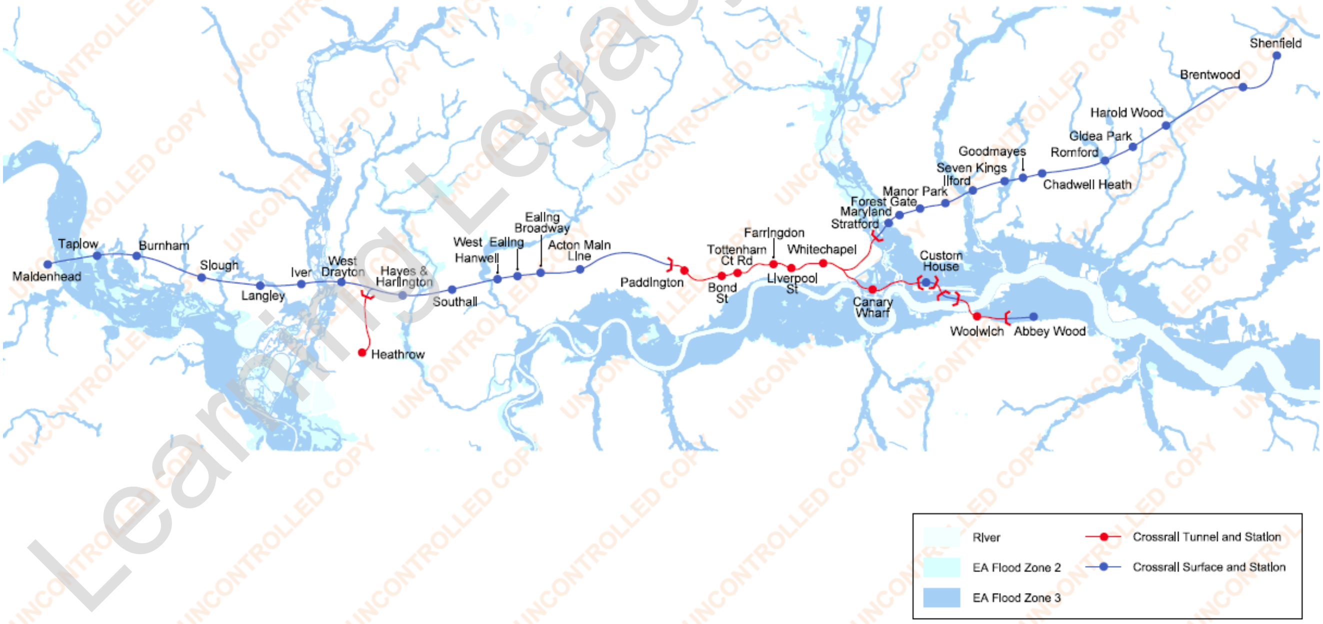
A significant amount of detailed work has gone into assessing flood risk (fluvial, tidal and pluvial or surface water) at critical points along the Crossrail route. This is because:

a) much of the Crossrail tunnel network is being or will be constructed in the floodplains of the River Thames and the River Lee (see **Figure 2**);
b) many of the central section stations are located in areas at risk of surface water flooding and;

c) the 120 year design life of the project is such that future flood risk as a result of climate change impacts necessarily requires consideration.

As a tidal river, the Thames through London could be particularly vulnerable to the future impacts of climate change. The ongoing Thames Estuary 2100 (TE2100) project and Planning Policy Statement 25 (PPS25) attempt to quantify the effect that climate change could have on mean sea level, tidal surge magnitude and peak river flows. Both documents concur that the tidal flood risk to London could increase significantly as a result of climate change. The values of sea level rise given in PPS25 indicate that the Mean High Water Spring tide (MHWS) at Southend could rise from its present value of 2.9mOD (metres above Ordnance Datum) to 3.8mOD by 2100. On top of this allowance for sea level, PPS25 suggests that tidal surges could become more frequent.

Figure 2. Environment Agency Flood Zones 1 & 2 and Crossrail route



Source: Crossrail, 2010.

The floodplains of the River Thames are defended but a failure of the defences – the overtopping or breaching of the embankments or the failure of the Thames Barrier to operate – would lead to the flooding of part of the floodplain and would put the Crossrail tunnels at risk of flooding. Not only would floodwater entering the tunnels put the infrastructure and the operation of Crossrail at risk it would also threaten London Underground to which Crossrail will be connected and vice versa. Crossrail might also convey floodwater across the River Thames through the Thames Tunnel. Therefore working in association with the Environment Agency, key thresholds have been identified and flood design levels and defence strategies for tunnel portals, shafts and station entrances have been determined.

Where possible, 'passive' flood protection measures, such as raising entry or egress levels, raising track or cill levels, or extending portal walls are preferred. However, passive measures have to be considered in the context of the Crossrail alignment, Limits of Deviation, surrounding environment and constraints imposed by local stakeholders. Where there is still some residual flood risk at certain points which passive designs cannot mitigate, then appropriate 'active' flood protection measures and procedures have been identified such as flood gates and stop logs (see **Table 5**). This recommendation has been adopted by the Crossrail Framework Design Consultants (FDCs) and is incorporated into their designs.

Table 5. Design solutions for flood prevention

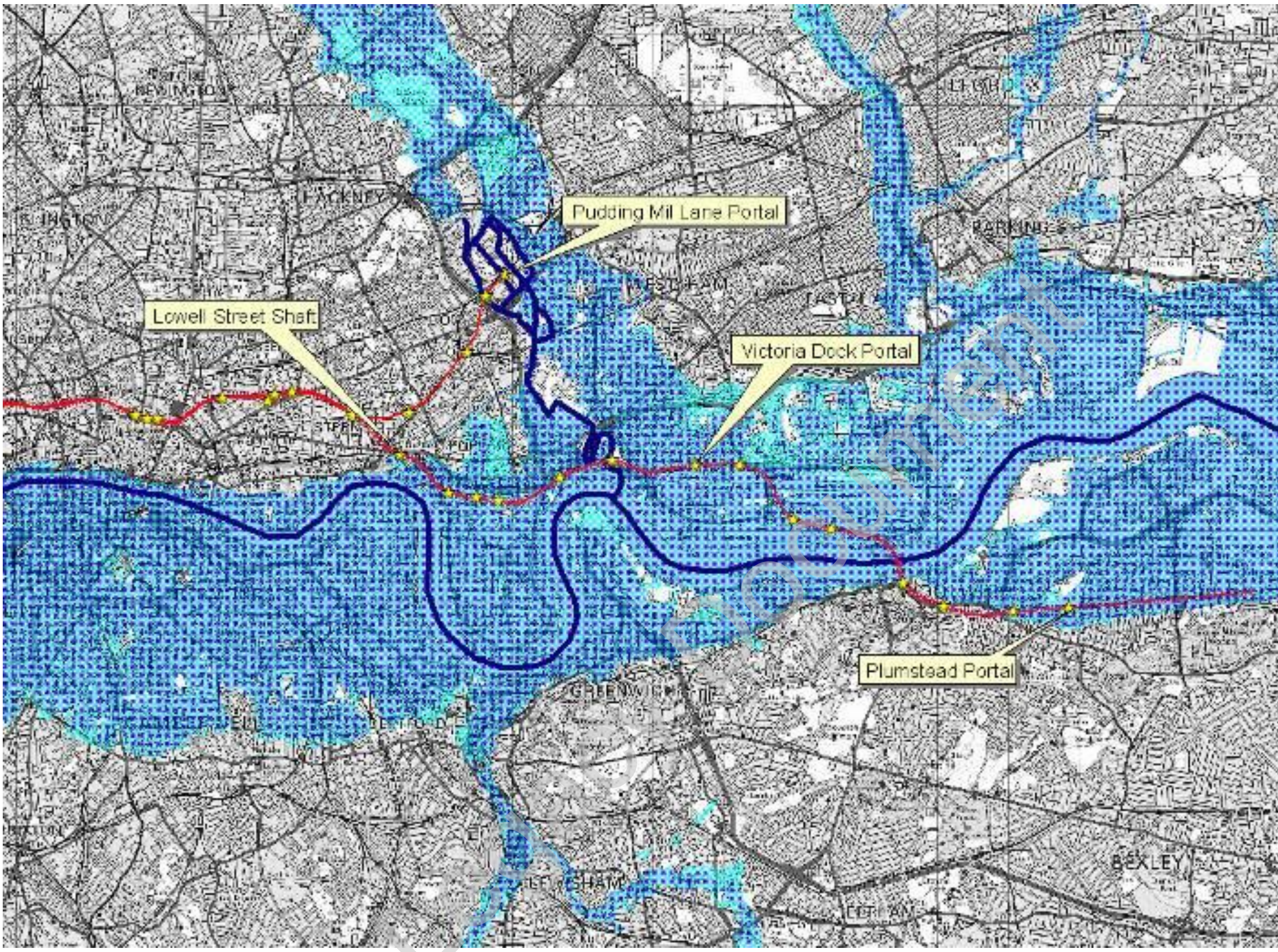
	Shaft / station	**Portal**
Passive system	Raise entry / egress levels	Raise track / cill levels Extend portal walls
Active system	Provide watertight doors Provide temporary floodgates	Install floodgates / doors / stop logs Implement anticipatory / reactive procedures

Source: Crossrail Engineering Flood Protection Strategy, 2009.

4.1.1 Fluvial and tidal flood risk to portals and shafts

The tunnel portals on the South Eastern spur of the Central section, Victoria Dock, Connaught West & East (part of an existing tunnel which already floods frequently), North Woolwich and Plumstead are at most risk of fluvial flooding (see **Figure 3** below).

