London Regional Flood Risk Appraisal

First Review

August 2014

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Updating the January 2014 Consultation Draft

This document represents an update of the draft, that was published in January 2014, in the light of a three-month consultation.

Alongside further assistance by the Environment Agency, this final version of the First Review was also informed by responses the Mayor received from TfL as well as the London Boroughs of Richmond, Havering and Southwark (see Statement of Consultation provided separately). Some factual changes and updates were also made.

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Executive Summary

The Mayor is aware that flood risk is a major issue for London, and the probability of flooding is increasing with climate change. The potential consequences of flooding could also increase as London's population continues to grow. The Regional Flood Risk Appraisal (RFRA) provides an overview of all sources of flooding in London and addresses its probability and consequences.

This First Review of the RFRA has been prepared by officers in close cooperation with the Environment Agency. It builds on and updates the original version that was published in October 2009 to support the preparation of the Replacement London Plan, which was published in 2011. In 2012 the Environment Agency's the Thames Estuary 2100 Plan was endorsed by Government. The GLA-led Drain London project has also progressed since 2009 and significantly improved the understanding of surface water flood risk across London. These represent key changes reflected in this First Review.

14 % of London is at risk of tidal and fluvial flooding, and 3 % at risk of surface water flooding. It is the impact of surface water flood risk which represents the key change in this RFRA compared with the 2009 version. At the centre of the RFRA is the spatial analysis of tidal, fluvial and surface water flood risk against a number of different receptors of flood risk, including major development locations, key infrastructure assets and services.

This RFRA represents important evidence to underpin the Further Alterations to the London Plan (FALP), which are currently being developed. It demonstrates that with the continued spatial focus on urban concentration spatial flood risk probability in London is not expected to increase significantly as a consequence of the anticipated levels of growth. The better understanding of surface water flood risk gained since 2009 provides a more robust baseline and opportunity to better monitor and manage flood risk from key sources of flooding. This RFRA includes a revised set of monitoring recommendations, which will be used to keep the information up-to-date and to ensure regular checks on broad mitigation measures.

The application of the relevant London Plan policies – in particular Policies 5.12 and 5.13 – will be required to sustainably manage flood risk through new development. New development represents one of the key opportunities to reduce overall flood risk, notably through improved management of surface water and allowing space for future maintenance and upgrade of flood defences. The planning of the major development locations and town centres, where the majority of the anticipated growth will be located, which increases the potential consequences of flood events, will have to address flood risk in more detail. This RFRA provides an updated overview of broad flood risk issues in each of these locations and a framework of potential mitigation measures on which the relevant partners can build locally. In terms of flood risk for London's key infrastructure and services this RFRA illustrates these risks spatially and identifies mechanisms to investigate, monitor and address flood risk of current and new infrastructure and services in cooperation with relevant partners.

Chapter 1 - Introduction

1. Chapter 1 deals with the strategic overview of flood risk in London with particular reference to the London Plan. Chapter 2 deals with a more detailed analysis of the risk from all six types of flooding that could affect London. Chapter 3 then examines flood risk in relation to particular locations, boroughs and important infrastructure. **Appendix 5** provides the related maps and detailed statistics.

1.1 Wider Policy Background

2. The issue of flood risk has become increasingly recognised over recent years with much publicised floods during the 1990s and early part of the 21st century including recent floods this winter (Dec 2013 / January 2014)[1]. This has followed a long period when major floods did not affect London and when, consequently, flooding had not received a high profile in matters relating to land use planning. Previous notable floods occurred in 1947, 1953 and 1968, each of which resulted in responses to increase flood protection through capital projects. The publication of PPG25 in 2001 marked a step change in the approach to flood risk management in the planning system. This was replaced by PPS25, published in 2006, and its Practice Guide, published in 2008, continued to raise the profile of flood risk management amongst land use and planning considerations.

3. Also in 2008 the Pitt Review was published. It examined all aspects of flood risk management from forecasting and warning, to flood event management and evacuation/rescue to recovery and rehabilitation. The Pitt Review was triggered by a series of major floods across England in 2007, particularly affecting Gloucestershire, Humberside and parts of Yorkshire. Whilst London was not significantly affected then, it has to be prepared for significant flooding events in the future.

4. One of the key elements PPS25 and its Practice Guide introduced is a flood risk appraisal hierarchy, with developers/landowners producing site-specific Flood Risk Assessments (FRAs) and local authorities producing Strategic Flood Risk Assessments (SFRAs). For Greater London, with its 33 local authorities, a Regional Flood Risk Appraisal (RFRA) with a broad consideration of flood risk across London's borough boundaries represents important evidence to underpin the Spatial Development Strategy, the London Plan. It also facilitates the application of the more recently introduced Duty to Cooperate within London but also beyond London's boundaries including the authorities in the Thames Estuary.

5. This First Review of the RFRA builds on and updates the original RFRA that was published in October 2009. It has been undertaken with the assistance of the Environment Agency, and the Mayor would like to thank the Environment Agency for their assistance in preparing this document. This is particularly important in the light of the Agency's new strategic overview role ensuring that the risk of flooding from all sources is properly managed alongside operational responsibilities for managing the risk of flooding from main rivers, reservoirs, estuaries and the sea.

6. This review deliberately crosses again the boundary between land use planning and emergency planning. This has been done as the Mayor recognises that there is not

[1] Different strands in terms of learning lessons from these floods are currently being pursued by the Environment Agency including a 'winter readiness statement' in collaboration with Defra.

always close liaison between the two disciplines and it will be important to stimulate greater links between them. The London Resilience Team has published its London Strategic Flood Framework in May 2012[2]. This seeks to co-ordinate emergency services and emergency planners across London in the event of a major flood.

7. Since the publication of the 2009 RFRA a number of changes have taken place: The Flood and Water Management Act 2010 (F&WM Act 2010) has come into force reflecting a range of recommendations from the Pitt Review. The Flood Risk Regulations 2009 were introduced and set out requirements to manage flood risk from all sources in order to reduce the consequence of flooding on human health, economic activity and the environment. The National Planning Policy Framework (NPPF) and the associated Technical Guidance on flood risk were published in 2012. They retain the importance of flood risk management considerations that had been introduced through PPG25/PPS25. The Thames Estuary 2100 Plan was published by the Environment Agency and endorsed by Government in November 2012. It addresses flood risk from the tidal Thames. Catchment Flood Management Plans addressing fluvial flood risk were published in 2009. Finally, the GLA-led Drain London project has also progressed since 2009 and significantly improved the understanding of surface water flood risk across London, and the Environment Agency has produced reservoir flood maps.

8. The 2009 RFRA included a range of recommendations. Progress against these has been monitored annually in the London Plan Annual Monitoring Report. Since 2009 progress against the recommendations reflects in particular the actions of Drain London in terms of the improved understanding of surface water flood risk. It also confirms the improvements to local flood risk policies based on completed Strategic Flood Risk Assessments (SFRAs).

9. The current scale and distribution of flood risk is shown through the first two maps included in **Appendix 5**: **Map 1** illustrates that 14% of Greater London has some extent of known tidal and/or fluvial flood risk (extent of Flood Zones 2 and 3). **Map 2** illustrates that 3 % of the area is at some risk from surface water flooding. **Table 1** combines the extent of tidal/fluvial and surface water flooding. In chapter 3 these combined flood risk areas will be compared with a number of different receptors of flood risk, including growth areas, infrastructure assets and services.

Table 1: Tidal/fluvial and Surface Water Flood Risk in London

Region	Hectares in Flood Area	Hectares out of Flood Area	Total Hectares	Portion at Risk of Flooding
Greater London	25,802	133,668	159,470	16%

1.2 The London Plan

10. The findings of the 2009 RFRA have shaped the policies within the current London Plan. Flood risk is recognised as an important consideration for all developments and in combination with the NPPF and its associated Technical Guidance, Policy 5.12 sets out the strategic approach in London.

[2] An update is expect in 2015.

POLICY 5.12 FLOOD RISK MANAGEMENT

Strategic

A The Mayor will work with all relevant agencies including the Environment Agency to address current and future flood issues and minimise risks in a sustainable and cost effective way.

Planning decisions

B Development proposals must comply with the flood risk assessment and management requirements set out in the NPPF and the associated technical Guidance on flood risk [footnote: Technical Guidance to the National Planning Policy Framework, Department for Communities and Local Government, March 2012 or any subsequent guidance on flood risk issued in support of the NPPF] over the lifetime of the development and have regard to measures proposed in Thames Estuary 2100 (TE2100 – see paragraph 5.55) and Catchment Flood Management Plans.

C Developments which are required to pass the Exceptions Test set out in the NPPF and the Technical Guidance will need to address flood resilient design and emergency planning by demonstrating that:
- a the development will remain safe and operational under flood conditions
- b a strategy of either safe evacuation and/or safely remaining in the building is followed under flood conditions
- c key services including electricity, water etc will continue to be provided under flood conditions
- d buildings are designed for quick recovery following a flood.

D Development adjacent to flood defences will be required to protect the integrity of existing flood defences and wherever possible should aim to be set back from the banks of watercourses and those defences to allow their management, maintenance and upgrading to be undertaken in a sustainable and cost effective way.

LDF preparation

E In line with the NPPF and the Technical Guidance, boroughs should, when preparing LDFs, utilise Strategic Flood Risk Assessments to identify areas where particular flood risk issues exist and develop actions and policy approaches aimed at reducing these risks, particularly through redevelopment of sites at risk of flooding and identifying specific opportunities for flood risk management measures.

11. As a significant measure to address in particular surface water flooding Policy 5.13 on Sustainable Drainage is quoted below as well. Over recent years the scale of sustainable surface water management measures in major planning applications in line with this policy has increased significantly. Many such applications achieve the Greenfield run-off rate the policy is aiming at. It is expected that relevant measures are far less common on smaller scale developments but should become more widespread with the enactment of SuDS Approval Bodies expected in 2015.

POLICY 5.13 SUSTAINABLE DRAINAGE

Planning decisions

A Development should utilise sustainable urban drainage systems (SUDS) unless there are practical reasons for not doing so, and should aim to

achieve greenfield run-off rates and ensure that surface water run-off is managed as close to its source as possible in line with the following drainage hierarchy:

1 store rainwater for later use
2 use infiltration techniques, such as porous surfaces in non-clay areas
3 attenuate rainwater in ponds or open water features for gradual release
4 attenuate rainwater by storing in tanks or sealed water features for gradual release
5 discharge rainwater direct to a watercourse
6 discharge rainwater to a surface water sewer/drain
7 discharge rainwater to the combined sewer.

Drainage should be designed and implemented in ways that deliver other policy objectives of this Plan, including water use efficiency and quality, biodiversity, amenity and recreation.

LDF preparation

B Within LDFs boroughs should, in line with the Flood and Water Management Act 2010, utilise Surface Water Management Plans to identify areas where there are particular surface water management issues and develop actions and policy approaches aimed at reducing these risks.

12. This RFRA represents important evidence to underpin the Further Alterations to the London Plan (FALP), which are currently being developed. It is not proposed to change Policies 5.12 or 5.13, but their Supporting Text is proposed to be updated to reflect the Government's endorsement of TE2100 and the better understanding of surface water flood risk through the Drain London project. In terms of the preparation of the FALP flood risk is an important constraint in identifying capacity for housing in London through the latest Strategic Housing Land Availability Assessment (SHLAA) that informs the FALP. Sites with a known flood risk have their capacity reduced depending upon the severity of the risk and no sites within the functional floodplain (Flood Zone 3b) or greenfield sites in Flood Zone 3a were identified as having housing capacity. With the continued spatial focus on urban concentration proposed in the FALP, the anticipated growth is planned to be accommodated in particular in London's major development locations and town centres, where individual risks will have to be looked at by the London boroughs in more detail.

13. The Mayor published a Sustainable Design and Construction SPG in April 2014[3]. In its section 3.4 it gives guidance for the implementation of Policies 5.12 and 5.13 addressing different sources of flooding including surface water flooding; sustainable drainage; resilience, resistance and safety including basement developments; and flood defences.

1.3 The Sequential Test

14. The NPPF contains a Sequential Test (paragraph 101) to ensure that development takes place in the areas available at lowest flood risk. London is a unique city in the UK. It is heavily built up with a tightly drawn administrative boundary. The Green Belt policy is now long standing and has been largely successful in its aims of preventing London from spreading, preventing the coalescence of peripheral settlements and protecting

[3] The SPG can be accessed via: http://www.london.gov.uk/priorities/planning/consultations/draft-sustainable-design-and-construction

open countryside. This success is now reaping the additional benefit of promoting the re-use and regeneration of brownfield land which is widely seen as an important element in achieving sustainable development. In some places that were generally undeveloped in the middle of the 20th Century, the Green Belt extends into London, for example in the Lee Valley. Other significant open spaces are also protected by the land use planning system with various levels of policy; for example, Metropolitan Open Land (MOL) provides a similar level of protection to Green Belt.

15. The delineation of the Green Belt and the other protected open spaces in London mean that the scope for new development on land other than brownfield redevelopment land is extremely limited. Over recent years the vast majority of new development has taken place on brownfield land[4]. This trend is expected to continue.

16. Many of London's remaining large brownfield areas are either substantially or partially within Flood Zones 2 and 3. **Map 3** demonstrates that 37% of the area of Opportunity Areas and 28% of the area of Intensification Areas are within these Flood Zones. However alternative sites for large scale development within London do not exist without encroaching into Green Belt, MOL or other protected spaces.

17. The latest SHLAA examines the potential housing capacity of over 9,000 sites within London. Flood Zone 3b and greenfield sites in Flood Zone 3a were excluded as a strategic approach to the sequential test. However, consideration has been given to brownfield sites in Flood Zone 3a to help address London's housing need.

18. Therefore from a strategic perspective, the sequential test permits the consideration of these sites for development. It will still be necessary for boroughs and developers to apply the sequential test locally and consider flood risk assessments at a more detailed level when allocating uses or applying for planning permission. It will still remain important to place more vulnerable uses in areas with lower flood risk in order to meet the Sequential Test at a local level.

1.4 How to use the RFRA

19. The RFRA is a strategic overview of flood risk across London. It does not represent a detailed analysis of flood risk in relation to any particular areas or sites. It contains a series of maps to illustrate flood risk spatially (see **Appendix 5**) and a series of revised recommendations (see **Appendix 1**), which are either London wide, applicable to boroughs in undertaking their SFRAs or apply to utility/service providers. These recommendations are meant as a monitoring tool and progress against them will continue to be reported annually in the London Plan Annual Monitoring Report.

20. The RFRA will remain a live document with regular updates to reflect the changing position in relation to both climate change and development pressure and policy responses. This is the First Review and future reviews should take place approximately every five years or after a major flooding incident.

21. The RFRA should be useful to spatial planners, developers, infrastructure and utility operators and emergency planners. It is a specific aim of this RFRA to give spatial planners and emergency planners a shared understanding and common baseline of information.

[4] For details see Key Performance Indicator 1 of the Annual Monitoring Report.

Chapter 2 - Overview of Flood Risk

22. London is exposed to six different potential sources of flooding. These are analysed below, each has different spatial impacts on London and requires a different set of responses. Some responses relate to the land use planning system, whilst others relate to broader spatial matters or operational considerations for a range of organisations.

23. Each type of flooding is analysed by examining:

- Nature of the risk
- Development locations that may be affected
- Information available
- Broad flood risk management options
- The likely impact of climate change
- Strategic recommendations

24. Chapter 3 goes on to consider flood risk in relation to key locations and infrastructure in London. In this way the RFRA represents an examination of both the potential future flood risk issues and the existing flood risk issues that affect London. By doing this it can make recommendations that fulfil one of two functions. Firstly, how to ensure that future flood risk is minimised and any residual flood risks are managed appropriately. Secondly, to promote new development that will help to reduce and manage existing flood risks. This approach is in line with the NPPF (paragraph 100).

2.1 Tidal Flood Risk

Nature of Risk

25. The River Thames and the lower reaches of some of the tributary rivers are affected by the tide. The River Thames has a very large tidal range, in excess of 7 metres on spring tides. The tide's influence reaches to Teddington Lock on the Thames and up several tributaries, for example as far as Lea Bridge on the River Lee.

26. Without the current river walls many areas of London alongside the Thames and along the tidal stretches of the tributaries would be inundated twice a day through the normal tidal cycle. River walls have been steadily built up since Roman times to give increasing levels of flood protection and to enable urban development.

27. The particular threat that has remained is from tidal surges. These occur when a combination of high tide, easterly winds and a weather system depression over the North Sea can cause the tide levels to increase significantly above the normal tidal range. Previous incidents of this type of flood risk date back to 1236. More recently, in 1928, 14 people were drowned in Westminster; this was the last time that central London suffered tidal flooding. In 1953 London was largely spared the impacts of a devastating tidal flood that cost the lives of over 300 people in the East of England. If that flood had funnelled further up the Thames the results could have been even more disastrous.

28. The area at risk of tidal flooding, including from storm surges, approximates to the 5 metre contour line and is shown on **Map 1**. The area of London below the normal high

tide range is approximately 6200ha and affects parts of 12 London boroughs. The area that could potentially be affected by a storm surge of the same magnitude as the 1953 flood covers 11 600ha and affects parts of 20 London boroughs.