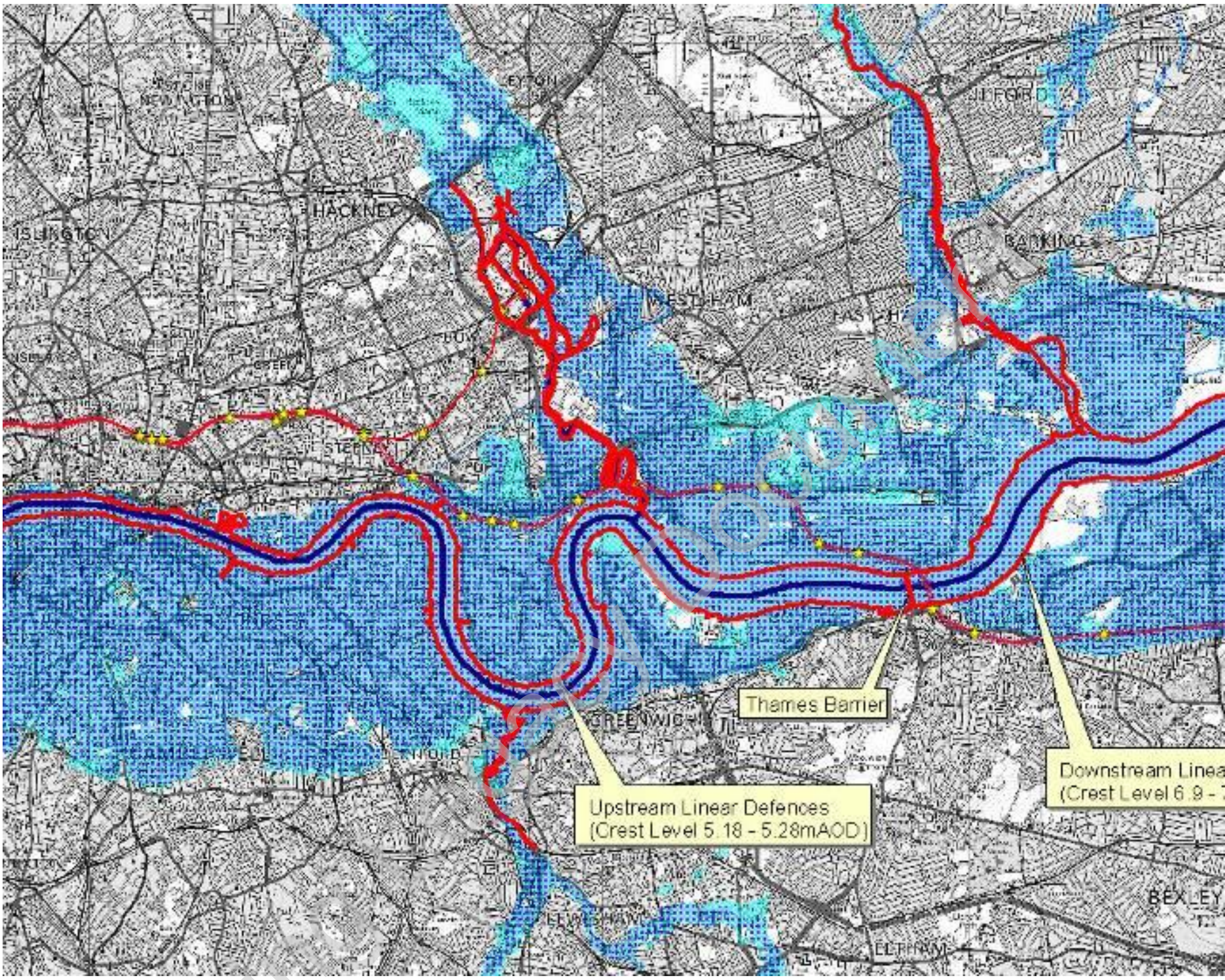
Figure 3. Environment Agency Flood Zones 1 & 2 and selected key Crossrail portals and shafts.



Source: Crossrail, 2010.

However, fluvial flooding of Crossrail tunnel portals and shafts will not occur unless there is a breach or overtopping of Environment Agency maintained flood defences (see **Figure 4** below). In addition, a catastrophic event leading to a breach of flood defences along the Thames and the Thames Barrier would cause problems for more people, assets and infrastructure in London than just Crossrail. It is noted that during the life of Crossrail (design life of approximately 120 years) these defences will require maintenance and possibly reconstruction to ensure a low probability of failure. Further information can be found in the findings of the Thames Estuary 2100 project (TE2100).

Figure 4. Environment Agency flood defences and Crossrail route



Source: Crossrail, 2010.

The Crossrail Flood Protection Strategy sets out standards for passive fluvial flood protection at all tunnel portals at risk of fluvial flooding. Originally these standards were based on a best estimate peak flood level of a 1 in 1000 year return period based on the Environment Agency's 2006 Tidal Thames Extreme Water Levels. However, these figures have been updated to reflect the Environment Agency's 2008 Tidal Thames Extreme Water Levels, and are based on a 1 in 200 year flood return period. The only tunnel portals to which these standards do not apply are the existing Connaught Tunnel portals as retrofitting passive flood protection measures has been assessed as too costly relative to the resulting social or economic benefits.

To protect against possible future climate change effects the strategy has developed people, processes and active protection measures for the at risk portals, except at the Connaught Tunnel portals, assuming Crossrail is operating in the year 2100 (see **Table 6**). These Design Flood Levels have been determined by a Fluvial Modelling study which identified scenarios for the current year and the year 2100 which would result in flood water entering the tunnels via the portals, from a breach in the river tidal defences. The study presents estimates of the levels of the flood water and the travel times for it to reach the portals for these different scenarios.

Table 6. Tunnel Portal Design Flood Levels

Tunnel Portal	Flood Level 1 (FL1) (mATD)	Flood Level 2 (FL2) (mATD)
Pudding Mill Lane	105.02	105.02
Victoria Dock	101.95	102.18
Connaught West	101.95	102.11
Connaught East	102.26	103.71
North Woolwich	102.86	104.3
Plumstead	103.29	104.53

Source: Crossrail Tunnel Flood Protection Strategy Risk Analysis, 2008.

Design Flood Level FL1 is a level that could be achieved with the current defences at the current year (based on a 1 in 200 year return period). Design Flood Level FL2 is a level that takes account of climate change effects by the year 2100 (also based on a 1 in 200 year return period). As a result of the study and the Design Flood Levels identified above, flood mitigation design measures have been specified for each tunnel portal (see **Table 7**).

Table 7. Tunnel Portals Flood Mitigation Design Measures

Royal Oak Portal	The Designer shall provide the following flood protection at Royal Oak Portal: • **Track Alignment:** The trackslab level at the entrance to the portal shall be set at a minimum of 250mm (100mm flood depth + 150mm freeboard allowance) above the adjacent ground level. • **Drainage:** Alternatively a cut-off drain may be designed at the entrance to the portal with a suitable capacity to collect water flowing into the portal at a depth of 100mm above the adjacent ground level. • **Parapet Walls:** The level of the top of the parapet walls shall be set at a minimum of 250mm above the adjacent ground level.
Victoria Dock Portal	The Designer shall provide the following flood protection at Victoria Dock Portal: • **Track Alignment:** The level of the top of the trackslab shall be a minimum of 102.1mATD. • **Parapet Walls:** The level of the top of the parapet walls shall be set at a minimum of 0.8m freeboard above flood level FL2. • **Active flood protection measures** shall be provided across the tracks to

	a minimum level of 103.00mATD (this is equivalent to 0.8m above FL2).
All other Portals	The Designer shall provide the following flood protection to all tunnel portals: • **Track Alignment**: The level of the top of the trackslab shall be set at a minimum of 0.5m freeboard above flood level FL1. • **Parapet Walls:** The level of the top of the parapet walls shall be set at a minimum of 0.5m freeboard above flood level FL2.

Source: Crossrail Tunnel Flood Protection Strategy Risk Analysis, 2008.

At Royal Oak Portal it has been established that in addition to fluvial flooding, pluvial flooding could occur from a 1 in 200 year probable maximum precipitation event. Following detailed topographical surveys and flood modelling of the area, flood protection levels for Royal Oak Portal have been specified as 250mm for the trackslab and parapet walls. At Plumstead Portal, passive protection against both fluvial and pluvial flooding is not possible and flood doors linked to the Crossrail control centre have been specified.

4.1.2 Pluvial flood design levels at stations

All sub-surface stations in the Central Section, except for Canary Wharf and Woolwich stations, are outside the fluvial and tidal flood area as illustrated in **Figure 2**. The entrance levels to Crossrail sub-surface stations and the pluvial design flood levels at these locations are shown in **Table 8.** These design flood depths are the results from a Surface Water Modelling study, and additional modelling undertaken by the Framework Design Consultants for those stations deemed to be at risk of surface water flooding. The original Surface Water Modelling study adopted Probable Maximum Precipitation values and assumed no losses of the water into the surrounding drainage and ground. The results therefore are considered to be an upper-bound estimate. All figures in **Table 8** and section **4.1.3** are based on data and information available in key Crossrail documents as at December 2010 and from forthcoming PDP and FDC contacts. The accuracy and consistency of these values has been checked as far as practically possible for the purposes of this report. However, it is strongly recommended that either the PDP Project Engineering Delegate, the relevant CRL Client Package Manager or the CRL Client Package Representative organises a double check of all values with the relevant individuals in the PDP and FDC teams as part of the ‘gate review process’.

Table 8. Flood Design Levels at Central Section Stations *mATD = metres above tunnel datum.

Station	Tunnel entry	Entry Level (mATD*)	Adjacent road	Pond or peak	Max flood Depth (m)
Paddington	1	124.25	-	Pond	0
	2	124.25	-	Peak	0
	3	124.10	-	Peak	0.04
	4	123.90	-	Peak	0.12
	5	123.75	-	Peak	0.3
	6	124.00	-	Pond	0
	7	124.30	-	Pond	0
	8	124.50	-	Pond	0
	9	124.70	-	Pond	0
	10	124.70	-	Pond	0
	Departures Road	123.75	-	Not known.	Not known.
Bond Street	Davies Street 1	119.90	New Bond Street	Peaks then ponds	2.48
	Hanover Street 1	123.85	-	Peak	0
Tottenham Court Road	East Entrances	125.60	-		tbc
	West Entrance Oxford Street	125.80	-	Peak	0.40
	West Entrance Diadem Court	125.80	-	Peak	0.40
Liverpool Street Station	Moorgate Ticket Hall	113.70	Finsbury Circus	Pond	0.17
	Broadgate Ticket Hall	112.82	-	Pond	0.78
	Blomfield Box Structure	112.82	Blomfield Street	Pond	0.78
Whitechapel	Ticket Hall	114.25	Durward Street	Pond	0
	DSS Escape Core	112.00	-	Pond	0
	CHS Escape Core	112.05	-	Peak	0.29
Canary Wharf	Main entrance	104.11	Canary Wharf	Pond	1.88
Farringdon	Not subject to surface water flooding.	-	-	-	-
Woolwich	Further work on determining surface water flood design levels to be undertaken at relevant design stage.	Station ground level is above tidal/fluvial flood level.	-	-	-

Source: CEDS 10 and additional modelling work and data supplied by WSP, Mott McDonald and work packages C130, C134 and C138. Data and information considered to be correct as at December 2010.

4.1.3 Pluvial flood risk mitigations at Central Section stations

Active flood mitigation measures are to be implemented at stations where the modelling results identify flood depths of 0.4m or greater. Flood depths below 0.4m shall be controlled by passive designs with station entrance thresholds above the local low points outside the station in accordance with Civil Engineering Design Standard Part 10 (CEDS 10) and London Underground (LU) Standards in combination with local measures deployed by station staff. The Framework Design Consultants for each station are required to determine the appropriateness of this 0.4m criterion at specific locations with reference to the surface water modelling results.

From **Table 8**, it is evident that passive pluvial flood protection is possible for all Central Section station entrances against a 1 in 200 year return precipitation event and the subsequent surface water run off, except at Bond Street, Tottenham Court Road, Liverpool Street and Canary Wharf Therefore active mitigation measures will be required for Bond Street (Davies Street entrance), Tottenham Court Road (East and West entrances) and Liverpool Street (Broadgate Ticket Hall entrance).

Bond Street

At Bond Street (Davies St) entrance modelling of the 1 in 200 year return precipitation event resulted in 2.48m of ponded water due to the local topography. A heavy duty flood gate of approximately 300mm high by 8m wide was recommended. Following additional flood modelling work undertaken by WSP, the revised recommended flood design level for the Bond Street Davies Street entrance is 21.4mAOD (metres Above Ordnance Datum), including the 300mm free board provided by the recommended flood gate. This equates to a flood level defence of 1.144m based on a station floor level of 20.243mAOD. This is a design standard equivalent to the 1 in 200 year event plus climate change with an allowance for sewerage and provision for 30% storage in basements given that when the event occurs the whole area will flood. If the recommendation is not accepted, the fall back would be in line with a 1 in 200 year event with climate change (but with no allowance for the existing sewerage system) which gives a flood design level of 21.567mAOD and a flood level of 1.324m. This is a ‘worst case’ scenario and could be lower, subject to review and agreement.

Tottenham Court Road (TCR)

A mix of active and passive pluvial flood protection measures compliant with the requirements of CEDS 10 can be provided at TCR west and east entrances. The measures will have to be consistent and coordinated with the flood protection strategy being provided by LU for the station upgrade. The station upgrade is an LU compliant design and as such has an approved flood protection strategy which will be used to confirm the provisions for flood protection at TCR. The impacts of the TCR Over Station Developments (OSDs) on flood mitigation at the west and east entrances have also been considered.

TCR West Entrance

The Surface Water Modelling Study gives a design flood level at TCR west of 26.20mAOD (equal to 126.20mATD) and CEDS 10 quotes a design flood depth (the difference between design flood level and station entrance level) of 400mm for TCR west. This assumes an old (now superseded) station entrance level of 125.80mATD and as a consequence, TCR west is identified as requiring active mitigation measures.

The level of the west station entrance at RIBA Stage E is actually 125.96mATD giving a design flood depth of 240mm. For this depth CEDS 10 advises that local active flood mitigation measures can be deployed, such as the provision of gel bags. However, more active barriers for flood mitigation have been proposed, with the provision of flood boards to a level of 126.35mATD at the main station entrance in Dean Street. This allows a freeboard of 150mm and is considered a more robust provision than relying on local active measures. The Flood Modelling Study shows that peak flood flows arrive at TCR almost 6 hours after the start of the Predicted Maximum Precipitation (PMP) event, providing adequate time for the installation of the flood boards. Design flood depths around the station entrances will vary from doorway to doorway because of variations in finished floor levels relative to the design flood levels. The different entrances and exits at the west entrance have been identified and an accompanying schedule of flood protection measures has been recommended.

TCR East Entrance

CEDS 10 does not provide any design flood depths for TCR east entrance but requires that the flood design levels be established by the LU Upgrade project. Subject to confirmation from LU, it has been assumed that the design flood level of 125.60mATD for TCR east entrance given in the Surface Water Modelling Study applies. To provide protection against flooding, flood boards are proposed to a level of 125.75mATD, providing a freeboard of 150mm above design flood. The different entrances and exits at the east entrance have been identified and an accompanying schedule of flood protection measures has been recommended.

Liverpool Street Station

At Broadgate Ticket Hall the highest point in the entry lobby cannot exceed 113.6mATD, the value specified in CEDS 10, in order to provide full passive flood protection. The passive water entry level point will be pavement level which at present is approximately 113.2mATD. The street level itself is around 112.5 mATD. Therefore the minimum water entry level of 700mm above street level is above the minimum passive provision required by LU standards. During further design development, active measures will be established to meet the CEDS 10 level subject to agreement with London Underground that these measures match or exceed LU flood defence levels at all their entrances.

At Moorgate Ticket Hall the design is to London Underground minimum flood design levels which are above those specified in CEDS 10. At both ticket halls, further designs for the urban realm may result in changes to street level. However, the design team are monitoring this.

The design flood levels at Liverpool Street Station are aligned with the climate change scenarios used in the model in terms of surface water flooding. Additional modelling work has not been undertaken to test these design levels, as has been undertaken at both Bond Street and Tottenham Court Road.

There is a potential flood water entry point via louvres on the ventilation shaft at Blomfield Box. These louvres are set 1m above the track bed of the Metropolitan Line which is in a retained cutting. This is therefore more than 10m below the design flood level given in CEDS 10. The Metropolitan Line and the Circle Line would have to flood to 1m for Crossrail to be at risk. This is a separate consideration from that modelled to define the surface water levels in CEDS but represents a clear flood risk interface with London Underground. The entry level and maximum flood depth for Blomfield Box is the same as for the Broadgate Ticket Hall. The Blomfield Box structure provides accommodation for ventilation shafts, emergency evacuation core and other station services. It incorporates structural provisions for support of an oversite development. The box is an irregular rectilinear shaped piled box, utilising 1200mm diameter contiguous bored piles. The box is approximately 30m x 20m and 34m deep with a 2.0m thick base slab. At street level there will be 2-storey Crossrail operational building. The street level also provides the Fire Brigade access point from Blomfield Street to the evacuation core.

Canary Wharf Station

Flood risk at Canary Wharf and Woolwich Stations was not studied in isolation but as part of the overall flood modelling work for Crossrail.

The potential flood water level entry point at Canary Wharf station is 6.05mAOD for the lower station entrance at the level of the promenade. Any features located below this level that could serve as a flood entry point (eg drainage outlets) shall be designed in order to prevent ingress of flood water into the station. This level was agreed through a formal consent submission. As Canary Wharf Group has considerable experience in this location and has discussed flood design levels with the Environment Agency on previous occasions, no new flood risk assessment was prepared for this submission.

Woolwich Station

Woolwich Station ground level is above the tidal and fluvial flood levels so the risk from this type of flooding is neglible. The designs for Woolwich station are not as advanced as for the other stations, and further work on determining surface water flood design levels will be undertaken at relevant design stage.

4.2 Overheating

There is a requirement that all Crossrail rolling stock will be mechanically cooled and maintained at a temperature of 29 degrees Celsius (29°C) and that all platforms in the Central section will be mechanically cooled and maintained at a temperature of no more than 27°C. There will be a gradation of temperatures from this maximum 29°C at train and 27°C platform level to external ambient temperatures at ticket hall and street level. All Central section tunnels will be mechanically ventilated and maintained at a temperature of no more than 40°C. **Table 9** summarises these requirements, with exceptions where they exist.

Table 9. Temperature design levels for platforms, tunnels and trains

NB. These are all mean design values.

• Central Section station platforms are to be designed so platform air temperatures do not exceed 27°C unless under extreme conditions such as extreme high external ambient temperatures.
• The average or likely ambient external temperature range upon which these figures are based is 22°C -24°C.
• The highest extreme external ambient temperature upon which these figures are based is 30°C – 32°C. There is flexibility for platform temperatures to exceed 27°C if external ambient temperatures exceed 30°C – 32°C,
• All Crossrail trains are to be designed so internal air temperatures do not exceed 29°C unless under extreme conditions such as a prolonged train breakdown within a tunnel, or if tunnel temperatures (for sub-surface sections) or external temperatures (for surface sections) exceed 40°C.
• Central Section running tunnels are to be designed so air temperatures do not exceed 40°C unless extreme conditions eg extreme external temperatures combined with prolonged train breakdown within a tunnel.

Source: Crossrail, 2010.

Meeting these requirements should ensure the risk of overheating of trains, platforms and tunnels is kept to a minimum, and will enable passengers and staff to travel and work respectively at comfortable, safe temperatures during the 30-35 year design life of the mechanical cooling and ventilation equipment for trains, platforms and tunnels required by Crossrail's sponsors, even if high external ambient temperatures are experienced during this time period.