29. As a result of the 1953 flood, a system of flood defences was constructed. The most iconic element of this is the Thames Barrier, which has been operational since 1982. There are also around 400 smaller barriers and movable flood gates downstream of the Thames Barrier and over 300km of river walls and embankments stretching into Essex and Kent that have been raised by 2 metres to give additional protection from storm surges. Upstream of the Thames Barrier river walls are still necessary to prevent the normal range of high tides from flooding parts of inner and central London. This system of tidal flood defences made allowance for sea level rise and London is therefore protected to a very high level. It is estimated that the level of protection will reduce down to a standard of 1 in a 1000 (0.1% chance per year) by 2030 and this will continue to decline if no further measures are taken.

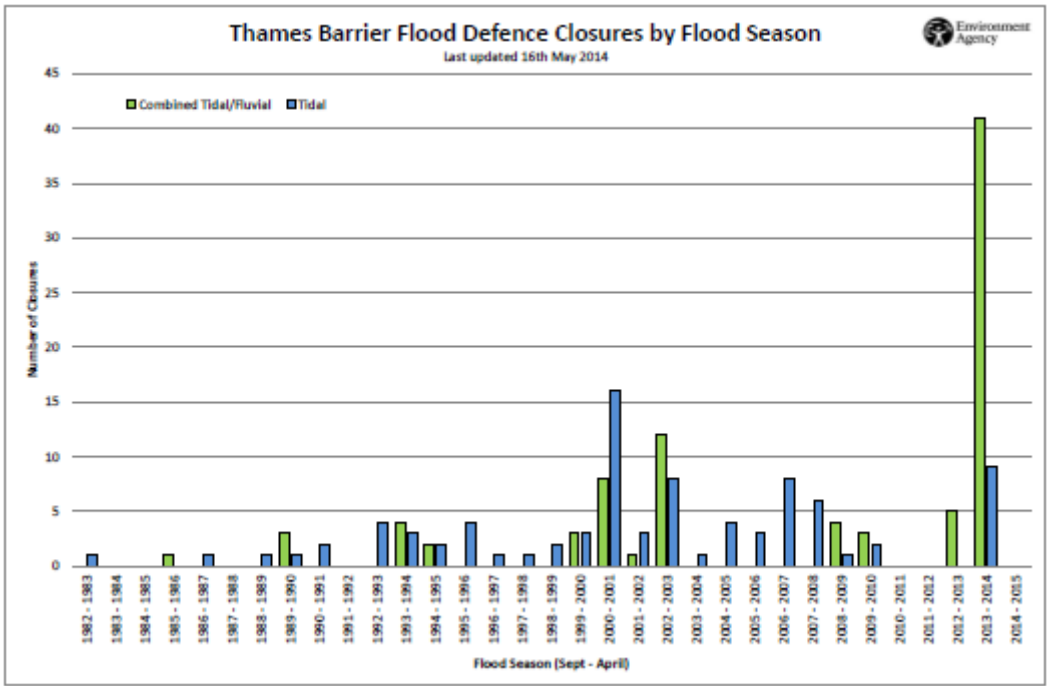
30. Since its completion in 1982, the Thames Barrier has been closed 175 times to prevent flooding. **Diagram 1** below indicates that the number of closures per year is fairly variable; however, there is a general increase in the number of closures. This ties in with climate change observations. Closure of the Thames Barrier also necessitates closure of other barriers and flood gates, and prevents navigation through the Barrier. This winter has seen a record number of 50 closures, which has triggered an investigation by the Environment Agency, which is currently underway. If there were to be 50 barrier closures year on year, the Environment Agency indicates that a review of relevant policies and plans (see TE2100 - paragraph 39) may have to be considered.

31. There are residual risks even given the high standard of flood risk management measures that are in place. These risks are:

- from an overtopping of the defences, i.e. a larger event than has been planned for, or
- from a breach in the defences, i.e. a failure, either accidental or deliberate, of the defences.

32. The likelihood of such residual risks are very small however, the scale of consequences from rapid inundation and deep water in heavily urbanised areas mean that these residual risks must be considered. Management and mitigation of residual risks in defended parts of London along the tidal Thames are a notable component of site-specific FRAs, with the approach to residual risk depending largely on surrounding ground levels and the type of land use proposed.

Diagram 1: Thames Barrier Closures



Source: Environment Agency

Locations

33. The tidal flood risk area through London affects areas to the north and south of the Thames and up some of the tributary rivers. Given that much of the land alongside the Thames in central and inner London has been in active urban uses for centuries, it is not surprising that there is a lot of infrastructure already in place there although it is protected to a high standard by the combination of the river walls and the Thames Barrier.

34. In north east and south east London there are large areas of derelict or under used land forming the Thames Gateway. These areas have mostly been in industrial uses, many of which have now ceased or are declining. These areas make up some of the major opportunities for London to accommodate its own growth pressures. Being alongside the river it is to be expected that many of these areas will have an associated element of flood risk. Despite their derelict, underused or industrial nature these areas are also protected from flooding to a high standard.

Information available

35. The 1 in 1000 (0.1%) tidal flood envelope is shown on Map 1 and covers a wide area. It is closely related to the 5m land contour. This area is currently defended to a high standard by the combination of flood walls and embankments and the Thames Barrier and other movable gates and barriers.

36. The condition of flood defences is held on a database by the Environment Agency which carries out regular inspections to update condition surveys and take appropriate action either directly or through riparian owners to ensure that structures are in a sound condition. The vast majority of flood defences along the Tidal Thames are in a good structural condition.

Flood Risk Management Options

37. Flood defences for the Thames Estuary have been built up over hundreds of years and have tended to respond to flood events by successively raising the height of flood defences walls and embankments. The current defences were constructed through the 1970s and 1980s in response to the tidal surge of 1953 and include the Thames Barrier. There are also many other flood gates and moveable structures that make up the defence system. This system of tidal flood defences was designed with knowledge of sea level rise and it made allowances for this. Therefore protection up to a 1 in 1000 (0.1%) event is estimated to be provided by the Thames Tidal Defences until 2030, after which the level of protection will decline below 1 in 1000 (0.1%) unless other measures are taken.

38. The Environment Agency has completed the Thames Estuary 2100 (TE2100) project. The plan was endorsed by Government and published in November 2012. This is the first time that planning for future flood risk management is taking place in anticipation of future flood risk rather than in response to a flood event. This RFRA takes account of its policy initiatives.

39. TE2100 indicates that the present system of flood risk management for tidal flooding can continue to provide an acceptable level of risk management up to 2030 without major alterations. Beyond 2030 more actions will be needed:

2012 – 2035:
- Work with Local Authorities and the construction industry to ensure that existing and new development is safe through spatial planning and local resilience measures
- Prepare joint riverside strategies establishing a shared vision for the riverside
- Continue to maintain, enhance, improve or replace existing flood management systems
- Work with Local Authorities and communities on the future use of the Thames Barrier in managing fluvial flooding in West London
- Continue flood forecasting and emergency planning activities
- Commence the creation of new inter-tidal habitat in the Lower Estuary which is being lost as sea levels rise

2035 – 2070:
- Maintain, improve or replace the walls, embankments, barriers and gates along the Estuary
- Work with Local Authorities and communities on enhancing and revitalising the Thames riverside
- Continue flood forecasting and emergency planning activities
- Continue replacing areas of inter-tidal habitats as sea-levels continue to rise
- Decide on and construct the option to manage increasing flood risk for the end of the Century and beyond

2070 – 2100:
- End of the century option operational (see 2035-2070).
- Further raising and adaptation of defences where required to keep new Barrier closures to within operational arrangements
- Continue programme of maintenance replacement and repair of upstream and downstream defences
- Continue flood forecasting and emergency planning activities

40. These actions will be easier, more affordable and more sustainably delivered if they are planned for from today. So, the Environment Agency is beginning to explore how to deliver them in collaboration with its partners. The Environment Agency has also identified four broad areas (Reaches) of the Thames and have outlined the following general spatial options. It will be important for SFRAs and new developments to identify methods of implementing these options:

West London Reach (Teddington Lock to Hammersmith Bridge)
41. Pursue alternative responses to managing fluvial risk such as flood resilience measures (e.g. flood gates) or potentially safeguarding land for future flood storage on the fluvial tributaries and setting back of development from river walls to enable river walls to be modified, raised and maintained in a sustainable, environmentally acceptable and cost effective way.

City Reach (Hammersmith Bridge to Thames Barrier)
42. Pursue options for small scale set back of development from river walls to enable river walls to be modified, raised and maintained in a more sustainable, environmentally acceptable and cost effective way.

Regeneration Reach (Thames Barrier to Tilbury Docks)
43. Pursue options for small scale set back of development from river walls to enable river walls to be modified, raised and maintained in a more sustainable, environmentally acceptable and cost effective way. In some cases there may be opportunities for larger scale set back as part of development in the Thames Gateway.

44. Large areas of currently undeveloped land such as Rainham/Wennington Marshes, Erith Marshes and Dartford/Crayford Marshes could potentially be used as strategic locations to increase available flood storage. It may be appropriate to consider ways to safeguard such land for future flood risk management uses or habitat creation.

Lower Estuary Reach (Tilbury Docks to Southend)
45. This is outside London but options sited here could protect London. This area may provide environmental mitigation and compensation for impacts inside London.

Confluences
46. Particular care will be needed when examining the confluences of tributary rivers with the Tidal Thames given the interaction between the different systems. In particular there may be particularly severe effects when a high tide combines with peak fluvial flows. In general the flood defences have been built to a very high standard and therefore these areas share high levels of flood protection.

The Likely Impact of Climate Change

47. Climate Change will have a major impact on the tidal flooding threat. The rising sea level will steadily reduce the level of protection that defences offer. The predictions for how quickly sea level will rise vary considerably depending on the assumptions used about emissions and climate modelling. The TE2100 Plan has considered a range of climate change derived sea level rises from 0.9m (Defra 2006 Climate Change Scenario) to 4.2m (High++ Level where all conceivable sea level rise contributions up to 2100 occur).

48. Up to 2030, there are limited differences between predictions and existing flood risk management options can continue to provide appropriate risk management for tidal flooding. Beyond 2030 there is more variation in the projections. However it is clear that by starting to plan for these changes now, the ability to cope with more extreme situations will be improved.

2.2 Fluvial Flood Risk

Nature of Risk

49. London has many tributary rivers leading to the River Thames and the Thames itself is a fluvial river upstream of Teddington Lock. These are shown on **Map 1**. As with any river system there is a possibility that any of these rivers could flood. This could come from either particularly intense rainfall within the catchment or from a blockage or restriction to flow within the river channel.

50. The Environment Agency has produced Catchment Flood Management Plans (CFMP) for fluvial rivers in England and Wales. These CFMPs examine the characteristics of rivers, current and future flood risk and potential flood risk management measures and set out a long term view of flood risk (50-100 years). The CFMPs relevant to London are:

- Thames CFMP – December 2009
- North Kent Rivers CFMP – September 2008

51. As a predominantly urban area London's rivers are often heavily modified from their natural state. This means that rivers have been straightened, deepened, widened and constructed from materials such as concrete. These changes have often been made specifically to reduce the risk of flooding by either increasing the physical size of the river channel or increasing the rate at which it can convey water.

52. The urbanised river environment also contains many bridges, tunnels and culvert structures. These culverts are often underneath roads or railways but sometimes flow under substantial areas of land. These form potential flood risks as they can become blocked or restricted through litter or more likely larger debris such as shopping trolleys, mattresses or even vehicles. Culverts present a particular difficulty in that it is difficult and expensive to determine their condition and to carry out maintenance and repairs. It can also be difficult to ascertain ownership and maintenance responsibility for some culverts. It is also known that there are a significant number of illegal mis-connections of foul sewers to surface water culverts, these lead to ongoing pollution of rivers. In general opportunities to remove and open up culverts should be taken on environmental and aesthetic grounds as well as improving flood risk management. This is also addressed in London Plan policy 7.28.

53. In London the rate at which rainwater enters urban rivers is significantly higher than normally occurs naturally. This is because a larger proportion of London's surface is covered by hard impermeable surfaces which are positively drained via surface water sewers into local watercourses and then to larger tributaries. This also increases the absolute volume of rainwater that reaches rivers because there is less chance for water to soak into the ground, be taken up by vegetation or evaporate.

54. Such urban rivers respond very rapidly to rainfall and the opportunity for flood warnings to be issued is limited to as little as one half to two hours in many cases. Some larger rivers such as the Lee or the fluvial Thames have much bigger upstream catchments so flood flows can be detected several hours or even days in advance, allowing for reasonable flood warnings to be issued.

Canals

55. London has many miles of canals. In general canals pose a low flood risk as they have limited surface water inputs. However, the Grand Union Canal alongside the Colne Valley and the River Lee Navigation are both linked to large fluvial catchments and may convey flood waters from fluvial sources. A further consideration is that any canal which is on land higher than the surrounding land has the potential for a breach. Therefore, consideration of flood risks from canals needs to be factored into SFRAs and FRAs.

Locations

56. Fluvial flooding affects parts of most London boroughs. As such it affects a number of Opportunity Areas, town centres and strategic infrastructure across the city. In general the scale is more localised than tidal flooding. Fluvial flooding has been more frequent than tidal flooding meaning that many areas of floodplain have been left un-developed, often forming parks within the wider urban setting, the most prominent example being the Lee Valley Regional Park.

Information available

57. The Flood Zones are shown on **Map 1**. The Environment Agency also has detailed floodplain modelling for some of the tributaries. Most tributaries have been modified to reduce the likelihood of flooding. In many cases these consist of raised river walls and widened channels. In the case of the River Lee an entire new flood relief channel was constructed along the east side of the Lee Valley in the 1970s. These channel modifications have generally resulted in a reduction of biodiversity value and amenity value and an increased maintenance requirement.

58. The CFMPs classify flood plains into 6 broad types:

- Undeveloped natural flood plain
- Developed flood plain with no built defences
- Developed flood plain with built defences
- Developed flood plain with typically concrete river channels
- Major urban expansion in or close to flood plains
- Narrow flood plains and mixed use land

59. The CFMPs then identify five policy options to manage flood risk and the key messages that are relevant to each of these approaches.

60. These approaches are applied to policy units (sub-regional areas) that have been identified by geography, floodplain characteristics and land use types. More detailed actions for each policy unit, reflecting the relevant approach, have been identified to manage flood risk, today and in the future. These actions can be split into two types:

those that help to reduce the likelihood of flooding occurring and those addressing the consequences if a flood does happen.

61. Three of the five policy options are used in London and they are specified below in relation to each of the catchments. SFRAs and FRAs should consider how to implement these policy approaches in local circumstances.

London Catchments *(local authorities in italics are outside London but relevant to the management of the catchment)*

62. Each tributary river system in London has different attributes, these are described below:

River Lee - Boroughs affected: Barnet, Enfield, W Forest, Haringey, Hackney, Tower Hamlets, Newham

63. The River Lee catchment is a mixture of relatively small urban tributaries with very fast reaction times to flood and the main River Lee channel which has a large and substantially rural upstream catchment. The River Lee suffered extensive flooding in 1947 as a result of rapid snowmelt. In the 1970s the River Lee Flood Relief Channel was completed to reduce the risk of flooding through the Lee valley. It is known that the design specification for the River Lee Flood Channel was to accommodate a 1 in 75 flood (1.3% chance of flooding in any year). This is below the level of protection that is now required for development under the NPPF. Furthermore the level of protection is likely to have been reduced further by the extensive development in the Hertfordshire and west Essex upper catchment of the River Lee. It will therefore be important for the current level of flood protection through the Lee Valley to be re-assessed. This is particularly relevant given the extent of built development (including raised reservoirs) in the natural flood plain and the fact that there are considerable development proposals both within and outside London.

64. The Lee catchment also includes several tributaries which have experienced localised flooding, notably Salmons Brook, Ching Brook, Turkey Brook and Pymmes Brook. These are all highly urbanised catchments where flood risk needs to be addressed strategically. The Environment Agency has recently started the construction of a flood alleviation scheme for Salmons Brook that will, together with maintenance of the existing river structures, reduce the risk of flooding to a 1.3% standard of protection (1 in 75 year; 1.3% chance of flooding in any year) for 1167 properties.

65. The CFMP recommends an approach to take further action to reduce the risk of flooding for the main River Lee river channels. For the tributaries of the Lee the CFMP recommends taking action to increase the frequency of flooding on open spaces to deliver benefits locally or elsewhere, which may constitute an overall flood risk reduction.

66. The Environment Agency has published a document summarising the findings of the Lower Lee Flood Risk Management Strategy. This covers the fluvial River Lee from Hertford to the Queen Elizabeth Olympic Park, including the tributaries of the River Lee, and outlines the proposals for managing fluvial flood risk in the catchment.[5]

[5] For further details please see http://www.environment-agency.gov.uk/research/library/consultations/54262.aspx

River Roding - Boroughs affected: Barking & Dagenham, Redbridge, Newham

67. The river here was extensively re-engineered during the 1980s and 1990s in conjunction with the construction of the North Circular Road and M11 and the introduction of a semi-tidal barrage in Barking. There has been localised flooding within London in recent years although most regular flooding occurs on agricultural land north of the London boundary. The Environment Agency's River Roding Flood Risk Management Scheme provides a strategic perspective on flood risk in the Roding catchment[6].

68. For the London reaches of the River Roding, the CFMP recommends an approach to take further action to sustain current scale of flood risk into the future (responding to potential increases in flood risk from urban development, land use change, and climate change).

River Rom/Beam - Boroughs affected: Barking & Dagenham, Havering

69. There has been limited localised flooding in this catchment and the Beam wetlands serve as a strategic flood storage area. Development proposals will still need to consider their flood risk.

70. The CFMP recommends an approach to take further action to sustain current scale of flood risk into the future (responding to potential increases in flood risk from urban development, land use change, and climate change).