The question of whether the highest extreme external ambient temperature should be reviewed and a higher figure of 35°C adopted due to projected global warming in the south-east of England, plus the exacerbating influence of the London Urban Heat Island effect, was raised in October 2009. 30°C was confirmed as the appropriate maximum temperature to design to, given the design life of, and replacement schedule for, the mechanical cooling and ventilation equipment to be specified by Crossrail. Future owners, operators and managers may need to specify upgrade equipment in 30-35 years time which can cope with the higher external ambient temperatures projected for the south-east of England and the UHI effect in London.

The ability of Crossrail to meet the temperature requirements for mechanically cooled rolling stock and platforms, and mechanically ventilated tunnels, depends upon a secure supply of power to the system. If there was a critical power or systems failure then there could be a risk of overheating on trains, platforms and in tunnels, both running tunnels and stations tunnels. However such a failure is considered relatively unlikely due to the robustness of sources of power supply to Crossrail, as described below.

National Grid is undertaking significant works to bring non-traction and traction power to Crossrail for both the construction and operation phases. These works are part of a more strategic project for increasing the resilience of London's power supply. Measures include the provision of two bulk supply points, one at each end of the Central section and three grid transformers. A single bulk supply point could provide the required electricity but having two increases efficiency and reliability of supply. This is known as the 'n+1 principle'. The possibility of both bulk power supply points going down is remote but if they did the whole of London would be without electricity, not just Crossrail.

Initial energy consumption targets for Crossrail rolling stock have been established. These will form the basis of assessment criteria for evaluation of tenders for rolling stock procurement. Therefore a train that reduces overheating to start with, and has an energy efficient cooling system will fare well under this type of assessment. In addition to energy efficiency targets, it is suggested that resilience to increased risk of overheating and robustness of equipment under higher temperatures may need to be considered as part of the assessment of rolling stock.

4.2.1 Tunnel temperatures

The maximum temperature in the running tunnels is required to be no more than 40^{o}C as stated in the Crossrail Programme Functional Requirements (CPFR). This is intended to ensure that onboard equipment such as air conditioning systems continue to function as designed, without loss of performance or efficiency. The 40^{o}C limit proposed is in line with London Underground standards, engineering practice and typical specifications for on-board equipment such as air conditioning units. However, during abnormal operations which could extend to external ambient temperatures over 30°C-32°C, an extended heatwave event leading to exceptionally high demand on London's electricity network, combined with prolonged train breakdown within a tunnel, there is flexibility for internal air temperatures of tunnels to exceed 40°C.

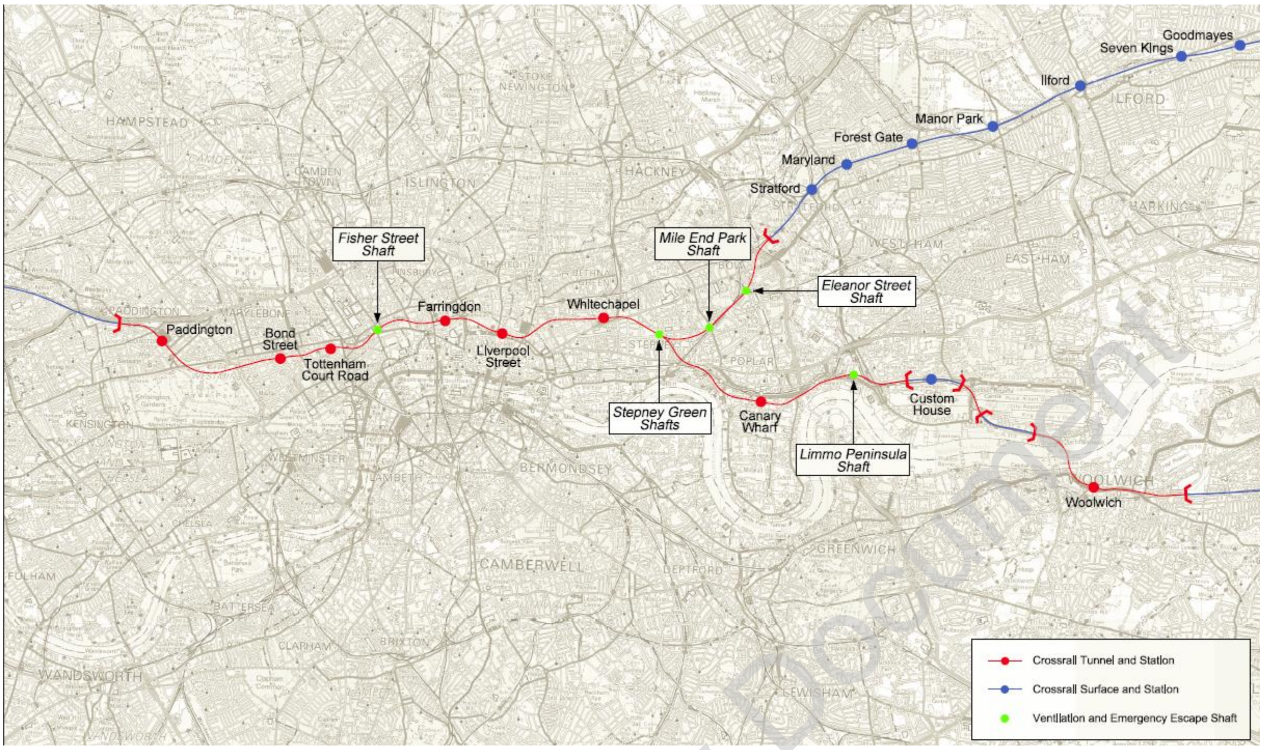
Thermal modelling and ventilation analysis undertaken for the Central Section tunnels has been based on both the current CIBSE Design Summer Year (DSY) and Test Reference Year (TRY) for London. Use of the CIBSE climate change adjusted DSY and TRY for 2050 which reflect the UKCIP projections of likely climate in London in the 2050s has been considered by work package C124. This is in relation to ensuring that the equipment in the tunnels is able to meet the performance targets throughout its operational life (approximately 35 years, similar to the rolling stock). London, in common with other urban areas, is affected by an urban heat island (UHI). The CIBSE Climate Change Weather Files do not currently incorporate the UHI effect, although there is work underway to establish how best to do so commissioned by CIBSE and the GLA.

4.2.2 Contribution to London's Urban Heat Island

There is a potential risk to London of waste heat expelled from the underground section of Crossrail exacerbating London's Urban Heat Island, as warm air will necessarily be expelled through the five ventilation shafts (see **Figure 5**) and station ventilation shafts along the route. However compared to other sources of waste heat in London, such as road traffic and building services, Crossrail's contribution is relatively small. In addition Crossrail has specified that rolling stock, track and equipment shall have good heat and energy efficiency to minimise waste heat loss from air-conditioning systems, acceleration and breaking techniques.

It could be suggested to Framework Design Consultants that the height and direction of ventilation shafts are positioned so as to avoid local increases in air temperatures where practicable and that cooling measures such as greenery and water features are considered at ventilation shaft locations.

Figure 5. Tunnel ventilation shafts along the Crossrail route



Source: Crossrail, 2010

4.3 Water scarcity

The main use of water during the life time of Crossrail is during construction (eg for concrete and cement mixing, spray concreting processes, wheel washing, keeping equipment cool and keeping dust from construction sites and activities to a minimum). Total water consumption during construction is an environmental Key Performance Indicator (KPI) which Crossrail monitors and reports to TfL. Crossrail requires its Contractors to monitor and report on their on-site water use.

There is relatively little use of water in operation except for tea points and toilets for station staff and the water required for the cleaning of stations, depots and rolling stock. All Central section stations are currently being designed to incorporate water efficient fixtures, systems and equipment which are specified in the Crossrail Design Manual for Architects and Building Services Engineers. There is a requirement for rolling stock to be designed to permit automated external cleaning and toilets will not be provided on trains themselves. There are interfaces with Network Rail, London Underground and Rail for London regarding operation and cleaning of stations, depots and rolling stock.

4.4 The Crossrail Programme Functional Requirements

The Crossrail Programme Functional Requirements (CPFR) outlines a number of key requirements for the project. The requirements which address the impacts of climate change to some extent include:

- That there will be no diminution of performance or capability of the Crossrail rolling stock due to seasonal weather effects, as currently experienced.
- That rolling stock will have a design life of 35 years, with major refit scheduled at half life.
- That the designer of the rolling stock is required to carry out a study into the design life and possible obsolescence of relevant components or systems. This will inform the design so that risks of reduced future reliability arising from the obsolescence are minimised at the design stage as far possible.
- That the design of Crossrail systems and equipment shall consider operational and maintenance tasks in emergency and abnormal scenarios, as well as in normal operations.
- That the environment of the rooms and spaces where assets and systems are located will be optimised to ensure that the design life of the asset or system is achieved.

5. Identifying risks due to the impacts of climate change

What evidence, methods, expertise and level of investment have been used when investigating the potential impacts of climate change? What evidence have you assimilated to inform your risk assessment? What has been your approach (quantitative, qualitative, scenario based)? What resource (£ / person / days) have been assigned to this assessment? Briefly summarise your approach – in house staff, professional advisors, research expertise?

5.1 Pre-climate change adaptation risk assessment and reporting requirement

Prior to the TfL requirement for Crossrail Ltd to undertake a climate change adaptation risk assessment and to prepare this report, a considerable amount of resource and expertise had been allocated to assessing risk to Crossrail presented by flood, heat and water scarcity impacts and risks. For example work undertaken by engineering consultancies Halcrow, Mott MacDonald and WSP working in partnership with the Environment Agency, London Underground, the GLA and CIBSE. Details of the methodological approaches underpinning these assessments are contained in the reports listed in **Appendix B.**

5.2 Post-climate change adaptation risk assessment and reporting requirement

Following the risk assessment and reporting requirement from TfL, Crossrail Ltd took the approach of commissioning a Senior Climate Change Adaptation Consultant from Arup to collate existing work and investigate potential impacts of climate change to Crossrail during the design and procurement, construction and operation phases. Over the course of 21 working days from 2 June – 31 August 2010, a largely qualitative methodology has incorporated:

- Literature review of key Department for Transport, Defra, Crossrail, Network Rail, Transport for London, London Underground, GLA and LCCP documents relating to sustainability, environmental management, risk assessment, extreme weather events and climate change adaptation.