River Ingrebourne - Boroughs affected: Havering, Brentwood

71. There has been some localised flooding to properties in Upminster and other flooding on open spaces through the river valley of this relatively natural tributary. There is also the tidal interaction where the southern part of the river becomes tidelocked at high tide.

72. The CFMP recommends an approach to take further action to sustain current scale of flood risk into the future (responding to potential increases in flood risk from urban development, land use change, and climate change).

River Brent - Boroughs affected: Barnet, Brent, Harrow, Ealing, Hounslow

73. The River Brent and its various tributaries have suffered localised flooding, particularly in the upstream catchments of Harrow and Barnet. The Environment Agency is examining options in partnership with the London Boroughs of Brent and Harrow and Thames Water to address this. These options will then be examined and recommendations will be taken forward by the partners. These recommendations will need to inform local policy objectives to reduce and store surface water run-off. This can be achieved through LDD policies, updates to Strategic Flood Risk Assessments and development of Local Flood Risk Management Strategies. The Brent flows through extensive park areas offering opportunities for flood risk management as well as potential for enhancement of the river corridor.

[6] For further details please see http://www.environment-agency.gov.uk/homeandleisure/floods/148706.aspx

74. The CFMP recommends an approach to take further action to sustain current scale of flood risk into the future (responding to potential increases in flood risk from urban development, land use change, and climate change).

River Crane - Boroughs affected: Harrow, Hillingdon, Ealing, Richmond, Hounslow

75. This river has historically suffered flooding problems in its lower reaches. The upper Reaches, known as the Yeading Brook, flow through considerable lengths of parks and open spaces giving some less sensitive areas for floodwater to be accommodated. Nevertheless a strategic examination of options for sustainable surface water management, bearing in mind climate change predictions, should be used to influence future development decisions and considerations of the management of the riverside open spaces.

76. The CFMP recommends an approach to take further action to sustain current scale of flood risk into the future (responding to potential increases in flood risk from urban development, land use change, and climate change).

River Colne and Pinn - Boroughs affected: Harrow, Hillingdon, *Spelthorne*

77. The Colne is a large tributary which in places forms London's western boundary. It has suffered extensive flooding in the past, although mostly of undeveloped land. Flood alleviation works have been undertaken. The River Pinn has had several recorded localised floods over recent years.

78. For the River Colne, the CFMP recommends an approach to take further action to sustain current scale of flood risk into the future (responding to potential increases in flood risk from urban development, land use change, and climate change) and for the Pinn it recommends taking action to increase the frequency of flooding on open spaces to deliver benefits locally or elsewhere, which may constitute an overall flood risk reduction.

Hogsmill River - Boroughs affected: Kingston, *Epsom & Ewell*

79. Some localised flooding has occurred on this river, notably through Kingston Town Centre. Most of the route of the river flows through open spaces and parts of the Green Belt. The Hogsmill is characterised by a developed floodplain with typically concrete river channels. The risk of flooding in these areas is relatively high and it is likely that this will increase in the future. Flooding caused by surface water, overflowing drainage systems, and the systems themselves, are the responsibility of several organisations.

80. The CFMP recommends taking action to increase the frequency of flooding on open spaces to deliver benefits locally or elsewhere, which may constitute an overall flood risk reduction.

Beverley Brook - Boroughs affected: Richmond, Wandsworth, Kingston, Merton.

81. Many parts of the floodplain remain as open space, notably through Richmond Park, although the Raynes Park area is identified as having an extensive floodplain. This coincides with the confluence of two tributaries and the river passing underneath several major road and railway structures.

82. The CFMP recommends an approach to take further action to sustain current scale of flood risk into the future (responding to potential increases in flood risk from urban development, land use change, and climate change).

River Wandle - Boroughs affected: Wandsworth, Merton, Sutton, Croydon.

83. The downstream area of this river catchment runs through a heavily built up area with flood plain covering significant areas of already developed land. Some upstream areas south of Mitcham are more open with some storage of floodwater possible.

84. The CFMP recommends an approach to take further action to sustain current scale of flood risk into the future (responding to potential increases in flood risk from urban development, land use change, and climate change).

River Ravensbourne - Boroughs affected: Lewisham, Bromley, Greenwich

85. This is a relatively large river with several tributaries. In the downstream reaches the river is tightly confined by urban development although in the more southerly upstream reaches the river and its tributaries often flow through open spaces. Parts of the river system have benefited from river restoration projects in recent years which have also improved flood risk management.

86. The CFMP recommends an approach to take further action to prevent an increase in flood risk into the future (responding to potential increases in flood risk from urban development, land use change, and climate change).

River Cray/Darent - Boroughs affected: Bexley, Bromley, Greenwich, *Dartford*

87. The upstream reaches stretch out into the Green Belt. Through much of the middle reaches the river runs through a mix of built up areas and open space and in the lower reaches there are extensive areas of floodplain and the interaction with the tidal Thames presents a further flood risk although the Dartford Barrier controls this risk with Dartford and Crayford Marshes providing large areas of flood storage upstream of the Barrier

88. These catchments are covered by the North Kent Rivers CFMP which recommends an approach to take further action to reduce the risk of flooding.

Marsh Dykes – boroughs affected: Bexley, Greenwich.

89. There are a number of modified and natural rivers in the Thamesmead/Belvedere area which are unusual in that they are below the height of Thames flood defences and rely on a system of lakes, canals and pumping stations to manage their discharge to the tidal Thames.

90. TE2100 recommends an approach to take further action to sustain current scale of flood risk into the future (responding to potential increases in flood risk from urban development, land use change, and climate change). Furthermore it recommends careful consideration of new development given the particular risks of this low lying area and the difficulties in managing surface water following heavy rainfall events.

Fluvial River Thames- boroughs affected: Kingston, Richmond, *Spelthorne*, *Elmbridge*

91. The fluvial reaches of the Thames are prone to large flood events from its extensive upstream catchment. There are no built flood defences and this stretch of the river is particularly noted for its historic and cultural value. Given the large upstream catchment close co-operation is needed with flood risk management approaches further to the west. The Environment Agency is developing the River Thames Scheme (formerly Lower Thames Flood Risk Management Strategy).

92. This River Thames Scheme (Datchet to Teddington) aims to reduce flood risk to 15,000 properties, which are currently at risk of a 1 in 100 (1% chance of flooding in any given year). The strategy combines a range of measures to reduce flood risk in the area, including building three flood diversion channels, capacity improvements to three weirs and individual property protection measures.

93. The CFMP recommends an approach to take further action to reduce the risk of flooding.

Flood Risk Management Options

94. Now that the CFMP policy approaches have been determined, there needs to be continued work to ensure that these policy approaches are implemented. The actual detail of how these need to be implemented will require careful consideration of the local river and its flood plain characteristics. London Plan policy 5.12 sets out the strategic policy of managing flood risk through new development. In many cases setting development back from river edges will enable a range of flood risk management options to be used. This should enable the most sustainable, aesthetically pleasing and cost effective options to be selected.

95. Boroughs and individual developments will need to consider the Sequential Test and the allocation of more vulnerable land uses to those areas at lowest risk.

96. Open spaces within development can be designed to accommodate flood waters. The Green Grid concept is a good example identifying such opportunities. In some cases the flood risk is such that upstream flood storage may prove to be the most realistic option. Efforts to restore damaged river environments also present good opportunities to improve flood risk management. Such measures will need to be considered in conjunction with neighbouring local authorities.

97. Where a residual flood risk remains, flood risk assessments should consider what would happen to the development and its users/occupants if a flood were to occur and how the development would recover from the flooding.

The Likely Impact of Climate Change

98. Climate change predictions suggest that there will be an increased risk of flooding on tributary rivers due to more intense patterns of rainfall. Most predictions estimate that peak flows will increase by 20% beyond 2050 with the possibility of up to 40% increases in peak flows.

99. This gives added emphasis to the need to consider the above range of flood risk management options and the Environment Agency's recommendations from CFMPs. Furthermore methods of reducing surface water run off from urban development are important. This applies not only to development in or near to a floodplain or river but across London. For those rivers whose headwaters originate outside London, the GLA will seek to work with the relevant authorities.

Recommendation 1
All Thames-side planning authorities should consider in their SFRAs and put in place Local Plan policies to promote the setting back of development from the edge of the Thames and tidal tributaries to enable sustainable and cost effective upgrade of river walls/embankments in line with Policy 5.12, CFMPs, TE2100 and advice from the Environment Agency.

Recommendation 2
The London Boroughs of Richmond, Kingston, Hounslow and Wandsworth should put in place policies to ensure alternative responses to managing fluvial risk such as flood resilience measures (e.g. flood gates) or potentially safeguarding land for future flood storage or, on the fluvial tributaries, setting back local defences or any resilience measures between Teddington Lock and Hammersmith Bridge in line with TE2100 findings.

Recommendation 3
The London Boroughs of Newham and Greenwich should work with the Environment Agency on issues such as the potential safeguarding of potential land needs around the existing Thames Barrier, and the London Borough of Bexley should work with the Environment Agency on future flood risk management options in line with TE2100 findings.

Recommendation 4
Boroughs at confluences of tributary rivers with the River Thames should ensure Flood Risk Assessments (FRAs) include an assessment of the interaction of all forms of flooding, but fluvial and tidal flood risks in particular. These are the London Boroughs of Havering, Barking & Dagenham, Newham, Tower Hamlets, Greenwich, Lewisham, Wandsworth, Hounslow, Richmond and Kingston.

Recommendation 5
Regeneration and redevelopment of London's fluvial river corridors offer a crucial opportunity to reduce flood risk. SFRAs and policies should focus on making the most of this opportunity through appropriate location, layout and design of development as set out in the Thames CFMP. In particular opportunities should be sought to:

- Set back development from the river edge to enable sustainable and cost effective flood risk management options
- Ensure that developments at residual flood risk are designed to be flood compatible and/or flood resilient
- Maximise the use of open spaces within developments which have a residual flood risk to make space for flood water.

2.3 Surface Water Flood Risk

Nature of Risk

100. This section deals with rainfall that overwhelms the drainage system or is of such intensity that it flows over land. This kind of flooding can happen in very localised areas as a result of particularly intense storm cells and as such it is hard to predict. Some recent developments in radar technology and improved weather modelling suggest that it may be possible to predict these storm events more accurately in the future. However, even if these storms can be predicted, there is likely to be only scope for action for particularly sensitive sites/uses. Since the 2009 RFRA significant work has been undertaken to assess, map and understand surface water risks. This is true nationally but in London has been given a particular focus through the Drain London project.

101. Drain London is a partnership led by the Mayor, Environment Agency, Thames Water and London Councils. It has been successful in producing surface water flood risk mapping and Surface Water Management Plans (SWMPs) for every London Borough and has funded detailed studies into over 20 high flood risk areas. The project also produced an initial assessment of groundwater flood risk – see groundwater flood risk section below. The project has been funded by Defra and has broadened its remit to support Community Flood Plans and research into household level measures that individuals can undertake to improve flood resilience at an individual property level.

102. Surface water flooding can be caused or exacerbated by blockages to the drainage network. New surface water drainage networks are normally designed to cope with storms of a 1 in 30 year intensity, however many existing systems may be constructed to different standards. It is to be expected that events above the design intensity will occur from time to time and will lead to surface water flooding. It is impractical and expensive to construct surface drainage networks that will cope with much higher storm return periods.

103. Within the F&WM Act 2010 there is a provision for the establishment of SUDS Approval Bodies (SABs). These will be run by the Lead Local Flood Authority and will control, permit and maintain SUDS on new development. These SABs are expected to be enacted in 2015, with a staged phasing-in of different scales of development that will require SAB Approval. It is anticipated that SABs will operate in a similar way to Building Control as a parallel process to planning permission. It is also anticipated that this requirement will result in a step change in the number of SUDS being implemented. The Drain London Forum will facilitate the information exchange between the boroughs on their experience of operating as SABs, and more widely it is anticipated that it will continue to assist boroughs as Lead Local Flood Authorities in sharing good practice in the delivery of these new duties.

Locations

104. The Drain London project has produced the first comprehensive series of surface water risk maps for London and these have been accompanied by a Surface Water Management Plan (SWMP) for each London Borough.

105. Surface water flood risks occur in lower lying areas of all London boroughs. Given the complexity of the land form, topography and the drainage network it is impossible to predict precisely where the risks will lie. Details such as the height of kerbs or level

and construction of boundary walls can determine whether surface water flows one way or another. Therefore any London wide or borough wide mapping must only be taken as a general indication of risk areas (see **Map 2**).

106. There are some general points that emerge from the analysis of the mapping. In central and inner London, where the natural drainage systems have been largely removed and built over, surface water flood risk tends to occur in lots of small, localized areas representing slightly lower ground than the surrounding land. Basement properties and entrances to sub surface car parks, servicing yards etc. can be at particular risk of ingress of water. It should be noted that such basements often house important utilities such as electrical sub stations/meters, lift motors/control gear, back up power generators or computer servers. It should be remembered that the circumstances under which surface water flooding is likely to occur are heavy rain when most places will be wet already. Often smaller natural drainage features such as tributary streams and ditches have been built over during the centuries of development, whilst the land may remain at a slightly lower level, thereby being likely to be subject to surface water flooding. Any blockages or failures of the drainage network will exacerbate such flooding and may even cause flooding in circumstances where the drainage system would otherwise have coped.

107. In the rest of London where the natural drainage system of rivers and streams remains, surface water flooding is often directed to the valleys of those streams which form the naturally lower land areas. Many of these urban rivers are immediately adjacent to built development or even underneath buildings and in such cases those buildings may lie within risk areas. Away from those river corridors surface water will pond in lower lying areas.

108. Buildings with large roof areas, such as mainline rail termini, hospitals, schools, retail warehouses are particularly prone to surface water risks under heavy rainfall situations. For such buildings it will be important to ensure that any new development proposals reduce those risks. Additionally through the Drain London programme there are projects which are examining those risks and seeking ways to demonstrate how to retrofit more sustainable drainage to reduce the risks.

109. It will often be unfeasible to address surface water risks at the specific location where the risk of flooding exists. Therefore it is important that steps are taken in the surrounding contributory catchment areas to manage surface water more sustainably. The implementation of London Plan Policy 5.13 (Sustainable Drainage) and the emerging Sustainable Design and Construction SPG is therefore important across all of London and not just in identified risk areas.

Information available

110. The Drain London project has produced surface water flood risk maps for each London Borough covering the following return periods: 1 in 30, 1 in 75, 1 in 100, 1in 100 + Climate change) and 1 in 200. This modelling is "intermediate" level modelling and made a general allowance of 6.5mm of rainfall per hour being absorbed by the drainage network. For a selection of high risk areas, Drain London has undertaken "detailed" level modelling in partnership with the relevant boroughs. This has generally shown that the extent of flood risk in the London-wide intermediate level modelling has been slightly over estimated. This is mainly because the 6.5mm/hour drainage

allowance has been a conservative estimate. The detailed level of work has enabled boroughs to determine whether they should progress with risk management works.

111. The mapping used in this RFRA shows the Drain London flood risk areas with deeper than 0.3m (300mm) of modelled flooding (see **Appendix 5**). This has been selected to increase the confidence in the mapping. For some flood risk receptors such as rail stations and emergency services manual screening of the Drain London data was undertaken to improve the reliability of the data further. For example in cases where sites/facilities do have some level of modelled flood risk, these may have still been excluded if these risks were assessed to be not significant.

112. In December 2013 the Environment Agency published updated surface water flood risk mapping for England. This has utilised advances in computer modelling power to generate flood risk maps, using some similar methodology to that of the Drain London project, for the whole country. The EA modelling technique tends to channel more surface water into identifiable features such as roads, thus suggesting greater impacts on the highway network but lower impacts on properties. If an area has an identified surface water flood risk, then more detailed site specific analysis is recommended.

113. There are still relatively few well documented records of surface water flooding. The nature of surface water flooding is often that it occurs and then dissipates quickly, usually within a few hours. Whilst historically this has made it difficult to make a reliable record of such an event, the prevalence of camera phones, social media and CCTV now makes it possible to build up an accurate picture of such events and in future events are likely to be recorded on a much more consistent basis. Furthermore, the London boroughs as Lead Local Flood Authorities now have a duty under the F&WM Act 2010 to maintain a register of any significant flood events.

Flood Risk Management Options

114. As mentioned before, it is often impossible to manage surface water flood risk at the locations where that risk is present and it is therefore important to apply London Plan Policy 5.13 across the whole of London. Drain London is also working on several retrofit projects to deliver sustainable drainage solutions where new development is not the primary driver.

115. Where development proposals are on brownfield sites, there are real benefits to be gained by making a substantial reduction in the amount of surface water run-off generated through the redevelopment of the site. In cases where sites were used for predominantly industrial purposes the proportion of drained area is often close to 100% of the site. A residential development is likely to be in the range of 40-80% positively drained, leading to a reduction in surface water run-off. Adding in measures such as porous road and parking surfaces, green/brown roofs, storage ponds/tanks, swales and soakaways could reduce run-off to an estimated 20-50% of previous levels, and in some cases may be close to the natural (greenfield) run-off rate. This should be the aim of a sustainable approach to urban drainage.

116. In some specific locations, for example where basements are at risk, there may be options to raise the threshold entrance to those basements. Additionally, as is often recommended for developments within the defended Flood Zone 3a, which meet the

Exceptions Test, placing important infrastructure, such as electrical supplies, lift motors, computer servers, within a flood proof room or enclosure may be a viable option.