- Reference to the UK Climate Impacts Programme (UKCIP) UKCP09 climate change projections for London and the South-East region.

- Semi-structured interviews with a representative cross-section of approximately 40 Crossrail staff during the period 2 June 2010 – 2 July 2010. Consideration of possible 'likely case' and 'worst case' scenarios discussed with interviewees which could be developed further if required.

- Identification and analysis of key maps and reports to ascertain key areas of climate change risks and impacts along Crossrail route, programme and systems.

- Meetings, interviews and communication with key stakeholders including Transport for London and its modes (Rail for London, London Underground, Surface, Streets), Network Rail, and external consultants working on the Crossrail project.

- Review of outputs from Phase 1 of the 'Tomorrow's Railway and Climate Change Adaptation' (TRaCCA) research project. Network Rail has managed the work with inputs from the Met Office and the Association of Train Operating Companies (ATOC).

- Review of the work in progress of the 'Future Resilient Transport Networks' (FutureNet) research project. This is a four year project (2009-2013) jointly funded by the Engineering and Physical Research Council (EPRC) and the Economic and Social Research Council (ESRC) as part of the Adaptation and Resilience to a Changing Climate (ARCC) programme.

- An internal high level Climate Change Risk Workshop in November 2010 with key Crossrail staff representing the Programme Risk management team, and the 10 route-wide and station-wide systems and sub-systems (see Table 3).

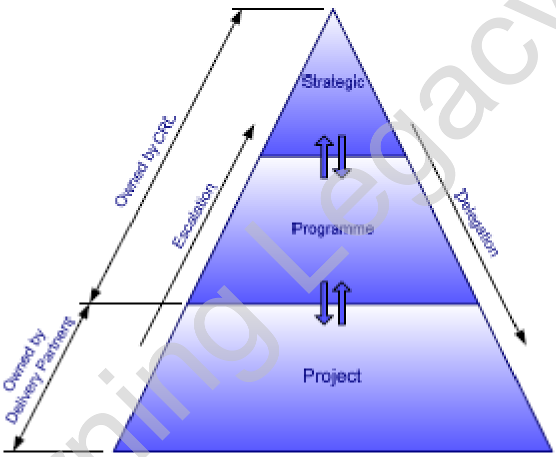
6. Assessing risks

How does your organisation quantify the impact and likelihood of risks occurring? Provide here a brief summary of the methodological approach to quantification where this has been possible and your categorisation of likelihood and impact. State what criteria you have used to characterise the significance of the risks (high, medium, low, negligible) and how these have been derived. What level of confidence do you have in the analysis?

As stated in **Section 4** Crossrail has not explicitly assessed or quantified the impact and likelihood of climate change risks occurring based on the UKCP09 projections.

However, Crossrail's risk management process provides a structured approach to the identification, assessment and treatment of risks. The Crossrail Risk Management Plan defines risk at three levels, Strategic, Programme and Project (see **Figure 6** below).

Figure 6. Crossrail's risk hierarchy



1. **Strategic Risks** are risks to Crossrail's strategic objectives. They are owned and managed by the Crossrail Executive and reviewed by the Crossrail Board on a regular basis. Strategic Risks can be all categories and can be caused by internal or external factors.

2. **Programme Risks** are risks to Crossrail's programme objectives. They are owned and managed predominantly by the Crossrail client organisation and provide the basis of programme wide reporting and management of risk at the Programme Level.

3. **Project Risks** are risks to the objectives of projects which make up the Crossrail programme. They are owned and managed predominantly by the delivery organisations Crossrail Central, Network Rail, London Underground, Canary Wharf Group, Berkeley Homes. They are the basis of project level reporting and are used for prioritising risk management activity at that level.

Climate change risks were considered by Crossrail to be Programme Wide risks which merited inclusion in the Active Risk Management (ARM) system. For the purposes of the climate change risk assessment and report we took a 'high, medium, low severity' approach to assessing climate change risks and vulnerabilities. This approach was based on existing literature on climate change risks for London and the South-East, Crossrail's own existing risk registers, along with a specific qualitative assessment of climate change risks to specific phases and systems of Crossrail. The final outcome of this risk assessment is included in this report as **Figure 9.** The Crossrail Programme Risk evaluation criteria are summarised in **Figure 7, and** those climate change risks which were considered significant enough for inclusion in the Transport for London climate change risk report are summarised in **Figure 8.**

We have a good level of confidence in this mainly qualitative risk assessment, with a quantitative output in terms of a numbered severity level, based upon available data and information as at December 2010. This has enabled these risks to be included in existing Crossrail risk registers in a comparable way to other risks already identified or closed out. However, it is suggested that Crossrail reviews these risks at appropriate phases of the project over its lifetime to ensure the risk levels are still applicable.

Figure 7. Crossrail 'Programme Risk' evaluation criteria

CROSSRAIL PROGRAMME RISK EVALUATION CRITERIA

Impact

	1 Insignificant	3 Minor	20 Moderate	100 Major	1000 Severe
Health & Safety	No lost time event. Non-reportable accident or injury. Non-first aid accident.	Lost time event. Reportable minor injury. Multiple non-reportable minor injuries.	Major injury. Multiple reportable minor injuries.	Multiple major injuries.	One or more fatalities.
	Supported and informed by Health & Safety Procedure Reference 206 "Health & Safety Risk Management"				
Environment	No measurable environmental impact or harm. No corrective action required.	Environmental impact confined to site. No significant harm but corrective action required.	3rd Party impact. Short term environmental impact but no significant harm.	Significant harm to environment that is repairable. Breach of legislation.	Significant harm to environment that is permanent or has long term effects.
Capital Cost	Less than £10m impact on Anticipated Final Cost.	Between £10m - £25m impact on Anticipated Final Cost.	Between £25-50m impact on Anticipated Final Cost.	Between £50m-£100m impact on Anticipated Final Cost.	More than £100m impact on Anticipated Final Cost.
	Note that cost calibration dependent on the scope of work being considered				
Time	Less than 1 months impact to a key milestone date.	Between 1-3 months impact to a key milestone date.	Between 3-6 months impact to a key milestone date.	Between 6-12 months impact to a key milestone date.	More than 12 months impact to a key milestone date.
Reputation	Individual comment or feedback. Isolated local media report.	Local community media reporting over a period. Localised public and/or stakeholder comment.	Significant local media campaign. National media interest. National stakeholder statements.	Extensive prolonged reaction from national media, public and/or key stakeholders.	Extensive widespread international reporting or public exchanges with key customers or stakeholders.
Quality	Non-compliance with standard or procedure that can be managed.	Developed component or system may not receive approval through assurance process.	Failure of manufacture or construction of approved component or system to meet design or specification.	Failure of a major component or system leading to rejection.	Catastrophic failure of a major component or system to function in either temporary or permanent condition.
Operating Cost	Less than £10m impact on Operating cost or revenue in a financial year.	Between £10m - £25m impact on Operating cost or revenue in a financial year.	Between £25-50m impact on Operating cost or revenue in a financial year.	Between £50m-£100m impact on Operating cost or revenue in a financial year.	More than £100m impact on Operating cost or revenue in a financial year.
Service Performance	Loss or disruption of service resulting in minor increase in journey times. Small impact on customers.	Loss or disruption of service resulting in a change to service pattern. Minor impact on customers.	Loss or disruption of service resulting in significant overcrowding. Adverse impact on customers.	Loss or disruption of service resulting in a significant loss of train paths. Significant impact on customers.	Loss or disruption of service resulting in suspension of train services. Major impact on customers.

Probability

	2 Very Low	4 Low	8 Medium	12 High	16 Very High
Probability Range	<5%	5% - 20%	20% - 50%	50% - 75%	>75%

Severity = Impact x Probability

Severity Group	Severity Status
Greater than 1000	High
101-1000	Medium
Less than 101	Low

Threat		Impact: 1 Insignificant	3 Minor	20 Moderate	100 Major	1000 Severe
Probability	16 Very High	16	48	320	1600	16000
	12 High	12	36	240	1200	12000
	8 Medium	8	24	160	800	8000
	4 Low	4	12	80	400	4000
	2 Very Low	2	6	40	200	2000

Figure 8. Crossrail CCA risks considered significant enough to include in the Transport for London CCA risk report

Crossrail Climate Change Adaptation Risk Map

As at Dec 2010

Objective: Addressing current and future risks due to climate change

Risks

1. High ambient temperature affecting railway tracks (surface tracks)
2. Extreme weather events (snow, ice and wind etc) disrupt Crossrail railway operation.
3. Pluvial flooding due to heavy rainfall events disrupt Crossrail railway operation.
4. Construction Logistics activities affected by extreme weather events in Thames Estuary or operation of Thames Barrier.