117. The Drain London project is now working with partners to broaden the delivery of sustainable drainage. It will be developing a London Sustainable Drainage Action Plan during 2014[7]. It will examine ways of encouraging and incentivising the retrofitting of sustainable drainage measures into the existing urban environment. Such measures will investigate how existing maintenance budgets for public and private buildings can deliver more sustainable drainage measures, how improvements to the road system, public realm and public transport network can be designed to incorporate more sustainable management of rainwater and how private individuals could be encouraged to adopt more sustainable rainwater management on their own properties.

118. It should also be remembered that for development close to tidal rivers, docks and potentially other water bodies, a direct discharge of clean rainwater to these may be the most sustainable option. London Plan policy 5.13 promotes this option.

119. There is also emerging evidence on rainwater management that even relatively extensive green roofs, as encouraged by London Plan Policy 5.11, can have a significant effect in reducing surface water run-off, particularly with the lower intensity rainfall events.

120. Drain London is working to deliver "Greenstreets" pilot projects across London. These are local projects to demonstrate how to manage surface water in a more sustainable way working with communities to bring additional benefits to the appearance and amenity of streets and individual properties. Thames Water is leading with three streets in the Counters Creek sewer catchment of Hammersmith & Fulham and Kensington and Chelsea; the Environment Agency is delivering a project in Beckton; and LB Newham, the GLA and the Environment Agency are working with LB Haringey to identify suitable measures. The lessons learnt from these pilots will help to shape future work under the London Sustainable Drainage Action Plan.

The Likely Impact of Climate Change

121. Current predictions anticipate that the intensity of storms is likely to increase. This will mean that both the likelihood of surface water flooding will increase and the consequences will increase as flood waters may be deeper given the higher volumes of rainwater. The application of the sustainable drainage hierarchy (Policy 5.13) and the London Sustainable Drainage Action Plan should improve the ability of the urban area as a whole to cope with such storm events but individual locations will still be affected.

Recommendation 6
Developments all across London should reduce surface water discharge in line with the Sustainable Drainage Hierarchy set out in Policy 5.13 of the London Plan, the emerging Sustainable Design and Construction SPG and the emerging London Sustainable Drainage Action Plan.

[7] A consultation draft is expected to be published in late 2014 and a final plan in the middle of 2015.

2.4 Foul Sewer Flood Risk

Nature of Risk

122. Foul sewer flooding occurs where sewers become blocked or overloaded and properties connected to the sewer system are located at a level below the hydraulic level of the sewage flow. These are often basement flats or premises in low lying areas. Sewer flooding is clearly particularly unpleasant and distressing as its contents are highly contaminated. At present Thames Water estimates that there are over 10,000 properties which are vulnerable to sewer flooding across the whole of Thames Water's operational area.

123. Thames Water is investing over £300million between 2010-2015 to combat sewer flooding at 2,500 properties. The aim is to eradicate the problem in the foreseeable future.

124. There will also be some potential synergies with the Drain London project, particularly within the Combined Sewer areas of London.

125. In most of central and inner London the surface water and sewerage networks are combined in "Combined Sewers". During periods of heavy rain the combined sewage and rainwater is diverted to the River Thames via combined sewer overflows to prevent significant flooding of homes, businesses, streets and gardens. The proposed Thames Tideway Tunnels will intercept overflows and transfer the flows for treatment at Beckton Sewage Treatment Works. London Plan policy 5.14 supports this project in principle. It will prevent the discharge of millions of tonnes of untreated sewage and rainwater to the Thames.

Locations

126. The locations affected tend to be small discrete sub-catchments on the sewer network rather than any specific patterns or particular locations.

Information available

127. Detailed records of locations where sewer flooding has been recorded either within a property or within the grounds of a property are held by Thames Water. The locations are generally very sporadic and not suited to mapping on a London-wide basis.

Flood Risk Management Options

128. The nature of the problem dictates that the most effective solution is for Thames Water to carry out direct works to those parts of the sewer network linked to the affected property or group of properties. This is an expensive operation – averaging over £120,000 per property for the programme between 2010-2015.

129. Future developments should be catered for by ensuring that the appropriate on and off site sewerage infrastructure is planned and delivered to fit in with proposed development. In line with London Plan Policy 5.13 it is important to promote that surface water is not discharged into the foul water system, thereby surcharging its capacity.

The Likely Impact of Climate Change

130. In theory climate change should not make a substantial difference to this problem. However, in practice, as surface water drains are often wrongly connected to the foul system, the expected increase in intensity of storm events will increase the likelihood of sewer flooding. Similarly, within the combined sewer area of London, increases in rainfall will trigger additional combined sewer discharges to the Thames. In central London this problem should be largely overcome through the completion of the Thames Tideway Tunnels[8]. In parallel, it will be important that developments follow the London Plan Sustainable Drainage Hierarchy (Policy 5.13) in order to ensure the continued effectiveness of the sewer system and to prevent gradual increases in the number and scale of overflows to the new Thames Tideway Tunnel, in particular as climate change will have more impact later in the century.

Recommendation 7
Thames Water should continue the programme of addressing foul sewer flooding.

2.5 Groundwater Flood Risk

Nature of Risk

131. Groundwater flows out of the ground at the point where the water table meets the surface; this acts as the source of many rivers and is also a valuable source of drinking water. Heavy rainfall can infiltrate the ground causing saturation; surplus water will then flow out to rivers or onto land potentially causing flooding. Groundwater tends to respond slowly to rainfall, so when groundwater flooding occurs it can persist for some time. Within London there have only been very few recorded groundwater flooding events, although it may be possible for groundwater to cause elevated base flows into some of the rivers entering London as a result of increased groundwater flows from the surrounding hills of the Chilterns or the North Downs. In February 2014 some South London boroughs were affected by groundwater flooding, with the Kenley Water Treatment Works and around 50 properties affected in particular in Croydon and Bromley.

132. London had an issue over the past 20 or so years with rising groundwater. This has occurred because the majority of London, including much of its underground infrastructure such as tube lines and foundations for large buildings, was built at a time when the natural groundwater was suppressed due to large scale abstraction by manufacturing industry. With the steady reduction of industrial activity in London during the second half of the 20th century, groundwater levels began recovering to their natural levels thereby threatening to inundate the underground infrastructure or de-stabilize the ground surrounding the structures.

133. This problem has been addressed by the General Aquifer Research Development and Investigation Team (GARDIT). Through increased abstraction of the groundwater, notably by Thames Water, groundwater levels are now relatively stable and the Environment Agency is maintaining a regular monitoring regime.

[8] The Secretary of State is expected to make a decision on Thames Water's Development Consent Order in Sept 2014.

Major Development Locations

134. There are no known locations where groundwater flooding has been a problem. The rising groundwater was mostly related to central and inner London, although this is now being managed.

135. The Drain London project undertook a London-wide assessment of groundwater flood risks. This combined several existing datasets to produce a map of "indicative Potential for Elevated Groundwater" (IPEG), which provides a starting point for further investigations. Detailed sites specific assessments are important, particularly where deep excavation is involved or where there is an indication that the groundwater levels may be elevated. The areas highlighted in the IPEG map are generally quite sporadic across London. See **Map 12** for an illustration of the IPEG.

Information available

136. The Environment Agency keeps detailed records of groundwater levels through a comprehensive monitoring regime. All boroughs with historic groundwater flooding records have incorporated them into their SFRAs. In addition, the IPEG maps can be used to highlight areas where there may be an increased potential for groundwater to rise sufficiently to cause flooding denoting where further, site-specific, assessment may be required as part of an FRA.

Flood Risk Management Options

137. The continued abstraction of water by Thames Water is important to manage groundwater levels in the foreseeable future. This is expected to continue.

The Likely Impact of Climate Change

138. Increased groundwater levels are normally the result of prolonged rainfall with a degree of delay built in as water percolates through the ground. It is not yet clear whether the increased amount of winter rainfall will increase this risk or, as the total amount of rainfall is expected to remain relatively unchanged (just fall in more concentrated periods), the effect upon groundwater patterns and flows may remain stable. This needs to be kept under review.

Recommendation 8
The groundwater flood risk in identified locations (see IPEG map) should be considered in FRAs and SFRAs to ensure that its impacts do not increase.

2.6 Reservoir Flood Risk

Nature of Risk

139. Reservoir flooding is extremely unlikely to happen. There has been no loss of life in the UK from reservoir flooding since 1925. Specific reservoirs must be inspected and supervised by reservoir panel engineers. As the enforcement authority for the Reservoirs Act 1975 in England, the Environment Agency ensures that reservoirs are inspected regularly and essential safety work is carried out. However, in the unlikely event that a reservoir dam failed, a large volume of water would escape at once and flooding could

happen with little or no warning. The resulting high consequence of flooding means that, although flooding from reservoirs is considered to be of very low likelihood, the risk should be considered in SFRAs and FRA.

Major Development Locations

140. The reservoirs in the Lower Lee Valley are the largest reservoir area within the GLA boundaries. They are well maintained and monitored. In the unlikely event of a reservoir flood the Lower Lee Valley downstream from the reservoirs could be significantly affected.

Information available

141. Reservoir flood maps were introcuced by the Environment Agency only after the 2009 RFRA. They are now available via the following website: http://maps.environment-agency.gov.uk/wiyby/wiybyController?ep=maptopics&lang=_e An extract covering London is included as illustration as **Map 13**. Reservoir maps display information for large reservoirs holding over 25,000 cubic meters of water. They show the largest area that might be flooded if a reservoir were to fail and release the water it holds. They do not display information about how likely any area is to be flooded or about the depth or speed of the flood waters.

Flood Risk Management Options

142. The Water Act 2003 amended the Reservoirs Act 1975 and introduced a requirement for reservoir flood plans. Since August 2013 requirements are based on risk and not on size[9]. The Environment Agency has started to review all reservoirs to determine their level of risk.

143. The Reservoirs Act requires that reservoir owners undertake all necessary steps to prevent breaches from occurring following regular inspection and reporting. The likelihood of breaching is very low, and therefore , when considering flood risk to new development it is unlikely that any particular mitigation measures will be required, unless a high vulnerability development was proposed immediately downstream of a high risk reservoir. There may also be implications for emergency planning and it may be necessary to incorporate the following aspects of the relevant reservoir safety plan, which represents an element of the reservoir flood plan and includes the three aspects below, into emergency plans for new developments:

- a reservoir flood map by the Environment Agency which identifies the extent and severity of flooding which could result from an uncontrolled release of water;
- an on-site reservoir emergency plan by the reservoir owner setting out what would be done in an emergency to try to contain and limit the effects of the incident. It will include a plan for communicating with external organisations, mainly the emergency services but also for example transport network operation centres;
- an off-site reservoir emergency plan by the Local Resilience Forum (LRF) setting out what the emergency services will do to warn and protect people and property downstream in the event of an incident which could lead to dam failure.

[9] Previously only applied to large raised reservoirs over 25,000 m3.

The Likely Impact of Climate Change

144 It is very unlikely that climate change will have a significant impact on reservoir flooding. However, this will be monitored through the above mentioned strict management arrangements.

Recommendation 9
The reservoir flood risk in identified locations (see reservoir flood maps) should be considered in FRAs and SFRAs to ensure its impacts do not increase.

Chapter 3– Spatial Implications of Flood Risk

3.1 Introduction

144. Chapter 1 dealt with the strategic overview of flood risk in London with particular reference to the London Plan. Chapter 2 dealt with a more detailed analysis of the risk from the six types of flooding that could affect London. Chapter 3 now examines flood risk in relation to particular locations, boroughs and important infrastructure. **Appendix 5** provides the related maps and detailed statistics, and **Appendix 4** represents a broad comparison of flood risk data with the 2009 RFRA.

London Boroughs – Strategic Flood Risk Appraisals (SFRAs)

145. Most London boroughs have some extent of identified flood risk; see **Maps 1 and 2**. For some this is limited to small areas along tributary streams, for others it includes large areas with potential for tidal flooding across a large proportion of the borough.

146. All boroughs have now completed their SFRAs. These will need to be kept up to date and reviewed approximately every 3-5 years or as and when significant new data becomes available. For specific strategic purposes joint SFRAs have been produced, including one for East London and one for North London to support the North London Waste Plan.

147. It is important for SFRAs to identify areas where there are particular flood risks. For example, some low lying areas of land will be susceptible to ponding of water, in other areas there may be particular risks of a breach of flood defences or rapid inundation of flood waters with high velocities. This type of analysis will assist in determining locations where development may have to be constrained or altered to avoid particularly high risks.

148. The SFRAs represent a baseline study of flood risk for each borough and have generated detailed descriptions of prevailing flood risk. When the SFRAs are updated, they should consider further;

- Where appropriate, taking forward key recommendations into flood risk management policies within the Local Plans.
- Using the characterisation of risk to identify areas where redevelopment could be an opportunity to reduce flood risk. Where redevelopment is likely and capable of contributing to a reduction in flood risk (reducing probability and/or consequence), this could be achieved for example through relocating buildings, improving layout and design (designing in resistance), removing certain vulnerable land uses or providing flood compatible open spaces.

149. These issues may require design considerations at the masterplan or community scale and a SFRA could identify where this type of planning is required. Some SFRAs have started to present this analysis through identification of character areas, others have started to link spatial planning policy to enhancement of emergency planning capability.

150. Complementing this planning specific tool, as Lead Local Lead Flood Authorities the London boroughs also have to produce Local Flood Risk Management Strategies

based on the F&WM Act 2010 requirements with measures to address local flood risk in their areas. All boroughs are currently in the process of developing these Strategies. They also have to maintain a register of Flood Risk Management Assets and must investigate reports of flooding.

3.2 Specific Development Areas

Major Development Locations

152. The London Plan contains two categories of major development location; Opportunity Areas and Intensification Areas. These are the places where London will accommodate the majority of its anticipated significant growth and where large scale development is expected to take place over the Plan period. Each of these will involve up to several thousand new dwellings and/or employment space for up to several thousand people and frequently a mix of many different land uses to promote sustainable development.

153. 33 of the 45 areas have some form of identified tidal or fluvial flood risk, whilst surface water flooding is much more dispersed (**see Map 3**). **Table 2** provides an overview of the current flood risk from these sources (for clarity the surface water flood risk element is provided in red) for the individual major development locations, and therefore a flood risk framework for more detailed investigations at the level of the individual location. In terms of surface water flood risk these major development locations offer opportunities to divert surface water away from the existing drainage network into more sustainable rainwater use or disposal techniques. This is especially important in areas served by the combined sewer network, as the benefits will also reduce the costs of operating the sewerage system. Furthermore, if planned across large scale developments such measures can reduce development costs compared with the provision of conventional drainage infrastructure.

154. The presence of an element of flood risk is something that needs to be understood, planned and managed. Appropriate development can still come forward and may actually result in a reduction of flood risk both on site and for surrounding areas. A further consideration in these important locations is to ensure that critical infrastructure is either located away from flood risk areas or has a high standard of protection.

Table 2: Flood Risk in Major Development Locations

	Current flood risk characteristics	Potential flood risk mitigation measures
Opportunity Areas		
	Current Flood Risk Characteristics	**Future Flood Risk Considerations**
Bexley Riverside	Downstream of the Thames Barrier protected from storm surges by raised river walls. Contains several shipping-related industries requiring operational access to the river. Also contains parts of the Darent flood plain which is protected by tidal defences. There are some surface water flood risk areas particularly where there is a dominance of large impermeable areas. Some areas rely on pumped drainage.	Located in the Thamesmead and Dartford and Erith TE2100 policy units. Raising river walls and embankments required by 2040 for normal tides and tidal surges. Open spaces to be retained for potential flood storage and work to flood defences in future. Need to consider future of Darent Industrial Estate and potential use of Crayford Marshes for tidal storage. Outputs from the River Cray flood risk management asset study should be considered. Measures to reduce surface water run-off will be important. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve Greenfield run-off rates and reduce the current risks. Development close to the Thames can discharge directly to the river.
Bromley	Identified fluvial flood risks along river Ravensbourne to the west of town centre and a tributary watercourse running close to Bromley South Station. Surface water risks broadly follows fluvial floodplains with some areas at risk of deep surface water flooding in extreme events.	Set development back from rivers edge to enable a range of flood risk management options. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks. Given the identified flood risk the control of surface water is particularly important for the development of the area. It is also important to consider the role of multipurpose open spaces and additional drainage attenuation from large roof/hardstanding areas.
Canada Water	Intensively developed, protected from daily flooding by river walls and from tidal surges by the Thames Barrier. Relatively minor surface water flood risks focused on London Overground lines around Surrey Quays station and Rotherhithe Tunnel approach road.	Located in Wandsworth to Deptford TE2100 policy unit. Raising river walls required by 2065. Set development back from rivers edge to enable a range of flood risk management options. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks.

	Current flood risk characteristics	Potential flood risk mitigation measures
Charlton Riverside	Straddling the Thames Barrier, protected from storm surges by raised river walls but with land lying significantly below high tide levels. There are notable areas of surface water flood risk around Horn Lane, Westmoor –Eastmoor Streets and at the low point on Bugsbys Way under the freight rail bridge.	Located in the Greenwich TE2100 policy unit. Raising river walls and embankments required by 2065 for normal tides and tidal surges. Open spaces to be retained for potential flood storage and work to flood defences in future. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve Greenfield run-off rates and reduce the current risks. Development close to the Thames can discharge directly to the river.
City Fringe / Tech City	Intensively developed, protected from daily flooding by river walls and from tidal surges by the Thames Barrier. Relatively minor surface water flood risks, mainly focused on the public highway network and the sub surface National Rail lines north of Liverpool St Station.	Located in the London City TE2100 policy unit. Raising river walls required by 2065 for normal tides and tidal surges. Open spaces to be retained for potential flood storage and work to flood defences required in future. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks.
Colindale / Burnt Oak	Relatively small proportion of area within flood plain but contains Silk Stream, a River Brent tributary where localised flooding has been recorded. Some surface water flood risk areas notably along tributary river corridors, especially in the vicinity of Burnt Oak LU Station.	Set development back from rivers edge to enable a range of flood risk management options. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks.
Cricklewood / Brent Cross	Small proportion of area is within floodplain. Some local flood history on the River Brent. There are some surface water flood risk areas particularly along the River Brent corridor, the A406 where it passes under the A41, the A41 south of the A406, Cricklewood Lane near Crickelwood Station and around Prayle Grove.	Set development back from rivers edge to enable a range of flood risk management options. Investigate opportunities to restore culverted watercourses. New development is a good opportunity to introduce more sustainable rainwater management there should be good scope for sustainable drainage options to achieve greenfield run-off rates and reduce the current risks.
Croydon	Small area within flood plain of the River Wandle. Extensive areas of surface water flood risk along the route of the largely buried River Wandle. Drain London has funded an initial study into this risk area.	Investigate opportunities to reduce flood risk for the Caterham Bourne. Measures to reduce surface water run-off will be important. New development is a good opportunity to introduce more sustainable rainwater management there should be good scope for sustainable drainage options to achieve substantial reduction in run-off rates and reduce the current risks.

	Current flood risk characteristics	Potential flood risk mitigation measures
Deptford Creek / Greenwich Riverside	Intensively developed, protected from daily tidal flooding and fluvial flooding from the River Ravensbourne by river walls and from tidal surges by the Thames Barrier. Localised areas of surface water flood risk with some particular risk areas along the national rail lines through Greenwich Town Centre.	Located in the Greenwich and Wandsworth to Deptford TE2100 policy units. Raising river walls required by 2065, setting development back from rivers edge to enable a range of flood risk management options. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks. Development close to the Thames can discharge directly to the river.
Earls Court and West Kensington	Protected from storm surges by raised river walls. Documented surface water flood risk areas and known capacity problems in the Counters Creek catchment, below ground level London Overground and Underground rail lines at risk and areas close to large footprint buildings. It is notable that most older properties in the area have basements which will be at a higher risk of overflow from the highway network.	Located in the Hammersmith TE2100 policy unit. Need to consider the role of multipurpose open spaces for flood risk management and management of surface water. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks, as has been achieved at Westfield with substantial rainwater storage.
Elephant and Castle	Intensively developed, protected from daily flooding by river walls and from tidal surges by the Thames Barrier. Relatively minor surface water flood risk present focus on the public highway network.	Located in Wandsworth to Deptford TE2100 policy unit. Raising river walls required by 2065. Set development back from rivers edge to enable a range of flood risk management options. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks.
Euston	No flood plain identified. Relatively minor surface water flood risks, mainly focused on the public highway network with the exception of more significant risks to the sub surface National Rail lines north of Euston Station and Euston Rd underpass.	New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks.

	Current flood risk characteristics	Potential flood risk mitigation measures
Greenwich Peninsula	Intensively developed, protected from daily flooding by river walls and from tidal surges by the Thames Barrier. Contains many shipping related industries requiring operational access to river. There are likely to be some surface water flood risk areas particularly where there is a dominance of large impermeable areas and there is a particular risk to the Blackwall Tunnel approach road.	Located in Greenwich TE2100 policy unit. Raising river walls required by 2065. Set development back from rivers edge to enable a range of flood risk management options. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks, notably to the Blackwall Tunnel approach roads. Development close to the Thames can discharge directly to the river.
Harrow and Wealdstone	Small area located in the Wealdstone Brook floodplain. The Brook flows through the site in culvert. Some surface water flood risk areas particularly to the highway network including low lying parts of the High St, Masons Ave and around Kenmore Ave.	Set development back from culverts. Look at opportunities to reduce flood risk for the Wealdstone Brook. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a greenfield run-off rates and reduce the current risks.
Heathrow	Relatively small proportion of areas within fluvial flood risk zones. Relatively minor surface water flood risks, although potentially risks to sub surface roads/rail. Heathrow benefits from the presence of surface water balancing ponds.	Set development back from rivers edge to enable a range of flood risk management options. Need to consider the role of multipurpose open spaces for flood risk management and management of surface water. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve greenfield run-off rates and reduce the current risks.
Ilford	Very small proportion of area within River Roding flood plain. Relatively minor surface water flood risks, mainly focused on the public highway network with the exception of the Cranbrook corridor along parts of Northbrook Road and parts of the National Rail lines east of Ilford Station where risks are more significant.	Set development back from rivers edge to enable a range of flood risk management options. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks.
Isle of Dogs	Intensively developed, protected from daily flooding by river walls and from tidal surges by the Thames Barrier. Relatively minor surface water flood risks, mainly focused on the public highway network and around Westferry Circus.	Raising river walls beyond 2030. Set development back from rivers edge to enable a range of flood risk management options. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks. Development close to the Thames and docks can discharge directly to the river.

	Current flood risk characteristics	Potential flood risk mitigation measures
Kensal Canalside	No identified flood plain. Grand Union Canal runs alongside the site. Relatively minor surface water flood risks, mainly focused on the public highway network	Set development back from canal edge to enable a range of flood risk management options. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve greenfield run-off rates and reduce the current risks. Development close to the Grand Union Canal may be able to discharge directly to the canal.
Kings Cross – St Pancras	No flood plain identified. Grand Union Canal runs through the site. Relatively minor surface water flood risks, mainly focused on the public highway network and sub surface National Rail lines.	Set development back from canal edge. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks, in particular around mainline station.
Lewisham / Catford / New Cross	Located in the floodplains of the Ravensbourne, Quaggy and Thames rivers. Catford and Lewisham have the river Ravensbourne and its tributaries running through them with locally recorded flooding. Intensively developed area protected from daily tidal flooding by river walls and from tidal surges by the Thames Barrier. Extensive areas of surface water flood risk along the tributary rivers through Catford and Lewisham Town Centres, some of these areas are at risk of deep surface water flooding in extreme events.	Part of the Opportunity Area is located in the Wandsworth to Deptford and Greenwich TE2100 policy units. Defence raising required on the Thames frontage by 2065. Need to consider the role of multipurpose open spaces within the wider development areas. Development to be set back from river edges to enable a range of flood risk management measures. Safeguarding land potentially required for future flood risk management measures on fluvial watercourses. Comply with the recommendations of the River Ravensbourne river corridor improvement plan. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks. Given the spread and depth of flood risk the control of surface water within this area and its contributing catchment is particularly important.
London Bridge, Borough & Bankside	Intensively developed protected from daily flooding by river walls and from tidal surges by the Thames Barrier. Relatively minor surface water flood risks, mainly focused on the public highway network.	Located in Wandsworth to Deptford TE2100 policy unit. Raising river walls required by 2065. Set development back from rivers edge to enable a range of flood risk management options. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks. Development close to the Thames can discharge directly to the river.

	Current flood risk characteristics	Potential flood risk mitigation measures
London Riverside	Downstream of the Thames Barrier, protected from daily flooding and storm surges by raised river walls. Contains many shipping-related industries requiring operational access to river. Tributary rivers of Rainham Creek, Rom/Beam, Gores Brook and River Roding. Relatively few incidences of flooding in the past. Relatively minor surface water flood risks, mainly focused on the public highway network and around existing water features.	Located in Barking and Dagenham and Rainham Marshes TE2100 policy units. Raising river walls and embankments required by 2040 for normal tides and tidal surges. Open spaces to be retained for potential flood storage. Set development back from rivers edge to enable a range of flood risk management options. The area may have a role for strategic flood storage – notably when tributaries become tide locked. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve greenfield run-off rates and reduce current risks. Development close to the Thames can discharge directly to the river.
Lower Lee Valley, including Stratford	Intensively developed protected from daily tidal flooding and fluvial flooding by river walls and from tidal surges by the Thames Barrier. River Lee and various tributaries flow through the Opportunity Area. Some significant areas of surface water flood risk in Hackney Wick and Wick Road area, around Oliver Road, and on parts of the highway network including lower parts of the Blackwall A102M and A12 and parts of the Jubilee Line/DLR corridor between Stratford and Canning Town.	Located in Royal Docks and Isle of Dogs and Lee Valley TE2100 policy units. Raising river walls required by 2065. Set development back from rivers edge to enable a range of flood risk management options. Interaction of tidal and fluvial flood risk will need consideration. Comply with the Lower Lee Flood Risk Management Strategy recommendations. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve greenfield run-off rates especially in areas that contribute to identified risk areas and reduce those current risks. Development close to the tidal River Lee and Bow Creek can discharge directly to the river.
Old Kent Road	Intensively developed, protected from daily flooding by river walls and from tidal surges by the Thames Barrier. Mostly relatively minor surface water flood risks but more extensive risk areas in the eastern part of the area close to Ilderton Rd and just outside the Opportunity Area to the south of Old Kent Rd.	Located in Wandsworth to Deptford TE2100 policy unit. Raising river walls required by 2065. Set development back from rivers edge to enable a range of flood risk management options. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks both within and just outside the eastern edge of the Opportunity Area.
Old Oak Common	No flood plain identified, Grand Union Canal runs through the site. Surface water risks generally localised and small scale, although some rail cuttings and road underpasses identified as at risk.	Set development back from canal edge. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks.

	Current flood risk characteristics	Potential flood risk mitigation measures
Paddington	No flood plain identified. Grand Union Canal runs through the site. Relatively minor surface water flood risks. It is notable that most older properties in the area have basements which will be at a higher risk of overflow from the highway network.	Set back development from canal edge. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks, in particular around the main line station.
Park Royal	Only identified flood plain lies along the River Brent to the west of North Circular. Grand Union Canal runs through the site. Some areas of localised surface water flood risks focused in areas close to large footprint buildings, A406 underpasses and lower stretches of the rail network.	Set development back from river Brent and canal edges to enable a range of flood risk management options. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve greenfield run-off rates and reduce current risks. Development close to the Grand Union Canal may be able to discharge directly to the canal. It is also important to consider the role of multipurpose open spaces and additional drainage attenuation from large roof/hardstanding areas.
Royal Docks and Beckton Waterfront	Straddles the Thames Barrier so is partially protected from storm surges by the Barrier and by raised walls downstream. Various watercourses flow through the site. Relatively minor surface water flood risks, mainly focused on the public highway network including parts of North Woolwich Road and lower parts of Royal Albert Way and lowers DLR lines along Royal Albert Way.	Located in Royal Docks TE2100 policy unit. Raising river walls and embankments required by 2040 for normal tides and tidal surges. Open spaces to be retained for potential flood storage. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve greenfield run-off rates and reduce current risks. Development close to the Thames and docks can discharge directly to the river.
Southall	Close to flood plain of Yeading Brook. Grand Union Canal runs alongside the site. Relatively minor surface water flood risks, mainly focused on the public highway network.	Need to ensure that development does not increase flood risk. Set back development from canal edge. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve greenfield run-off rates and reduce current risks. Development close to the Grand Union Canal may be able to discharge directly to the canal.

	Current flood risk characteristics	Potential flood risk mitigation measures
Thamesmead and Abbey Wood	Within tidal Thames floodplain with large areas significantly below high tide level. Parts of the areas are dependent on pumping stations and storage reservoirs for continuous flood risk management. Various watercourses flow through the site. There are some surface water flood risk areas particularly where the National Rail line embankment acts as an informal flood barrier. There are surface water features within Thamesmead and some areas rely on pumped drainage.	Located in Thamesmead TE2100 policy unit. Raising river walls and embankments required by 2040 for normal tides and tidal surges. New development needs careful consideration, particularly of residual risks and emergency measures. Set development back from rivers edge to enable a range of flood risk management options. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks. Development close to the Thames can discharge directly to the river.
Tottenham Court Road	No floodplain identified. Relatively minor surface water flood risks. It is notable that most older properties in the area have basements which will be at a higher risk of overflow from the highway network.	New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks.
Upper Lee Valley	Includes extensive areas of Lee Valley floodplain. River Lee and tributaries flow through the area. Some notable surface water risk areas around Tottenham Hale and SW of Northumberland Park, Hall Lane and industrial estates close to the A406 and some low lying parts of the River Lee floodplain.	Set development back from rivers edge to enable a range of flood risk management options. Need to consider the role of multipurpose open spaces within the wider development area. Should be considered in association with measures across London's boundaries in Herts and Essex. Comply with the Lower Lee Flood Risk Management Strategy recommendations. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks. In areas close to the Lee Valley greenfield run-off rates should be achievable.

	Current flood risk characteristics	Potential flood risk mitigation measures
Vauxhall / Nine Elms / Battersea	Intensively developed, protected from daily flooding by river walls and from tidal surges by the Thames Barrier. Contains several shipping related industries requiring operational access to river. Relatively minor surface water flood risks, mainly focused on the public highway network with the exception of more significant risks on streets to the north west of Wandsworth Road. The access road into New Covent Garden under the railway lines is shown at particular risk and should be investigated.	Located in Wandsworth to Deptford TE2100 policy unit. Raising river walls required by 2065, setting development back from rivers edge. Climate change is expected to increase the residual risks posed by breaches in the tidal defences and it is important that developments take account of this residual risk when considering the safety of proposed developments. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve greenfield run-off rates and reduce the current risks. Development close to the Thames can discharge directly to the river. See also the Water Strategy of the Opportunity Area Planning Framework - Technical Appendix 7.
Victoria	Intensively developed protected from daily flooding by river walls and from tidal surges by the Thames Barrier. Relatively minor surface water flood risks, mainly focused on the public highway network and the National Rail lines into Victoria Station. It is also notable that most older properties in the area have basements which will be at a higher risk of overflow from the highway network.	Located in London City TE2100 policy unit. Raising river walls required by 2065 on river frontage section. Set development back from rivers edge to enable a range of flood risk management options. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks, in particular around mainline station.
Waterloo	Intensively developed, protected from daily flooding by river walls and from tidal surges by the Thames Barrier. Relatively minor surface water flood risks, mainly focused on the public highway network with a concentration around Waterloo Station.	Located in Wandsworth to Deptford TE2100 policy unit. Raising river walls required by 2065. Set development back from rivers edge to enable a range of flood risk management options. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks, in particular around mainline station. Development close to the Thames can discharge directly to the river.
Wembley	Relatively small proportion of area within flood risk zones. River Brent flows through the area. Relatively minor surface water flood risks focused on the Wealdstone Brook corridor and areas close to large footprint buildings.	Set development back from rivers edge to enable a range of flood risk management options. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve greenfield run-off rates and reduce current risks. It is also important to consider the role of multipurpose open spaces and additional drainage attenuation from large roof/hardstanding areas.

	Current flood risk characteristics	Potential flood risk mitigation measures
White City	Very small area of River Thames tidal floodplain. Documented surface water flood risk areas and known capacity problems in the Counters Creek catchment, below ground level London Overground and Underground rail lines at risk.	Located partially within Hammersmith TE2100 policy unit. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks, as has been achieved at Westfield with substantial rainwater storage. It is also important to consider the role of multipurpose open spaces and additional drainage attenuation from large roof/hardstanding areas.
Woolwich	Downstream of the Thames Barrier, protected from storm surges by raised river walls but with land lying significantly below high tide levels. Some parts of Woolwich Town Centre, notably the national rail lines are at risk of surface water flooding with flows running off the ridgeline to the south.	Located in Thamesmead TE2100 policy unit. Raising river walls and embankments required by 2040 for normal tides and tidal surges. Open spaces to be retained for potential flood storage. Set development back from rivers edge to enable a range of flood risk management options. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks.
Intensification Area		
	Current flood risk characteristics	**Future flood risk considerations**
Farringdon / Smithfield	No floodplain identified. Some localised surface water flood risks that should be investigated in more detail at a site specific level. Other risk areas focused on the below ground level LU and National Rail lines around Farringdon Station and the lower sections of Farringdon Ave around Holborn Viaduct.	New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks.
Haringey Heartlands / Wood Green	No flood plain identified, although includes upper reaches of Moselle brook in culvert. Relatively minor surface water flood risks, mainly focused on the public highway network with higher risk areas to the west of the National Rail lines.	Set development back from culverts. Look at opportunities to reduce flood risk for the Moselle Brook. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks and in particular the discharge to the Moselle Brook.

	Current flood risk characteristics	Potential flood risk mitigation measures
Holborn	No floodplain identified. Regent's Canal culverted watercourse flows through the site. Some localised surface water flood risks that should be investigated in more detail at a site specific level.	Set development back from culverts. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks and in particular the discharge to Wealdstone Brook.
Kidbrooke	Substantial area within the River Quaggy and Kid Brook floodplains. Some surface water flood risk areas mainly focused on the highway network. Sutcliffe Park acts as a flood storage area.	Need to consider the role of multipurpose open spaces within the wider development area. Setting development back from rivers edge to enable a range of flood risk management options. Measures to reduce surface water run-off will be particularly important. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a greenfield run-off rates and reduce the current risks elsewhere in the catchment such as at Lewisham.
Mill Hill East	No floodplain identified. Relatively minor surface water flood risks, mainly focused on the public highway network and the Dollis Brook corridor to the south east is a notable flood risk area.	Measures to reduce surface water run-off will be particularly important. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a greenfield run-off rates and reduce the current risks.
South Wimbledon / Colliers Wood	Substantial proportion of area is within the Wandle Valley floodplain. Some localised surface water flood risks that should be investigated in more detail at a site specific level and general risk areas along the route of the River Wandle.	Set development back from rivers edge to enable a range of flood risk management options. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks.
West Hampstead Interchange	No floodplain identified. Relatively minor surface water flood risks, mainly focused on the public highway network with the exception of some more significant risks to low lying parts of the rail network.	Measures to reduce surface water run-off will be important. New development is a good opportunity to introduce more sustainable rainwater management and should readily be able to achieve a substantial reduction on current run-off rates and reduce the current risks.