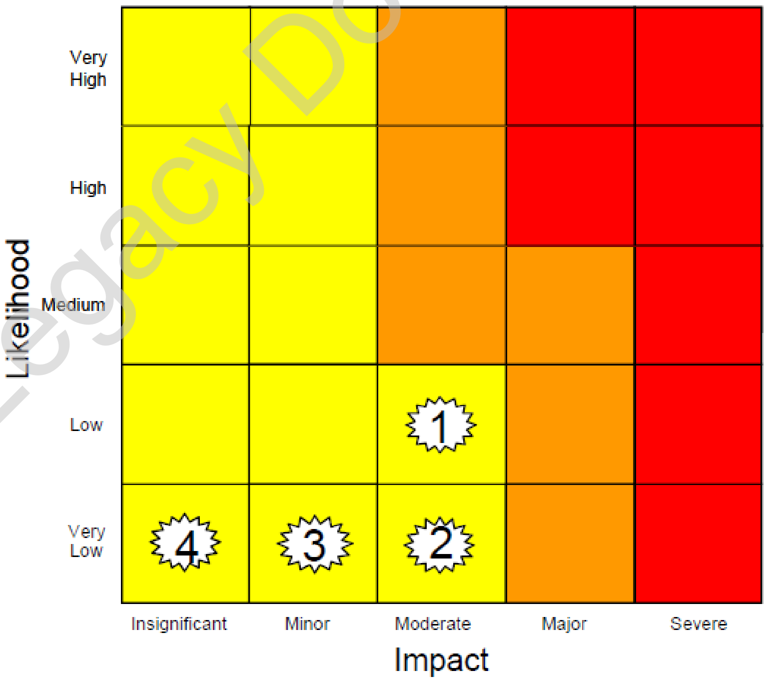


Figure 9. Extract from the final Crossrail climate change adaptation risk register

Activity / Objective	Risk Description	Status	Risk Owner	Cause	Effect	Current			Impact Type	Active Responses/Existing Controls
						Prob	Impact	Severity		
Operation	High ambient temperature affecting railway tracks (surface tracks). New tracks in the central section have been designed to cope with higher temperatures and will be de-stressed accordingly (allowing expansion), but existing surface tracks may not be upgraded.	Active	Rob Paris	1. New tracks for Crossrail in central section have been designed to cope with high temperatures and de-stressed accordingly (designed to cope with expansion due to high temperatures). 2. However, where Crossrail runs on existing on-network track infrastructure, these sections may not have been 'de-stressed' or upgraded and therefore may be subject to 'LU/NR Hot Weather Programme'.	1. A train derailment or rail buckling is unlikely to occur on continuously welded, de-stressed track. 2. If 'LU/NR Hot Weather Programme' applies to existing on-network surface tracks, which have not been upgraded then speed restrictions will be imposed with potential delays and congestion.	Low	Moderate	80	Service Performance	1. Continuously welded, de-stressed track has been specified for all surface rail in the central section. 2. Seasonal track stretching and rail replacement programmes for all other on-network surface track which has not already been de-stressed will have to consider projected future peak temperatures and address this to minimise speed restrictions, and possible derailments. 3. The majority of the existing on-network surface track in the West and North-East sections of the Crossrail route will not be modified by NR. This risk should therefore be taken forward into GRIP4. Any new track will be re-laid to modern (i.e. continuously welded and de-stressed) standards. 4. The track for the South-East spur of the Crossrail route will be new and installed to modern (i.e. continuously welded and de-stressed) standards.

Operation	High ambient temperature affecting rolling stock. High temperatures can cause overheating of rolling stock, both in tunnels, and on surface sections which can adversely affect passenger and staff comfort, health and safety.	Closed	Rob Paris	1. Ambient external temperatures exceeding 32ºC, or tunnel temperatures exceeding 35ºC (or 40ºC in degraded situations). 2. Solar gain due to poor design. 3. Failure of on-board HVAC.	1. Affect on passenger comfort, and health and safety of passengers and train staff. 2. Train taken out of service.	NIL	Moderate	0	Service Performance	1. CRL is specifying all trains to be designed so internal air temperatures do not exceed 29ºC unless under extreme conditions such as a prolonged train breakdown within a tunnel, or if tunnel temperatures (for sub-surface sections) or external temperatures (for surface sections) exceed 40ºC. Tenders which do not meet these requirements will not be accepted. 2. CRL is specifying an HVAC system for the rolling stock that meets the general requirements of BS EN 14750 - 1:2006 (includes temperature ranges for warmer climates in southern/central Europe). Tenders which do not meet these requirements will not be accepted. 3. CRL is specifying tunnel ventilation systems for central section tunnels to be designed so air temperatures do not exceed 40ºC unless in extreme conditions eg extreme external temperatures combined with prolonged train breakdown within a tunnel. Tenders which do not meet these requirements will not be accepted. Air temperatures in tunnels can affect efficiency of HVAC systems on rolling stock 4. 30-35 year design life of the mechanical cooling and ventilation equipment for trains, platforms and tunnels specified by CRL provides flexibility for future operator/infrastructure manager to upgrade/replace this equipment if required in the future. 5. 'Cool roof' technology (highly reflective, well-insulated roofs) could be specified for trains to further reduce demand for mechanical cooling.
Operation	High ambient temperature affecting station infrastructure/passenger safety. High temperatures can cause overheating of station infrastructure (e.g. ticket hall, platform waiting areas etc) which can adversely affect passenger and station staff comfort, health and safety.	Closed	Rob Paris	1. Ambient external temperatures exceeding 32ºC. 2. Heat brought in/down to platform level by passengers.	1. Station concourses/ticket halls/platforms overheating resulting in local closure of stations. 2. If ambient external temperatures exceed 32ºC then some mechanical/electrical cooling and ventilation equipment may work less efficiently, or have to work harder, using more energy or, in worst case scenario combined with other non-CRL demands on power supply in London/SE England, cease working altogether. 3. Affect on passenger and station staff comfort, health and safety.	NIL	Moderate	0	Service Performance	1. CRL is specifying all platforms in the central section to be mechanically cooled and maintained at a temperature of no more than 27ºC. 2. Station buildings and infrastructure (non-platform spaces) are being designed to minimise the need for cooling as far as possible. 3. CRL is ensuring that where cooling is still required, low-carbon, energy and heat efficient methods are used. 4. 30-35 year design life of the mechanical cooling and ventilation equipment for trains, platforms and tunnels specified by Crossrail provides flexibility for future operator/infrastructure manager to upgrade/replace this equipment if required in the future.

Operation	Pluvial flooding due to heavy rainfall events disrupt Crossrail railway operation. Extreme weather above BS EN 50125 and CEDS 10 standards.	Active	Rob Paris	1. Heavy rainfall event in exceedance of Predicted Maximum Precipitation (PMP) levels in standards. 2. Certain existing LU stations with interchanges with Crossrail, are at greater potential risk of flooding due to heavy rain events. 3. Passive flood protection measures at Connaught tunnel have been deemed economically unviable, therefore active flood protection procedures are in place.	1. Inundation at street level leading to water making it down to platform / tunnel level resulting in local closure of station. 2. Mechanical and/or electrical equipment failure causing damage/suspension of services. 3. If flooding occurs at Connaught tunnel, SE spur would be affected.	Very Low	Minor	6	Service Performance	1. CRL has undertaken flood risk assessment and modelling work with its Framework Design Consultants. As a result Flood Design Levels have been established and will be designed to. 2. Crossrail equipment is to be designed to operate in all extremes of temperature ranges and environmental conditions for operation in the UK, in accordance with BS EN 50125 'Environmental conditions for equipment in railway applications'. These include being able to withstand current and possible future anticipated extremes of sunshine, humidity, wind, rain, snow and ice over the lifetime of the system, including climate change projections. 3. All response actions have been completed. The next review will be in Dec 2011.
Operation	Extreme weather events (snow, ice and wind etc) disrupt Crossrail railway operation. Extreme weather above BS EN 50125 thresholds.	Active	Rob Paris	1. At transitions from surface to underground (portal sections), condensation may occur due to variance of temperatures. 2. Snow settling on overhead cables. 3. Ice settling on tracks at gradient. 4. Snow or ice preventing drivers reaching depot by various modes (e.g. rail, road).	1. Local closure of station, or in worse case, mechanical and/or electrical equipment failure shutting the railway. 2. Drivers unable to reach depots.	Very Low	Moderate	40	Service Performance	1. Crossrail is specifying all equipment to be designed to operate in all extremes of temperature ranges and environmental conditions for operation in the UK, in accordance with BS EN 50125 'Environmental conditions for equipment in railway applications'. These include being able to withstand current and possible future anticipated extremes of sunshine, humidity, wind, rain, snow and ice over the lifetime of the system, including climate change projections. 2. Crossrail is specifying that rolling stock providers address condensation at transition from surface to underground. 3. All response actions have been completed. The next review will be in Dec 2011.

Construction	Water scarcity during Crossrail construction leading to drought orders.	Rejected	Rob Paris	1. Reduced summer rainfall leading to drought orders for non-essential uses of water.	Drought order may result in disruption to some construction activities due to: - dust levels causing a nuisance- restrictions of use for concrete mixing/spraying- ban on cooling/cleaning construction equipment and machinery- ban on logistics vehicles as wheels cannot be cleaned- insufficient water to support Tunnel Boring Machines (TBMs)	NIL	Minor	0	Environment	1. There are national and water company responses to drought, but there is no specific emergency drought plan for London or SE England. 2. Water efficient fixtures and fittings specified for construction sites. 3. Could specify easy to clean, low maintenance materials and surfaces of construction equipment/machinery to reduce need for cleaning with water.4. CDM regulations 2007 - Construction Code KPI requirements for water efficiency during wheel washing. 5. Environmental Minimum Requirements (EMR) specify minimising dust and dampening down loads.6. TBMs do use water for cooling systems but this is largely contained within closed circuits, thus continually recycled. 7. Some water is however consumed on cleaning of plant equipment and normal operatives' welfare but in relatively modest quantity.8. The biggest and only significant water consumption lies in manufacture of concrete tunnel linings, however is probably negligible compared with consumption in the industry and across London.
Construction	Pluvial flooding due to heavy rainfall events disrupt Crossrail construction. Extreme weather above past 10-year historical weather records.	Closed	Rob Paris	1. Heavy rainfall event in exceedance of 10-year historic data (provided to the contractors to include as part of their tender). 2. This will mainly affect surface works rather than sub-surface works.	1. Landslips, slumps or inundated sites. 2. Limited access to and from sites and holding points for excavated material. 3. Impact on health and safety - on site (surface) and in tunnels (sub-surface).	NIL	Insignificant	0	Time	1. CDM regulations 2007 construction contracts allow for a certain number of days for delay. 2. CRL has provided contractors with 10-year historic weather data, including rainfall data, to assess and include as part of their tender.
Construction	Construction logistics activities affected by extreme weather events in Thames Estuary or operation of Thames Barrier. If seas are rough or the Thames Barrier is raised due to a threat from fluvial flooding/high tides, this may restrict transportation of excavated materials by barge.	Active	Rob Paris	1. Operation of Thames barrier due to flooding risk. 2. Rough seas in Thames Estuary	1. Barge transportation of excavated materials halted or delayed, therefore impacting TBM operation.	Very Low	Insignificant	2	Time	1. CDM regulations 2007 construction contracts allow for a certain number of days for delay. 2. CRL will be asking contractors to include contingency plans to avoid knock-on effects from barge transportation of excavated materials on construction (tunnelling) operations. This will take place in September 2011 where the risk will be reviewed.