Town Centres and the Central Activities Zone

155. Intensification of development at Town Centre locations is generally sustainable, given the high levels of public transport accessibility and concentration of facilities. New development will still need to be accompanied by a Flood Risk Assessment where required as set out in the NPPF.

156. Given that development at town centres tends to be high density there are likely to be high run-off rates and limited scope for floodwater or rainwater attenuation in the immediate vicinity. In addition, many new developments will come forward in a piecemeal manner. Therefore, surface water management in constrained town centre sites needs to be considered particularly early in the design process so it can be satisfactorily accommodated and managed. **Map 4** illustrates the location of tidal/fluvial and surface water flood risk of the Metropolitan (18%) and Major Town Centre (28%) areas, and **Table 3** provides an overview of the current flood risk in the individual Town Centres.

157. The Central Activities Zone (CAZ), which includes both the West End and Knightsbridge International Town Centres as well as a number of Opportunity Areas and Areas of Intensification, is at risk of tidal flooding from the Thames, which flows through the CAZ. Flood risk to the south of the Thames and in particular in the Pimlico/Victoria area is quite extensive. However, the area is defended to a very high standard by a combination of the Thames Barrier and the Thames tidal flood defences. Particular attention should nevertheless be paid to the layout and design of development close to the River itself in order to allow for the appropriate maintenance and potential upgrade of the flood walls. Setting development back from the existing walls will generally be desirable in order to enable a range of flood risk management options. Consideration should also be given to the residual risk should the defences fail or be breached. This includes locating significant infrastructure and more vulnerable types of development in areas at lowest risk or implementing flood resilience measures. In addition developments with basements should consider the safety, continuity of services and recovery from a flood, should one occur.

158. Surface water flood risks are relatively minor for the majority of the CAZ but particular attention should be paid to flood risk management for any specific low lying areas and to buildings with basements. Sustainable Drainage techniques should be delivered wherever is reasonably practical and there is increasing evidence of such techniques being implemented in high density CAZ locations to achieve significant reductions in rainwater discharge rates. Green roofs and rainwater harvesting systems can be economically viable for commercial and even residential development within the CAZ. Locations close to the Thames may be able to discharge clean rainwater direct to the Thames without the need for any other attenuation measures.

Table 3: Flood Risk in Town Centres

Metropolitan centres	
	Flood Risk Issues
Bromley	Small proportion within the River Ravensbourne flood plain and significant surface water risk areas co-inciding with the Ravensbourne floodplain and flowpath from the east passing under Bromley South station
Croydon	Partially within the River Wandle flood plain and close to culverted sections of the river and significant surface water risk areas co-inciding with the former course of the River Wandle
Ealing	No identified fluvial flood risk issues but surface water flood risk areas have been identified along rail lines
Harrow	No identified fluvial flood risk issues but surface water flood risk areas have been identified along rail lines
Hounslow	No identified fluvial flood risk issues but some surface water flood risk areas have been identified close to LU rail lines

Ilford	Small proportion within the River Roding flood plain and some relatively minor surface water risks affecting rail lines to the east of the town centre and Northbrook Road to the north
Kingston	Substantially within the flood plains of the River Thames and the Hogsmill River and some localised areas of surface water flood risk
Romford	Partially within the River Rom flood plain, river flows through the Town Centre in a culvert and significant surface water risks following the river Rom and River Ravensbourne corridors through the Town Centre
Stratford	Partially within the River Lee flood plain, and some localised surface water risk areas mainly affecting below ground level rail corridors
Shepherd Bush	Small proportion within the River Thames flood plain. Some localised areas of surface water risk identified, notably along rail lines and in the vicinity of Tadmor St.
Sutton	No identified fluvial flood risk issues but surface water flood risk on flow path from the south west with risk areas to the south of the station and on Langley Park Rd under rail lines
Uxbridge	Small proportion within the floodplains of the Frays River, River Colne and Grand Union Canal which flow through the Town Centre. Some localised areas of surface water risk identified, notably along rail lines just outside Station
Major centres	
	Flood Risk Issues
Angel	Culverted watercourses flow through the Town Centre. No identified fluvial flood risk issues but some localised surface water risks.
Barking	No identified fluvial flood risk issues, but some localised surface water risks
Bexleyheath	No identified fluvial flood risk issues, but some localised surface water risks to the west of the town centre
Brixton	Significant surface water flood risk identified through the town centre along the course of the Lost River Effra and continuing north along Brixton Road
Camden Town	Grand Union Canal flows through the Town Centre. No identified fluvial flood risk issues but some localised surface water risks.
Canary Wharf	Wholly within the Thames tidal flood plain but protected by the Thames tidal defences
Catford	Partially within floodplain of the River Ravensbourne with significant areas of surface water risk along the the Ravensbourne corridor
Chiswick	Wholly within the River Thames flood plain - both tidal and fluvial flood risk and some localised surface water risk areas
Clapham Junction	Small proportion within the River Thames flood plain and significant surface water flood risk identified through the town centre along Northcote Rd, St Johns Rd, under railway and affecting a large area to the north of rail lines
Dalston	No identified fluvial flood risk issues, but some localised surface water risks, notably the sub-surface London Overground rail lines
East Ham	No identified flood risk issues
Edgware	Partially within the Silk Stream flood plain with some significant surface water risk areas following the corridors of small local tributary rivers
Eltham	No identified fluvial flood risk issues, but some surface water risks around Well Hall Parade and risks to the A2 below the town centre
Enfield Town	No identified fluvial flood risk issues, but surface water flood risks under investigation through Drain London and LB Enfield project
Fulham	Wholly within the Thames tidal flood plain but protected by the Thames tidal defences, some localised surface water risks
Hammersmith	Almost entirely within the Thames tidal flood plain but protected by the Thames tidal defences, some areas of surface water flood risk, notably on roads under rail to the north of King St.
Kensington High Street	No identified flood risk issues

Kilburn	No identified fluvial flood risk issues, but some localised surface water risks, mainly affecting public highway
Kings Road East	Small proportion within the River Thames flood plain
Lewisham	Substantially within the floodplains of the Rivers Ravensbourne and Quaggy with significant areas of surface water risk along the floodplains
Nags Head	No identified fluvial flood risk issues, but some localised surface water risk areas
Orpington	Significantly within the River Cray flood plain with extensive surface water flood risk areas along Sevenoaks Rd- Orpington High St corridor
Queensway/Westbourne Grove	No identified fluvial flood risk issues, but some localised surface water flood risk areas, notably affecting basements
Peckham	No identified fluvial flood risk issues, but some significant surface water risks, notably to the east of the town centre along the Copeland Rd-Clayton Rd corridor
Putney	Small proportion within the Thames tidal flood plain but protected by Thames Tidal Defences including the Thames Barrier
Richmond	Small proportion within the Thames flood plain, some localised surface water risk areas around The Quadrant and affecting the sub surface rail station
Southall	No identified fluvial flood risk issues, but some localised surface water risk areas
Streatham	No identified fluvial flood risk issues, but a significant area of surface water flood risk to the north east of Streatham Station
Tooting	No identified fluvial flood risk issues, but some localised surface water risks, possibly focused on the route of the River Graveney
Walthamstow	No identified fluvial flood risk issues, but some localised surface water flood risk areas
Wandsworth	Significantly within the tidal Thames and River Wandle flood plains and the River Wandle flows through the Town Centre and some significant surface water risk areas focused on the Wandle Floodplain and roads passing under the railway
Wembley	No identified fluvial flood risk issues. Wembley Brook flows in a culvert under part of the Town Centre and some localised surface water risks notably to the east of Lancelot Rd
Wimbledon	No identified fluvial flood risk issues, but some risks to below ground level railway
Woolwich	Partially within the River Thames flood plain and some significant surface water risk areas

Recommendation 10
Detailed flood risk assessments should be undertaken at an early stage at the level of individual major development locations and town centre development sites, and opportunities to reduce flood risk should be maximised where possible.

3.3 Main Rail Network and Major Stations

159. **Map 5** shows that there are a total of 76 mainline stations and 217 km of mainline rail corridor at risk of tidal/fluvial and/or surface water flooding[10]. This represents 23% of London's stations and 27% of its rail corridor. A key issue will also be the vulnerability of power supplies, signalling and communications equipment to flood risk.

160. Rail lines cross rivers on bridges, viaducts and embankments meaning that the route is generally at low flood risk. This is demonstrated with the elevated rail lines

[10] Total figures for rail lines and stations are based on the Ordinance Survey's Meridian dataset, 2013.

through London Bridge and into Waterloo, Blackfriars and Victoria. Many stations are also on elevated sections of track and therefore at lower risk. The rail lines into Liverpool Street and Stratford along the Lee Valley and the c2c lines east of Barking travel through the River Lee and Thames floodplains respectively often at ground level. These lines can be expected to have a higher level of flood risk.

161. The High Speed 1 Rail Link is substantially in tunnel through the flood plains of the tidal Thames and River Lee and parts of the line is at ground level and elevated through tidal flood risk zones in the Dagenham and Rainham areas. It is understood that the tunnel portals have been built to a very high standard of flood protection.

162. Surface water is responsible for over half of the rail line and station flood risk. Appropriate mitigation measures include flood warning and emergency procedures. Rail services within cuttings or stations with large roof areas may be at particular risk from surface water flooding during heavy storms and these are set to increase. Measures to store or disperse rainwater from heavy storms are therefore particularly important.

3.4 London Underground & DLR Networks

163. **Map 6** shows that 30% of the London Underground and DLR stations and 27% of the lines are at risk of tidal/fluvial and/or surface water flooding[11]. The majority of these are within the tidal Thames floodplain through central London. The stations on the DLR branch to Stratford and Jubilee line from Stratford to Canning town are also within the River Lee Fluvial floodplain, although most of the DLR network at flood risk is elevated on raised tracks. There are also some outlying stations and tracks which are in the flood plain and/or at risk of surface water flooding. However, notable sections of the tube network are also on raised tracks including for example parts of the District Line (Hammersmith to Acton, Putney Bridge to Wimbledon, around West Ham) as well as Outer London parts of the Central, Piccadilly, Northern and Metropolitan Line.

164. Flood water getting into underground stations presents a particular hazard and a major engineering problem if the flood waters were to enter tube tunnels. This risk is extended geographically as tunnel portals could act as a conveyance route for flood water from a wide variety of locations, especially in the event of a tidal flood. The tube and DLR lines listed in **Table 4** have tunnel portals within floodplains:

Table 4: Tunnel Portals in Floodplain

Tube Line	Tunnel Portal	Flood plain
Central Line	Eastern Portal	River Lee
London Overground	Southern Portal	Tidal Thames
Jubilee Line	Eastern Portal	Tidal Thames
Victoria Line	Northern Portal	River Lee
DLR Lewisham branch	Thames Tunnel both portals	Tidal Thames
DLR Woolwich branch	Thames tunnel both portals	Tidal Thames

165. It is acknowledged that the underground location of stations and tracks means that the flood risk may not necessarily be highest in the corresponding overground

[11] Total figure for lines and stations are based on TfL and GLA data.

flood risk areas. This is why the portals are highlighted, and there may also be other potential flood routes including emergency access points and ventilation shafts.

166. Risk management measures could include physical barriers (e.g. flood gates, vent covers); flood warning systems; the relocation of sensitive equipment (e.g. electrical/telecommunications equipment); or the provision of sump areas to facilitate that flood water can be pumped out after the event. London Underground is currently undertaking a review of flood risk from all sources that may affect its lines, stations, depots and other infrastructure. Its outcomes are expected to be available in 2015.

3.5 Main Road Network and Airports

167. The road network is a critical element of London's infrastructure. The bus network transports around 6 million people per day[12] and much of the network is heavily used by private passenger and goods vehicles. The road network is also of critical importance to emergency services. The road network is managed by a combination of the Highways Agency for motorways and some trunk roads, TfL for the Transport for London road network (TLRN) and local boroughs for local roads. The density of the road network in London is likely to mean that alternative routes will be available in localised flood situations. However the volume of traffic is likely to lead to significant congestion.

168. This RFRA has made an initial scoping of locations on the TLRN where flooding may present a potential risk. **Map 7** shows that 26% of the TLRN are at risk, the majority of which is in the tidal floodplain. However, some important road sections including parts of the A13 and the North Circular are elevated, and TfL has a pro-active monitoring programme of its network to report on flooding incidents, assess risks and implement remedial measures. In terms of surface water flood risk Drain London is investigating several high risk sections of the highway network, notably underpasses on the TLRN. TfL will then be encouraged to investigate other specific risk areas.

169. Tunnels under the Thames have a particular risk as their portals are all within the tidal Thames flood plain. In a similar way to tube tunnels, ventilation shafts or emergency shafts may also present potential routes for the conveyance of flood water. Other underpasses are low points within the network and are more likely to be at risk of surface water flooding although a few are also within a flood zone.

Subterranean river crossings (road and pedestrian)
Rotherhithe Tunnel
Limehouse Link Tunnel
Greenwich Foot Tunnel
Blackwall Tunnel x2
Woolwich Foot Tunnel
Proposed: Silvertown Crossing

Road Underpasses
A501 Euston Road
A406 Edmonton – River Lee Floodplain
A406 Stonebridge Park

[12] http://www.tfl.gov.uk/corporate/modesoftransport/1548.aspx

A406 Crooked Billet
A12 Wanstead/Green Man junction
A102/A11 Bow – River Lee Floodplain
A13 Movers Lane – River Thames Floodplain
A113/A1400 Charlie Browns Roundabout – River Roding Floodplain
A4088 Neasden Lane /A406 underpass
A4 Hyde Park Corner underpass
A214 Trinity Road/East Hill Underpass
A3 Tibbetts Corner underpass
A3 Tolworth Underpass
A3 Hook Road underpass
Heathrow Access Road

170. Highways flood management measures could include the provision of pumping stations – they already exist for most underpasses – and possible improvements to their flood resilience (e.g. back-up power supply) as well as flood warning systems and diversionary routes.

Bus Depots

171. There are 76 bus garages[13] serving London's bus operators. Some of these are within flood risk areas. A flood affecting a garage may have the direct impact of making buses unusable or may have other indirect impacts for example the loss of electricity supply rendering fuel pumps inactive or employees who are unable to reach work.

172. Bus depot flood management measures could include green roofs, attenuation measures, flood warning systems, as well as locating vulnerable equipment and potentially polluting materials (e.g. fuel and oils) above potential flood levels. There are good practice examples of green roofs at bus depots, such as at West Ham, where also rainwater is captured for use in vehicle washing.

Airports

173. Heathrow Airport is largely free from flood risk, although some of the peripheral areas to the west of the airport could be affected by large floods on the River Colne system. The airport has large surface water attenuation areas.

174. London City Airport is wholly within the floodplain of the tidal Thames. It is in an area that is close to the Thames Barrier. It is protected by the existing flood defences to a standard of at least 1 in 1000 years.

Recommendation 11
Relevant transport authorities and operators should examine and regularly review their infrastructure including their networks, stations, depots, underpasses and tunnels for potential flooding locations and flood risk reduction measures. For large stations and depots, solutions should be sought to store or disperse rainwater from heavy storms.

[13] http://londonbusesbyadam.zenfolio.com/london-bus-garages

3.6 Emergency Services

175. The London Resilience Partnership has published in May 2012 its London Strategic Flood Framework. It is important for emergency services to remain operable during major flood events. Localised flooding events should be able to be managed by other supporting emergency services. Major flood events affecting either the tidal Thames or the major tributaries will need consideration and co-operation between several services. This RFRA has carried out an initial examination to identify whether there are any potentially vulnerable concentrations of emergency service facilities within flood risk areas.

Main Hospitals

176. NHS London data from May 2012 were used[14] as basis for the investigation of main hospitals. There are 15 hospitals at risk of tidal/fluvial and/or surface water flood risk, see **Map 8**. The 8 hospitals in a flood zone are all upstream of the Thames Barrier and therefore protected to a high standard in particular from tidal flooding. 4 of these hospitals are in the floodplains of tributary rivers.

177. 12 hospitals are at risk of surface water flooding. 5 of them are also at risk of fluvial/tidal flooding. Drain London has commissioned more detailed reviews. This work is currently on-going but initial results indicate that they are generally able to manage their risks at an acceptable level. For Edgware Hospital a detailed flood risk assessment has already been undertaken and mitigation works necessary to ensure that the hospital can continue to operate in the event of a flood on the Silk Stream have been identified.

Fire Stations

178. Fire stations are likely to be important bases during flood events. **Map 9** indicates that 26 fire stations from a total of 112[15] within London (23%) are at risk of fluvial/tidal and/or surface water flooding. The majority of these are in central/inner London Thames tidal floodplain and as such have a high degree of flood protection in particular from tidal flooding. They are also generally well covered by other fire stations just outside the flood zone.

179. Drain London has identified 8 fire stations at risk of surface water flooding and has commissioned more detailed reviews of those stations and their risks. The work is currently on-going and the results will be shared with London Fire Brigade.