Construction	Extreme weather events (wind storms, snow and ice etc) disrupt Crossrail construction. Extreme weather above past 10-year historical records.	Closed	Rob Paris	1. Extreme weather in exceedance of 10-year historic data (provided to the contractors to cost as part of their tender) e.g. increased frequency of stronger/gustier wind, extreme cold spells leading to frost, ice and snow. 2. This will mainly affect surface works rather than sub-surface works. 3. Bulk power supply from third party may fail during extreme weather event due to exceptional heating/cooling demand on grid.	1. Limited access to and from sites and holding points for excavated material limited, or inability of staff to get to work. 2. Impact on human comfort, health and safety - ability for workers to undertake construction activities. 3. Functioning of tools, equipment and plant (e.g. cranes in windy conditions, diggers in icy conditions etc). 4. Water freeze preventing cleaning. 5. Snow melt causing flooding. 6. Wind storms could affect barge transport of excavated materials by barge. 7. Freezing of excavated materials in barge.	NIL	Insignificant	0	Time	1. CDM regulations 2007 construction contracts allow for a certain number of days for delay. 2. Refer to BS 6164 for health and safety of workers. 3. National Grid is undertaking significant works to bring non-traction and traction power to Crossrail for both the construction and operation phases. 4. Two bulk supply points (BSPs) will be provided to supply traction power (at Kensal Green and Pudding Mill Lane) and two BPSs will be provided for non-traction power (at Griffiths House and West Ham). These sites are not in flood risk zones. 5. A single bulk supply point could provide the traction and non-traction power required by CRL but having two BPSs allows for redundancy, thus increasing efficiency and reliability of supply. This is known as the 'n+1 principle'. 6. The possibility of both bulk power supply points going down for both traction and non-traction power is remote, but if they did the whole of London would be without electricity, not just Crossrail.
Operation	High ambient temperature affecting signalling, communications or other electrical equipment. Extreme weather above BS EN 50125 thresholds.	Closed	Rob Paris	1. Ambient external temperatures exceeding design of 32ºC, or tunnel temperatures exceeding 35ºC (or 40ºC in a degraded situation).	1. If temperatures exceed 32ºC then some mechanical/electrical/signalling equipment may work less efficiently, or have to work harder, using more energy, or cease working altogether.	NIL	Major	0	Service Performance	1. Crossrail infrastructure is designed to minimise the need for cooling as far as possible. 2. Ensuring that where cooling is still required, that low-carbon, energy and heat efficient methods are used. 3. Crossrail equipment is to be designed to operate in all extremes of temperature ranges and environmental conditions for operation in the UK, in accordance with BS EN 50125 'Environmental conditions for equipment in railway applications'. These include being able to withstand current and possible future anticipated extremes of sunshine, humidity, wind, rain, snow and ice over the lifetime of the system, including climate change projections. (BS EN 50125 includes temperature ranges for warmer climates in southern/central Europe) 4. Signalling and communications infrastructure are designed to much higher tolerances.

Operation	Critical power or systems failure disrupting Crossrail operation due to extreme weather event.	Closed	Rob Paris	Bulk power supply from third party may fail during extreme weather event - either due to exceptional heating/cooling demand on grid, or due to physical damage to power supply points. Probability of failure is low, but impact is extremely significant.	1. Failure of traction, cooling/heating and ventilation systems. 2. Suspension of service.	NIL	Severe	0	Service Performance	1. National Grid is undertaking significant works to bring non-traction and traction power to Crossrail for both the construction and operation phases. 2. Two bulk supply points (BSPs) will be provided to supply traction power (at Kensal Green and Pudding Mill Lane) and two BPSs will be provided for non-traction power (at Griffiths House and West Ham). These sites are not in flood risk zones. 3. A single bulk supply point could provide both the traction power and non-traction power required by CRL but having two BPSs allows for redundancy, thus increasing efficiency and reliability of supply. This is known as the 'n+1 principle'. 4. The possibility of both bulk power supply points going down for both traction and non-traction power is remote, but if they did the whole of London would be without electricity, not just Crossrail.

7. Uncertainties and assumptions

What uncertainties have been identified in evaluating the risks due to climate change? Where are the key uncertainties in the analysis of the impacts of climate change and what impact do these have on the prioritisation of adaptation responses and risks for your organisation. How have these uncertainties been quantified and, in brief, what are the implications for the action plan?

What assumptions have been made? The key strategic business assumptions and methodological assumptions that underpin your analysis of impacts, action plan and analysis of risks. Well-evidenced and justified assumptions are important to the credibility of and confidence in the risk assessment.

7.1 Uncertainties

The models and projections which form the basis of the Flood Risk Assessment and the flood design levels incorporate a degree of uncertainty and climate change projections to the 2050s are more certain than those for 2080 and beyond. There is also uncertainty around what the most appropriate or likely extreme high external ambient temperature should be specified as given the UKCP09 projections for higher temperatures in London combined with the UHI effect.

Other social, economic and environment scenarios, unknown at present, could exacerbate or ameliorate the risks to Crossrail due to climate change. Greater than anticipated population growth in the Greater London region could put increased demand on the Crossrail system. This could lead to services and systems running at capacity more frequently, generating maximum heat loads, and requiring higher energy supply. Crossrail will be designed to provide sufficient capacity to be able to handle a 35% increase in peak passenger demand by 2076. Peak passenger demand is based on estimated figures at opening in 2016. It is possible that these numbers may change and is feasible that Crossrail will be at peak capacity sooner than expected in Central London. This could increase risks to passenger health and comfort during an extreme heat event, and could increase the risk of systems failure. However, Crossrail has been designed to work efficiently at capacity so if peak capacity is reached earlier than expected the system should still be able to cope.

7.2 Assumptions

Assumptions made in the preparation of this report are that:

- The Crossrail Programme Functional Requirements and Sponsor Requirements will remain as they are.
- The design lifetime of the Crossrail project including new tunnels and civil engineering structures including portals, vent, shaft and stations will be approximately 120 years.
- The design lifetime of rolling stock and tunnel equipment is approximately 35 years with major refit scheduled at half life.
- Assets and systems will be developed, designed and constructed in a way that minimises whole life costs on the basis of an appraisal period of 50 years from the Target Final Delivery date.
- This report has been commissioned by Crossrail. The final report will be owned, integrated, monitored and developed by all levels and relevant teams within the organisation.

8. Addressing current and future risks due to climate change

8.1 Identifying risks

A starting point for assessing climate change impacts and risks to Crossrail during design and procurement and construction is to consider those extreme weather related impacts and risks which currently affect London and the South East, Network Rail, London Underground and the design, engineering and construction sector. This is because one way of understanding future climate change impacts is to view today's extreme events as likely to become tomorrow's normal events. A literature review of relevant documents as described in **Section 5.2** included:

Greater London Authority documents:

- Draft climate change adaptation strategy for London (2010)
- The London Plan – consultation draft replacement (2009)

London Climate Change Partnership documents:

- 'Wild weather warning: a London Climate Impacts Profile' (2009) summarising recent extreme weather events in London and the South East
- 'Climate change and London's transport systems: Summary Report' (2005) based on UKCIP02 climate change projections

CIRIA documents:

- 'Climate change risks in building – an introduction' (2005)
- 'Flood resilience and resistance for critical infrastructure' (2010)

Arup/Network Rail document:

- 'Review of Potential Effects of Climate Change on Seasonal Preparedness' (2010)

Network Rail and Rail for London work on the CCA report for TfL/Defra/DfT.

London Underground work on 'Cooling the tube' and 'Surface water flood risk'.

Crossrail's existing risk registers for different stages of the project and for different work packages.

As outlined in **Section 4,** the key risks to Crossrail from future climate change impacts are those arising from the three main climate change impacts for London and the South-East. These three impacts and associated risks to Crossrail can be broken down into more specific potential risks across different phases of the project and across the different systems and sub-systems which comprise it. These risks are summarised in a separate risk assessment matrix in **Appendix A.**

8.2 Interdependencies

8.2.1 Transfer of risks

Some of the climate change risks to Crossrail are not within the direct control of Crossrail Ltd. For example surface water flood risk at certain points along the route can be controlled by Crossrail Ltd to some extent through passive and active design strategies at the design and procurement phase. However, this risk could be exacerbated or ameliorated by the actions of Thames Water, the Highways Agency and TfL's Surface and Streets teams between now and the operational phase.

Some of the risks to the Crossrail project are not, or will not be, within the direct ownership *of* Crossrail Ltd. However Crossrail Ltd has an opportunity and a responsibility to influence and ameliorate those risks. For example, overheating of trains, tunnels and platforms will be a risk which Network Rail and London Underground will own in the operational phase of Crossrail, but which Crossrail Ltd has the remit and scope to influence in the design and procurement phase.

Due to the size and timescale of the Crossrail project, capital costs and operational costs of the Crossrail project are incurred by different parties. If Crossrail Ltd's capital costs are squeezed during the design, procurement and construction phases, this may result in higher operational costs from 2017 onwards for Network Rail and London Underground. For example a cheaper, less energy efficient air conditioning system procured for the rolling stock by Crossrail Ltd may result in more frequent breakdowns, replacement costs, energy bills and possible financial penalties due to passenger or staff discomfort for Network Rail, London Underground or Rail for London.