Ambulance Stations

180. **Map 9** also indicates that 13 of London's 70[16] ambulance stations (19%) are at risk of fluvial/tidal and/or surface water flooding. The significant majority of these are in central/inner London Thames tidal floodplain and as such have a high degree of flood protection in particular from tidal flooding. They are also generally well covered by other ambulance stations just outside the flood zone.

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[14] 'Walk in Centres' and 'Minor Injury Units' were excluded. The total number of hospitals is with 86 instead of 112 lower compared to the 2009 RFRA.

[15] Data source – London Fire Brigade

[16] Data source updated with London Ambulance Service, July 2013 - total of 63 stations only in 2009 RFRA.

181. Drain London is currently considering whether to commission more detailed reviews of those stations specifically at risk of surface water flooding.

Police Stations

182. **Map 9** also indicates that 23 of London's 167[17] police stations (14%) are at risk of fluvial/tidal and/or surface water flooding. The majority of these are again in central/inner London Thames tidal flood plain and as such have a high degree of flood protection in particular from tidal flooding. They are also generally well covered by other police stations just outside the flood zone. The Metropolitan Police Service is in the process of re-organising their estate through their Estate Strategy 2010 - 2014. This is likely to mean that some back office functions will be moved away from traditional police stations. Care will be needed to ensure that this does not reduce the resilience of the service through a lack of back-up options that are at low flood risk.

183. Drain London is currently considering whether to commission more detailed reviews of those stations specifically at risk of surface water flooding.

Prisons

184. London has 9 prisons/detention centres. Only the collocated prisons Belmarsh, Isis and Thameside in Greenwich are at risk of flooding. They are within the tidal Thames floodplain but currently protected to a standard of 1 in 1000 years by the existing flood defences. Nevertheless, this presents particular challenges in the event of a flood as issues of safety and security will arise. Therefore, detailed emergency plans should be in place for the event of a flood.

Recommendation 12
Emergency service authorities and operators covering hospitals, ambulance, fire and police stations as well as prisons should ensure that emergency plans in particular for facilities in flood risk areas are in place and regularly reviewed so that they can cope in the event of a major flood. These plans should put in place cover arrangements through other suitable facilities.

3.7 Schools

185. Schools need to serve their local population. **Map 10** indicates that 445 of London's 3,143[18] schools (14%) are either wholly or partially at risk of fluvial/tidal and/or surface water flooding, although for some of them it may only be to a minor extent, for example within playing fields. The majority of schools affected are in central/inner London part of the Thames tidal floodplain and as such have a high degree of flood protection. However, a flood would represent a direct risk to the pupils and staff at schools and would cause longer-term disruption whilst any repairs are made. The analysis has examined public sector and private schools, further and higher

[17] Figure updated by Metropolitan Police Service in April 2013 (includes premises open to the public including Front Counters and Contact Points – total significantly lower than 2009 RFRA figure of 215
[18] 'Edubase' database (Department of Education), Sept 2013 – total figure included in the 2009 RFRA was lower with 3,064 schools.

education facilities, but not pre-schools and nurseries. Free schools represent the most significant addition to the total number of schools included in the 2009 RFRA.

186. Schools are also important in terms of managing civil emergencies as they are often used as emergency shelter, food and supply bases. If the emergency is a flood, then this may mean that the school cannot fulfil this function.

187. Drain London has examined secondary schools across London and has identified 21 secondary schools at highest risk of surface water flooding and has commissioned more detailed reviews of those schools and their risks. The work is currently on-going and will be shared with the schools/local education authorities.

Recommendation 13
Education authorities should ensure that emergency plans in particular for facilities in flood risk areas are in place and regularly reviewed so that they can cope in the event of a major flood. These plans should put in place cover arrangements through other suitable facilities.

3.8 Utilities

188. This section covers a wide range of utility installations. **Appendix 3** provides an overview of known installations over 1000m^2 and related to energy, water and waste management as well as telecommunications that are at risk from fluvial/tidal flooding. This should serve as a resource and initial input for the London boroughs to pursue their own investigations into flood risk of their most important utilities. **Map 11** provides a spatial overview showing 448 sites at risk of flooding. As the underlying data set is not up-to-date, this will require further investigation as part of the next review.

Major Electrical Installations

189. Many power generation plants are located near rivers or the sea as they require large volumes of water for cooling purposes. Therefore they have an associated flood risk. Most of London's electricity supply is generated outside London and transmitted to London via high voltage power lines, either on pylons or underground. London does have some energy generation capability and also has many switching and transformer stations. Major installations are listed in **Table 5**.

Table 5: Electrical Installations in Floodplain

Installation	Flood Risk Zone
Brimsdown Power Station	Adjacent to River Lee floodplain
Barking Power Station	Wholly within the Thames Tidal flood plain
Greenwich Power Station	Wholly within the Thames Tidal flood plain
Park Royal Power Station	Not within a flood zone
Hayes Power Station	Not within a flood zone
City Road Switching Station	Not within a flood zone
St Johns Wood Switching Station	Not within a flood zone
Croydon/Beddington Switching Station	Partially within River Wandle floodplain
Edmonton Waste to Energy	Wholly within River Lee floodplain
SELCHP Waste to Energy	Wholly within the Thames Tidal flood plain
Belvedere Waste to Energy	Wholly within the Thames Tidal flood plain

Major Gas Installations

190. Gasholders and pipelines are unlikely to be directly affected by a flood given that they are gas tight containers and therefore will not let water in. However, in the unlikely event of water entering a gasholder, drying it out again is a difficult and costly process. There may also be issues around ancillary power and access to gas sites.

Water and Sewage Treatment Plants

191. The nature of water and sewage treatment plants is that they are located close to major rivers in order to abstract water from them and discharge sewage effluent to them. It is therefore to be expected that these plants will have a certain level of flood risk.

192. A significant flood at a water treatment plant could result in the contamination of drinking water supplies by flood water. This risk may trigger the shutting down of the plant. The operation of the plant may also be affected by ancillary power losses. However, the London Ring Main means that water supplies can be flexibly managed and supplies derived from several works, and given the geographical spread of the works as listed in **Table 6** they are unlikely all to be affected by one flood. In addition, the four water companies supplying London with drinking water all have operational plans to cope with flooding.

Table 6: Water Treatment Plants in Floodplain

Water treatment plant	Flood Risk Zone
Hampton	Substantially within River Thames floodplain
Coppermills	Partially within River Lee floodplain
Hornsey	Not within a flood zone
Walton (outside London but supplying parts of London)	Partially within River Thames floodplain
Chigwell (outside London but supplying parts of London)	Not within a flood zone

193. Thames Water operates all the sewage treatment works included in **Table 7** and has operational plans to cope with flooding. A significant flood at a sewage treatment plant could result in the contamination of rivers and land as the flood spreads untreated or partially treated sewage and effluent from the works. The operation of the works may also be affected by ancillary power losses.

Table 7: Sewage Treatment Plants in Floodplain

Sewage Works	Flood Risk Zone
Beckton	Wholly within the Thames Tidal flood plain
Crossness	Wholly within the Thames Tidal flood plain
Mogden	Not within a flood zone
Riverside	Wholly within the Thames Tidal flood plain
Deephams	Substantially within River Lee floodplain
Beddington Farm	Partially within River Wandle floodplain
Hogsmill	Substantially within Hogsmill Brook floodplain

Sewage Works	Flood Risk Zone
Luxborough Lane (outside London but treats sewage from parts of London)	Wholly within River Roding floodplain
Long Reach (outside London but treats sewage from parts of London)	Wholly within the Thames Tidal flood plain

194. In addition to the listed water treatment and sewage works there may also be pumping stations and other installations that relate to water infrastructure (see **Appendix 3**). There are also a number of pumping stations to manage surface water. These are particularly relevant to low lying areas such as Thamesmead.

Waste Management Sites

195. Waste management sites are also included in **Appendix 3**. In addition, waste licencing data from the Environment Agency have been used to generate a more specific overview of the scale of flood risk of waste sites (see **Table 8**). The 105 sites specifically identified by the Environment Agency for this purpose include operational treatment plants plus a selection of other types of sites such as transfer stations and metal recovery facilities. Almost half of the sites are at risk of flooding, and appropriate mitigation measures include flood warning and emergency procedures.

Table 8: Waste Sites in Flood Risk Areas

Flood area	Number in Flood area	Number Outside Flood area	Total Number in Greater London	Portion in Flood area
EA flood zone 2&3	45	60	105	43%
Drain London > 0.3m	10	95	105	10%
Combined flood area	49	56	105	47%

Recommendation 14
Operators of electricity, gas, water, sewerage, and waste utility sites should maintain an up to date assessment of the flood risk to their installations and, considering the likely impacts of failure, establish any necessary protection measures including secondary flood defences.

3.9 Other Sites

196. This RFRA is not intended to provide a comprehensive list of all vulnerable infrastructure. Some of the other vulnerable land uses include nursing homes where the safety and ability to evacuate residents may be difficult and council/benefits offices where closure would have an immediate impact on the welfare of local communities, particularly the most vulnerable. COMAH sites, petrol stations and other sources of pollution are also particular risks as flood water may liberate and spread polluting and/or dangerous substances that will have further impacts over and above the physical impacts of the flood waters.

Chapter 4 – Conclusions and Look Ahead

197. Flood Risk is a serious consideration for London. It is important that London's future is planned for and delivered in the fullest knowledge of flood risk and how it is likely to change in future. That knowledge is advancing rapidly and it will be important to keep this RFRA under regular review.

198. This RFRA demonstrates that with the continued spatial focus on urban concentration flood risk in London is not expected to increase significantly as a consequence of the anticipated levels of growth. The better understanding of surface water flood risk gained since 2009 provides a more robust baseline and opportunity to better monitor and manage flood risk from key sources of flooding.

199. The application of the relevant London Plan policies – in particular Policies 5.12 and 5.13 – will be required to sustainably manage flood risk through new development. New development represents one of the key opportunities to reduce overall flood risk, notably through improved management of surface water and allowing space for future maintenance and upgrade of flood defences. The planning of the major development locations and town centres, where the majority of the anticipated growth will be located, which increases the potential consequences of flood events, will have to address flood risk in more detail. This RFRA provides an updated overview of broad flood risk issues in each of these locations and a framework of potential mitigation measures on which the relevant partners can build locally. In terms of flood risk for London's key infrastructure and services this RFRA illustrates these risks spatially and identifies mechanisms to investigate, monitor and address flood risk of current and new infrastructure and services in cooperation with relevant partners.

200. This RFRA includes a revised set of monitoring recommendations, which will be used to keep the information up-to-date and to ensure regular checks on broad mitigation measures. This will also help to focus attention on the strategic issues relating to flood risk in London. Progress against the recommendations will continue to be monitored annually in the London Plan Annual Monitoring Report. Since the publication of the 2009 RFRA progress against the original recommendations reflects in particular the actions of Drain London in terms of the improved understanding of surface water flood risk. It also confirms the improvements to local flood risk policies based on completed Strategic Flood Risk Assessments (SFRAs).

201. Finally, it should be noted that the Mayor has recently published a long-term London Infrastructure Plan 2050 for consultation. It addresses a wide range of infrastructure needs and challenges for London including drainage and flood risk. It highlights, for example, the emerging Sustainable Drainage Action Plan and promotes the idea of long-term (25 years) climate resilient, multi-source, flood risk management and investment plans for each of London's catchments covering all sources of flooding. The Environment Agency would work through seven strategic Flood Risk Partnerships in London to develop and monitor this long-term plan. It would integrate the actions identified in the boroughs', water companies' and GLA's flood risk and water management plans. It would also identify synergies with planning policy, regeneration and redevelopment[19].

[19] The draft London Infrastructure Plan 2050 and its background documents are available via http://www.london.gov.uk/priorities/business-economy/vision-and-strategy/infrastructure-plan-2050

202. Appendix 1

List of Monitoring Recommendations

Recommendation 1
All Thames-side planning authorities should consider in their SFRAs and put in place Local Plan policies to promote the setting back of development from the edge of the Thames and tidal tributaries to enable sustainable and cost effective upgrade of river walls/embankments in line with Policy 5.12, CFMPs, TE2100 and advice from the Environment Agency.

Recommendation 2
The London Boroughs of Richmond, Kingston, Hounslow and Wandsworth should put in place policies to ensure alternative responses to managing fluvial risk such as flood resilience measures (e.g. flood gates) or potentially safeguarding land for future flood storage or, on the fluvial tributaries, setting back local defences or any resilience measures between Teddington Lock and Hammersmith Bridge in line with TE2100 findings.

Recommendation 3
The London Boroughs of Newham and Greenwich should work with the Environment Agency on issues such as the potential safeguarding of potential land needs around the existing Thames Barrier, and the London Borough of Bexley should work with the Environment Agency on future flood risk management options in line with TE2100 findings.

Recommendation 4
Boroughs at confluences of tributary rivers with the River Thames should ensure Flood Risk Assessments (FRAs) include an assessment of the interaction of all forms of flooding, but fluvial and tidal flood risks in particular. These are the London Boroughs of Havering, Barking & Dagenham, Newham, Tower Hamlets, Greenwich, Lewisham, Wandsworth, Hounslow, Richmond and Kingston.

Recommendation 5
Regeneration and redevelopment of London's fluvial river corridors offer a crucial opportunity to reduce flood risk. SFRAs and policies should focus on making the most of this opportunity through appropriate location, layout and design of development as set out in the Thames CFMP. In particular opportunities should be sought to:

- Set back development from the river edge to enable sustainable and cost effective flood risk management options
- Ensure that developments at residual flood risk are designed to be flood compatible and/or flood resilient
- Maximise the use of open spaces within developments which have a residual flood risk to make space for flood water.

Recommendation 6
Developments all across London should reduce surface water discharge in line with the Sustainable Drainage Hierarchy set out in Policy 5.13 of the London Plan, the emerging Sustainable Design and Construction SPG and the emerging London Sustainable Drainage Action Plan.

Recommendation 7
Thames Water should continue its programme of addressing foul sewer flooding.

Recommendation 8
The groundwater flood risk in identified locations (see IPEG map) should be considered in FRAs and SFRAs to ensure that its impacts do not increase.

Recommendation 9
The reservoir flood risk in identified locations (see reservoir flood maps) should be in considered in FRAs and SFRAs to ensure its impacts do not increase.

Recommendation 10
Detailed flood risk assessments should be undertaken at an early stage at the level of individual major development locations and town centre development sites, and opportunities to reduce flood risk should be maximised where possible.

Recommendation 11
Relevant transport authorities and operators should examine and regularly review their infrastructure including their networks, stations, depots, underpasses and tunnels for potential flooding locations and flood risk reduction measures. For large stations and depots, solutions should be sought to store or disperse rainwater from heavy storms.

Recommendation 12
Emergency service authorities and operators covering hospitals, ambulance, fire and police stations as well as prisons should ensure that emergency plans in particular for facilities in flood risk areas are in place and regularly reviewed so that they can cope in the event of a major flood. These plans should put in place cover arrangements through other suitable facilities.

Recommendation 13
Education authorities should ensure that emergency plans in particular for facilities in flood risk areas are in place and regularly reviewed so that they can cope in the event of a major flood. These plans should put in place cover arrangements through other suitable facilities.

Recommendation 14
Operators of electricity, gas, water, sewerage, and waste utility sites should maintain an up to date assessment of the flood risk to their installations and, considering the likely impacts of failure, establish any necessary protection measures including secondary flood defences.

Appendix 2

Glossary

CAZ	Central Activities Zone
CFMP	Catchment Flood Management Plan
EA	Environment Agency
F&WM Act	Flood and Water Management Act
FALP	Further Alteration to the London Plan
FRA	Flood Risk Assessment
GLA	Greater London Authority
IPEG	Indicative Potential for Elevated Groundwater
LB	London borough(s)
LSFP	London Strategic Flood Plan
NPPF	National Planning Policy Framework
PLA	Port of London Authority
PPG/PPS25	Planning Policy Guidance/Statement 25 Development and Flood Risk
RFRA	Regional Flood Risk Appraisal
SAB	SUDS Approval Body
SFRA	Strategic Flood Risk Assessment
SHLAA	Strategic Housing Land Availability Assessment
SUDS	Sustainable Urban Drainage System
SWMP	Surface Water Management Plan
TE2100	Thames Estuary 2100 project
TfL	Transport for London
TLRN	Transport for London Road Network

Appendix 3 - Utility Infrastructure within Flood Risk Zones

Borough	Ref	Street	Post Code	Type	Comment	
Barking & Dagenham	1	Merrielands Crescent	RM9	unknown		
Barking & Dagenham	2	Chequers Lane	RM9	Electricity	Barking Power Station	
Barking & Dagenham	3	Chequers Lane	RM9	Fuel	Oil Storage Depot	
Barking & Dagenham	4	Hindmans Way	RM9	Fuel	Oil Storage Depot	
Barking & Dagenham	5	River Road	IG11	unknown	Apparently disused site	
Barking & Dagenham	6	Rewick Road	IG11	Electricity	former Power Station/sub station	
Barking & Dagenham	7	Barking Barrier East	IG11	Flood Defence	Tidal barrier	
Barking & Dagenham	8	Kingsbridge Road	IG11	Sewage	Gascoigne Road Pumping Station	
Barking & Dagenham	9	west of Northern Relief Road, Barking	IG11	Drainage	Pumping Station	
Barking & Dagenham	10	Hertford Road	IG11	Unknown		
Barnet	0	None found				
Bexley	1	Belvedere Road	SE2	Sewage	Crossness Sewage Treatment Works	
Bexley	2	Norman Road	DA17	Electricity	Belvedere Sub station note Disused Belvedere Power Station/proposed waste to energy plant not included yet	
Bexley	3	Norman Road	DA17	unknown	Likely Fuel/gas use	
Bexley	4	Yarnton Way	DA17	Gas		
Bexley	5	Station Road North	DA17	unknown		
Bexley	6	Crabtree Manorway	DA17	unknown		
Bexley	7	Viking Way	DA8	unknown	possible telecommunications	
Bexley	8	West Street/Maxim Road	DA8	unknown		
Bexley	9	Slade Green Road	DA8	unknown	possible electricity	
Bexley	10	Hollywood Way	DA8	unknown	possible pumping station	
Bexley	11	Industrial estate, north of River Cray	DA1	unknown	possible waste/council depot	
Bexley	12	South of Thames Road	DA1	unknown		
Bexley	13	South of Thames Road	DA1	unknown		
Bexley	14	Station Road	DA1	Drainage	Pumping Station	
Bexley	15	Weir Road	DA5	unknown		
Bexley	16	Riverside Road	DA14	Water	Pumping Station and covered reservoir	
Brent	0	None found				
Bromley	1	Beck Lane	BR3	Council	Council Depot	
Bromley	2	Kelsey Park Road	BR3	unknown	possible telecommunications	
Bromley	3	Valley Road	BR2	Drainage	Pumping Station	
Bromley	4	Liddon Road	BR1	Gas		
Bromley	5	Coates Hill Road	BR1	unknown	possible telecommunications	
Bromley	6	Bridge Rd/Cray Avenue	BR5	Electricity	Sub station	
Bromley	7	Orpington High Street	BR6	Post	Sorting Office	
Bromley	8	Tower Road/Sevenoaks Road	BR6	Drainage	Pumping station	
Bromley	9	north of Sevenoaks Road/A21	TN14	unknown	possible drainage use	

Borough	Ref	Street	Post Code	Type	Comment	
Camden	0	None found				
City	0	None found				
Croydon	1	Godstone Road	CR8	unknown		
Croydon	2	Factory Road	CR0	Gas		
Croydon	3	Factory Road	CR0	Electricity	Sub Station	
Ealing	1	Ruislip Road East	W7	Drainage	Pumping Station	
Ealing	2	Warple Way	W3	Sewage	Acton Pumping Station	
Enfield	1	Leeside Road	N18	Gas		
Enfield	2	Albany Road	N18	Gas		
Enfield	3	Bolton Road	N18	unknown		
Enfield	4	Balham Road	N9	unknown		
Enfield	5	Lee Park Way	N18	Waste	North London Waste to Energy	
Enfield	6	Picketts Lock Lane	N9	Sewage	Deephams Sewage Treatment Works	
Enfield	7	Woodhall Road	EN3	Gas		
Enfield	8	Edison Road	EN3	Electricity		
Enfield	9	Brancroft Way	EN3	Electricity	Brimsdown Power Station	
Enfield	10	Lee Valley Reservoirs	EN3	Water	Reservoirs including pumping stations	
Enfield	11	Brancroft Way	EN3	Electricity	Sub Station	
Enfield	12	Hadley Road	EN2	Drainage	Pumping Station	
Enfield	13	Station Road	N11	Gas		
Enfield	14	Dendridge Close	EN3	unknown		
Greenwich	1	Borthwick Street	SE8	Electricity	Deptford Grid	
Greenwich	2	Stowage	SE8	Electricity	Disused ?	
Greenwich	3				Deleted	
Greenwich	4	Maze Hill/Greenwich Park Street	SE10	Telecomms	Training and exchange on upper floors	
Greenwich	5	Boord Street	SE10	Gas		
Greenwich	6	Barrier Approach	SE7	Flood Defence	Thames Barrier	
Greenwich	7	White Hart Road	SE18	unknown	possible waste use	
Greenwich	8	Nathan Way/Eastern Way	SE28	Council office		
Greenwich	9	Nathan Way	SE28	Council depot		
Greenwich	10	Sewell Road	SE2	Electricity	unknown	
Greenwich	11	west of Wilton Road	SE2	unknown	possible telecommunications	
Greenwich	12	Thamesmere	SE28	Drainage	pumping station	
Greenwich	13	Old Woolwich Rd	SE10	Electricity Generation	Greenwich Power Station - Back up to London Underground and grid	
Greenwich	14	Greenwich High Rd	SE10	Water	Thames Water Pumping Station	
Hackney	1	Millfields Road	E5	Electricity		
Hackney	2	Millfields Road	E5	Waste		
Hammersmith and Fulham	1	west of Weltje Road/great West Road	W6	unknown		
Hammersmith and Fulham	2	south of Riverside Gardens	W6	unknown		
Hammersmith and Fulham	3	Chancellor Road	W6	unknown		
Hammersmith and Fulham	4	north of Yeldham Road	W6	unknown		

Borough	Ref	Street	Post Code	Type	Comment	
Hammersmith and Fulham	5	south of Thaxton Road	W6	unknown		
Hammersmith and Fulham	6	Pulton Place	SW6	Post		
Hammersmith and Fulham	7	Peterborough Road	SW6	unknown		
Hammersmith and Fulham	8	Townmead Rd adj Swedish Wharf	SW6	unknown		
Hammersmith and Fulham	9	south of Townmead Rd, west of superstore	SW6	unknown		
Hammersmith and Fulham	10	Townmead Road	SW6	Electricity		
Hammersmith and Fulham	11	Imperial Road	SW6	Gas		
Haringey	1	Leeside Road	N17	Electricity		
Haringey	2	Marsh Lane	N17	Drainage	Pumping Station	
Haringey	3	Reform Row	N17	unknown		
Harrow	1	Wolverton Road	HA7	Electricity		
Harrow	2	Canon Lane	HA5	unknown	not the disused gas works	
Havering	1	South of Coldharbour Lane	RM13	unknown	appears to be Tilda Rice plant	
Havering	2	Manor Way	RM13	Sewage	Riverside Sewage Treatment Works	
Havering	3	Rainham Road opp Dominion Way	RM13	unknown	possible telecommunications	
Havering	4	Dagenham Road	RM13	Drainage	Pumping Station	
Havering	5	South Street	RM1	Unknown	opp Gloucester Road	
Havering	6	Exchange Street	RM1	Electricity		
Havering	7	St Mary's Lane	RM14	Sewage	Sewage Treatment Works Anglian Water	
Havering	8	Cortina Drive, off Thames Avenue	RM9	unknown		
Havering	9	Warley	CM14	Sewage	Sewage Treatment Works	
Hillingdon	1	Former Perry Oaks Sewage Works	TW6	Sewage	now disused	
Hillingdon	2	Bath Road adj Moor Bridge	TW19	unknown	possible pumping station	
Hillingdon	3	Bath Road adj White Hart Pub	TW6	Electricity		
Hillingdon	4	North Hyde Gardens	UB3	Electricity	sub station	
Hillingdon	5	north of Charvill Rd south of A40	UB10	unknown	possible waste use	
Hillingdon	6	east of Tavistock Road	UB10	unknown	possible waste use	
Hillingdon	7	Cowley Mill Road	UB8	Post	Also former Gas use	
Hillingdon	8	Waterloo Road	UB8	Electricity		
Hillingdon	9	west of Springwell Lane	WD3	unknown		
Hillingdon	10	Slough Road	SL0	Electricity	sub station just outside London boundary	
Hillingdon	11	Maple Lodge Close	WD3	Sewage	Maple Lodge Sewage Treatment Works just outside London boundary	
Hounslow	1	Heathfield Terrace	W4	unknown		
Hounslow	2	Sutton Court Road	W4	unknown		

Borough	Ref	Street	Post Code	Type	Comment	
Hounslow	3	North of Kew Bridge Road	TW8	unknown		
Islington	0	None found				
Kensington and Chelsea	0	None found				
Kingston	1	north of Kingshill Avenue	KT17	Gas	Motspur Park	
Kingston	2	Lower Marsh Lane	KT1	Sewage	Hogsmill Sewage Treatment Works	
Kingston	3	Dawson Road	KT1	Post	Sorting Office	
Kingston	4	Ashdown Road	KT1	unknown		
Kingston	5	Downhall Road	KT2	Electricity	Sub station	
Kingston	6	Skerne Road	KT2	Gas		
Kingston	7	Portsmouth Road opp Grove Road	KT5	unknown		
Kingston	8	Portsmouth Road	KT5	Water	Seething Wells filter beds	
Lambeth	1	Vauxhall Street	SE11	Gas	Kennington Gas Works	
Lambeth	2	Kennington Park Road/Kennington Way	SE11	unknown		
Lewisham	1	Chilton Grove	SE16	unknown		
Lewisham	2	Landmann Way	SE14	Waste	SELCHP	
Lewisham	3	Copperas Street	SE8	unknown		
Lewisham	4	Brookmill Road, opp Stricland St	SE8	unknown	possible Council Depot	
Lewisham	5	Beck Close	SE13	unknown		
Lewisham	6	Armoury Road	SE13	Electricity		
Lewisham	7	Engate Street	SE13	unknown		
Lewisham	8	Canadian Avenue	SE6	unknown		
Lewisham	9	Barmeston Road	SE6	unknown	possible Post use	
Lewisham	10	Callander Road	SE6	unknown		
Lewisham	11	Selworthy Road	SE6	unknown	possible disused sewage site	
Merton	1	Bye Grove Road	SW19	Sewage	operational sewage site	
Merton	2	Plough Lane	SW17	Electricity	Sub Station	
Newham	1	Jupp Road	E15	unknown	possible telecommunications	
Newham	2	Abbey Lane	E15	Gas		
Newham	3	Abbey Lane	E15	Post		
Newham	4	Abbey Lane	E15	Sewage	Abbey Mills Pumping Station	
Newham	5	Channelsea Island	E15	unknown	Apparently disused site	
Newham	6	Crows Road/Canning Road	E15	unknown	Apparently disused site	
Newham	7	Twelvetrees Crescent	E3	Gas	Bromley By Bow Gas Works	
Newham	8	Stephenson Street	E16	Post		
Newham	9	Cody Road	E16	Electricity		
Newham	10	Western Gateway	E16	unknown	Possible Jubilee Line Vent Shaft	
Newham	11	Coolfin Road	E16	unknown		
Newham	12	south of North Woolwich Road	E16	Flood Defence	Thames Barrier	
Newham	13	Connaught Road	E16	Electricity		

Borough	Ref	Street	Post Code	Type	Comment	
Newham	14	Royal Albert Way south of Beckton Park DLR	E16	unknown		
Newham	15	Factory Road	E16	Drainage	Pumping Station also add adjacent satellite station as a new site	
Newham	16	Woolwich Manor Way adj Royal Victoria Gdns	E16	Drainage	Pumping Station	
Newham	17	Gallions Roundabout	E16	Drainage	Pumping Station	
Newham	18	Gallions Road	E16	unknown		
Newham	19	east of Royal Docks Road	E6	Gas	Beckton Gas Works	
Newham	20	Alpine Way	E6	unknown		
Newham	21	Woolwich Manor Way east of Alpine Way	E6	Drainage	Pumping Station	
Newham	22	Northern Outfall Sewer	E6	Sewage	apparently part of NOS	
Newham	23	Jenkins Lane	IG11	Sewage	Beckton Sewage Treatment Works	
Newham	24	Jenkins Lane	IG11	Waste	waste Transfer Station and possible Council Depot	
Newham	25	Watson Avenue	E6	Gas		
Newham	26	Grantham Road	E12	Electricity	Also former Gas use	
Newham	27	Barking Barrier West	IG11	Flood Defence	Tidal barrier	
Redbridge	1	Cranbrook Road/The Drive	IG1	Telecommunications		
Redbridge	2	Royston Gardens	IG1	Drainage	Pumping Station	
Redbridge	3	Redbridge Lane West	E11	unknown		
Redbridge	4	Roding Lane South	IG4	Electricity	Sub Station	
Redbridge	5	Snakes Lane East	IG8	Gas		
Richmond	1	Mellis Avenue	TW9	Sewage	Biothane Plant	
Richmond	2	Mortlake high Street	SW14	Electricity	Sub Station	
Richmond	3	Lower Sunbury Road	TW12	Water	Treatment Plant	
Southwark	1	Old Kent Road	SE15	Gas	South Eastern Gas Works	
Southwark	2	Verney Road	SE16	Electricity	sub station	
Southwark	3	Lynton Road/Monnow Road	SE17	Telecommunications		
Southwark	4	Dockley Road	SE16	Post		
Southwark	5	Salter Road	SE16	Gas		
Southwark	6	Hatfields	SE1	unknown		
Sutton	1	Beddington Lane	CR0	Electricity	Switching Station	
Sutton	2	Beddington Lane	SM6	Sewage	Beddington Sewage Treatment Works	
Sutton	3	Water Mead Lane	SM5	unknown	possible sewage use	
Sutton	4	Buckhurst Avenue	SM5	unknown	possible pumping station	
Sutton	5	Grove Road	SM1	unknown	possible post use	

Borough	Ref	Street	Post Code	Type	Comment	
Sutton	6	Crown Road	SM1	Gas		
Sutton	7	Green Lane	KT4	unknown	possible telecommunications	
Tower Hamlets	1	Three Colt Street	E14	unknown		
Tower Hamlets	2	Ontario Way	E14	unknown		
Tower Hamlets	3	West India Dock Road	E14	unknown	possible police use	
Tower Hamlets	4	Castor Lane	E14	Electricity		
Tower Hamlets	5	Watts Grove	E3	unknown		
Tower Hamlets	6	Leven Road	E14	Gas		
Tower Hamlets	7	Aspen Way	E14	Vent Shaft	Blackwall Tunnel	
Tower Hamlets	8	Law Street	E14	Vent Shaft	Blackwall Tunnel	
Tower Hamlets	9	Yabsley Street	E14	Waste	Northumberland Wharf	
Tower Hamlets	10	Stewart Street	E14	Drainage	Pumping Station	
Waltham Forest	1	Westdown Road	E15	unknown		
Waltham Forest	2	Osier Way	E10	Sewage	Auckland Road Pumping Station	
Waltham Forest	3	Clementina Road	E10	Gas		
Waltham Forest	4	South Access Road	E17	Council Depot		
Waltham Forest	5	Coppermill Lane	E17	Water	Coppermills Waterworks	
Waltham Forest	6	South of Lockwood Reservoir	E17	Water	Pumping Station	
Waltham Forest	7	west of Chingford Road	E4	Electricity		
Waltham Forest	8	May Road	E4	unknown		
Waltham Forest	9	Harbert Road	E4	Water	Pumping Station	
Waltham Forest	10	Lee Valley Reservoirs	E4	Water	Reservoirs	
Wandsworth	1	Longmead Road	SW17	unknown		
Wandsworth	2	Lynden Grove	SW18	unknown		
Wandsworth	3	Mapleton Road	SW18	Electricity		
Wandsworth	4	Morie Street	SW18	unknown		
Wandsworth	5	Armoury Way	SW18	Gas		
Wandsworth	6	The Causeway	SW18	Electricity		
Wandsworth	7	Smugglers Way	SW18	Waste	Riverside Waste Transfer Station and Council Depot	
Wandsworth	8	Paveley Drive	SW11	unknown	Possible Aggregates Depot	
Wandsworth	9	York Road/Plough Road	SW11	unknown	Within York Gardens	
Wandsworth	10	Prince of Wales Drive	SW8	Gas		
Wandsworth	11	Kirtling Street	SW8	unknown		
Wandsworth	12	Stewarts Road	SW8	Telecommunications		
Westminster	1	Gatliff Road	SW1	unknown	Former Grosvenor Dock waste transfer station	
Westminster	2	Ebury Bridge	SW1	unknown		
Westminster	3	Francis Street	SW1	unknown		

Source: Cities Revealed Land Use, 2003 – including comments from GLA, 2009, and updates from the London Boroughs of Richmond and Havering, 2014

Appendix 4

Comparison of Flood Risk Data with 2009 RFRA

Flood Receptor at risk	2009 RFRA (EA Flood Zone risk)	2013 RFRA (EA Flood Zone risk)	2013 RFRA (EA and DL flood risk)
Flood Risk Area	23,279 ha 15 %	22,857 ha 14 %	25,802 ha 16 %
Mayor Development Locations	OA: 10,345 ha 42 % AoI: 155 ha 24 %	OA: 9,169 ha 37 % AoI: 109 ha 28 %	OA: 9,502 ha 39 % AoI: 125 ha 32 %
Town Centres	Major: 274 ha 26 % (total 980) Metro: 89 ha 14 % (total 641)	Major: 230 ha 24 % (1048) Metro: 98 ha 13 %(total 739)	Major: 275 ha 28 % Metro: 133 ha 18 %
Mainline Rail Network	Track: 115 km 14 % Stations: 37 12%	Track: 110 km 14 % Stations: 37 11%	Track: 217 km 27 % Stations: 76 23%
Underground and DLR Network	Track: 87.5 km 19 % Stations: 72 24 %	Track: 89 km 20 % Stations: 71 24 %	Track: 123 km 27 % Stations: 90 30 %
TfL Road Network	131 km 22 %	126 km 22 %	150 km 26 %
Hospitals	8 7 % (total112)	8 9 % (total 86)	15 18 %
Emergency Services	Amb 8 13 % (total 63) Fire 21 19 % Police 44 20 % (total 215)	Amb 13 19 % (total 70) Fire 20 18% Police 21 13 % (total 167)	Amb 13 19 % Fire 26 23 % Police 23 14 %
Schools	385 13 % (total 3064)	399 13 % (total 3143)	445 14 %
Utilities	223 34 %	223 34 %	448 68 %