8.2.2 Scope to influence risks

Certain design and engineering decisions relating to the Crossrail project have already been made based on sound analysis prior to this climate risk assessment and report. For example flood design levels should address future fluvial, tidal and pluvial flood risk and the requirement for continuously welded pre-stressed railway lines should address future high temperature risks. Other decisions are yet to be made, such as the procurement of rolling stock, design guidance for the collaborative and non-collaborative Over Station Developments and the risk assessment for construction logistics and transportation. Work is going on to consider how best to influence these decisions, however design, procurement and construction processes are moving relatively quickly so any additional guidance or inputs as a result of this report will need to be considered promptly. A short summary of where key decisions and designs for the areas of rolling stock, Over Station Developments and construction and excavation logistics is provided below.

8.2.2.1 Rolling stock

The technical specification for rolling stock is currently being prepared before hand over to the procurement team. The specification will be completed this year and put out to tender in spring 2011. The rolling stock order needs to be issued in 2012. Therefore there is scope to influence the specification to include requirements for reflective roofs, energy efficient and robust air-conditioning systems, openable windows and doors if air-conditioning systems fail on trains whilst on surface network.

8.2.2.3 Over Station Developments (OSDs) – collaborative and non-collaborative

The majority of Crossrail stations are currently at RIBA Stage D, with some at C and a few at E, therefore there may not be much scope to influence station design much further. However the majority of Over Station Developments (OSDs) are generally getting towards RIBA Stage C, with most aiming for planning submission by end of 2010 to mid-2011. There may be an opportunity for Crossrail to suggest design measures for the OSDs which support GLA and London Borough climate change adaptation targets. These may relate to ameliorating flood risk, water efficiency measures, and minimising the contribution to London's UHI. These measures will need to be evaluated using some kind of multi-criteria or cost-benefit analysis for all stakeholders.

8.2.2.2 Construction and excavation logistics

The logistics team is currently undertaking a risk assessment of the three available transport modes for construction and excavation materials - water, rail and road. There is an opportunity to incorporate UKCP09 climate change projections for London and the south-east to this risk assessment, and to incorporate consideration of climate change impacts into contracts to be let in August 2010 to transportation and logistics companies.

9. Barriers to implementing adaptation programme

What are the main barriers to implementing adaptive action? What do you see as the key challenges to implementation of your action plan? How will these be resourced and addressed? Briefly, what additional work is required?

Has the process of doing this assessment helped you identify any barriers to adaptation that do not lie under your control? Interdependencies may arise where others' actions are likely to impact on your ability to manage your own climate change risks. Briefly comment on where this is the case.

At the moment there are no actual barriers to Crossrail procuring systems and professional services or delivering designs which incorporate climate change adaptation considerations or specific measures. However, through the process of undertaking this assessment a number of interdependencies have been identified which impact on the ownership and transfer of climate change risks but these interdependencies have been summarised in **Section 8.**

10. Report and review

How will the outcome of the adaptation programme be monitored and evaluated and what is the timetable for this? Adaptation programmes are expected to reduce the residual risk to organisations from climate change. What measures will you put in place to monitor this?

Existing monitoring and reporting arrangements within Crossrail fall under the Crossrail Management System (CMS) and include Interface Management, Systems Integration, Risk and Hazard Management systems, which feed into the Crossrail Active Risk Management system (ARM), and Environmental Key Performance Indicators. These are summarised in **Table 13.**

Table 10. Crossrail's existing monitoring and reporting arrangements

Crossrail Management System (CMS)	The Crossrail CMS System…
Interface Management	The *Crossrail Interface Management Plan* is applicable to all the systems, sub-systems, components and interfaces that make up the Crossrail central section, including all civil, infrastructure and rolling stock elements plus interfaces to surface section elements.
Systems Integration	The Crossrail Central System Integration Team is responsible for managing processes to ensure that the component parts that make up the Crossrail rail system: • The Environmental Minimum Requirements; • The Standards Baseline
Risk and Hazard Management systems	• Strategic Risk • Programme Risk • Project Wide Hazards • Active Risk Manager (ARM)
Environmental Key Performance Indicators (KPIs)	Management of supplier and contractor performance

How do you propose to monitor the thresholds above which impacts will pose a threat to your organisation (including the likelihood of these thresholds being exceeded and the scale of the potential impact)? It is possible that the current risk appetite within your organisation will change on account of the climate change risks identified. How will this be monitored?

A strategy for monitoring climate change impacts, risks and thresholds is yet to be determined by Crossrail Ltd. However, there is potential to incorporate climate change impacts, risks and thresholds into existing Crossrail management systems or risk registers (eg CMS, ARM or the Project Wide Hazard Record). This is a TfL suggestion for all its transport modes. Even if some risks have already been mitigated completely or to some extent, incorporating them into these systems and registers could still be a useful way of recording and auditing how climate change risks have been or will be identified, managed and 'closed out' in the context of other risks and hazards.

How will the benefits of the programme be realised and how will this feed into the next risk assessment and options appraisal? Briefly state your plans for the next iteration of your climate change risk assessment.

A strategy for the realisation of benefits of this report is yet to be determined by Crossrail Ltd. Plans for the next iteration of the Crossrail climate change risk assessment and report are to be determined by Defra requirements and timescales, which are not known at present.

How have you incorporated flexibility into your approach? State whether your approach leaves you open to exploring different pathways in future or whether any of the measures have locked the approach into one particular path, with justification

The Crossrail project will be a permanent and significant piece of transport infrastructure for London and the South-East with an estimated design life of approximately 120 years. Given this, it is difficult to make genuinely 'flexible' design and engineering decisions which leave scope for exploring different solutions in the future.

However, the 'end to end' and 'systemwide' approach taken by Crossrail provides some opportunities to build in a degree of adaptive capacity during design and procurement.
In addition whilst the Crossrail project as whole has a estimated design life of 120 years, different structures, assets, systems, sub-systems and equipment have different design lifetimes, replacement schedules and maintenance regimes (see **Table 14** below). It is a requirement that designers shall identify the monitoring and maintenance works required to achieve or maximise the design life of structures or assets. The period for first maintenance of non-structural elements shall be a minimum of 15 years. Particular attention shall be given to deterioration of elements which cannot be easily accessed for maintenance or repair during the

design life, such as reinforcement of inaccessible parts of structures. In such cases designers shall ensure that the durability of the element can be achieved without maintenance.

Table 11. Design life for different elements of the Crossrail project

Element	Design life	
• Underground structures	120 years	
• Bridge structures and assets	120 years	
• Building and station structures and assets	120 years*	**In the event that building structures constructed over the railway are actually replaced within the 120 year design life period, the design shall incorporate provisions to permit safe demolition of the original buildings and construction of replacement structure without impacting on the railway infrastructure.*
• Load bearing brick work and block work	120 years	
• Waterproofing	120 years**	***Where this cannot be achieved, the design shall provide for a minimum period of 15 years for first maintenance, and shall facilitate future remedial works.*
• Structural steelwork	120 years**	
• Structural timber	120 years**	
• Structural temporary works	5 years***	****Where applicable temporary works shall have a minimum design life of 5 years or more depending on the construction programme.*
• Non-structural brickwork and block work	120 years	
• Non-structural components e.g floors, finishes, lighting, mechanical, electrical and ITC equipment.	30 years	

Source: Crossrail, 2010.

There is therefore scope to incorporate revised climate change projections or new railway industry standards for climate change resilient infrastructure as they come about into these lifetimes, schedules and regimes. This means there is some flexibility. However some measures could be more difficult and costly to retrofit at a later date if not factored into planned maintenance and replacement regimes now.

It is also made clear in Crossrail guidance that in designing structures, assets and systems for durability, reliance shall not be placed solely on the recommendations of existing codes and standards. Climate change related aspects which may adversely affect the durability of the Railway Infrastructure include wetting and drying, high-ambient temperatures and freeze-thaw actions. In selecting materials and taking measures to provide durability, due account shall be taken of the environment in which these structures are located, particularly where these differ from what is covered in by Codes and Standards. Deterioration of materials throughout the design life of the structure or asset shall be taken into account. The design shall include mitigating provisions to counter any adverse effects of the physical and operational environment in which the asset will be required to operate.

11. Recognising opportunities

What opportunities due to the effects of climate change and which the organisation can exploit have been identified? The risk assessment is also expected to generate opportunities for organisations, have these been captured? What are the key ones and the expected net benefits?

11.1 Wallasea Island Wild Coast Project

A significant opportunity arising from the effects of climate change or strategies identified by Crossrail for dealing with them is the Wallasea Island Wild Coast Project. Here, Crossrail is working in partnership with the Environment Agency and the Royal Society for the Protection of Birds (RSPB) on one of the largest and most important coastal habitat creation schemes in the UK. The project involves transforming 2.5 miles^2 of arable farmland on Wallasea Island back into coastal marshland. This will create a wetland mosaic of mudflats and saltmarshes, shallow lagoons and pastures. Currently the island is 2m beneath high water level. Crossrail's contribution to the project is to bring excavated material (mainly clay, chalk and gravel) from sites along the Crossrail route to Wallasea Island by ship to 'build up' the low-lying island. Crossrail is contributing approximately 5million m^3 of a total of 10million m^3 to create new habitats. This will provide an additional degree of protection from tidal flooding and storm surges for areas further up the Thames Estuary, in particular the town of Burnham-on-Crouch at the confluence of the River Crouch and the Thames.

11.2 Taking the pressure off London's existing transport network

As stated in Section 3, once Crossrail is complete and operational it will reduce passenger numbers and overcrowding on London's existing transport network. In particular passenger forecasts anticipate that a significant number of people who currently use the Central Line, one of London's busiest and warmest tube lines, will use Crossrail instead. This could have the effect of making journeys on the Central line more comfortable for remaining passengers, as heat loads will be reduced due to fewer people, and trains not being full to capacity. This may mean that any ventilation or cooling upgrades to tunnels, platform and trains on this line could be deferred, possibly freeing up resources for London Underground 'Cooling the tube' strategies on other lines. Crossrail may also contribute to a significant modal shift from car to train amongst commuters from the West and East of London thereby reducing the contribution of car exhaust emissions to London's UHI, the effect of which exacerbates high ambient temperatures in London.