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EXECUTIVE SUMMARY

The London Borough of Enfield published its Level 1 Strategic Flood Risk Assessment (SFRA) in February 2008. As well as examining flood risk issues at a borough-wide scale the Level 1 SFRA identified the requirement for a more detailed analysis of flood risk in certain Priority Regeneration Areas. This Level 2 SFRA is the increased scope report referred to in the earlier document, it looks at two Priority Regeneration Areas in the east of Enfield:

- Ponders End; and
- Meridian Water.

For both areas the primary source of flood risk is fluvial flooding from the River Lee and its tributaries, flood risk from other sources has also been considered for this assessment in accordance with the National Planning Policy Framework (NPPF).

The principal purpose of the Level 2 SFRA is to facilitate application of the Sequential Test and Exception Tests as described in the NPPF, it also makes specific spatial planning and development management recommendations for future development. It maps the distribution of flood risk across the flood zones and considers the role and condition of existing flood defences. It also provides guidance on future site-specific Flood Risk Assessments and the application of Sustainable Drainage Systems. Though both areas are considered to be exposed to significant flood risk, it is concluded that with appropriate measures it is feasible to re-develop these areas in a way that will reduce flood risk both on and off-site.

1.0 INTRODUCTION

Background

- 1.1 The London Borough of Enfield is situated at the very north of London, it is broadly bounded by the M25 Motorway, River Lee valley and the North Circular Road to the north, east and south respectively. The borough covers an area of 8,200 hectares and is home to about 300,000 people. It is estimated that there are approximately 9,000 residential properties at risk of a 1 in 1000 year flood event.
- 1.2 In accordance with the National Planning Policy Framework (NPPF)¹ and the Technical Guidance to the NPPF² Enfield commissioned a Strategic Flood Risk Assessment (SFRA) to inform the development of the Council's emerging Core Strategy. The Enfield Level 1 SFRA³ was published in February 2008. It delineates the borough into zones of high, medium and low fluvial flood risk, assesses the risks from other sources of flooding and provides specific spatial planning and development management recommendations for future development.
- 1.3 The Level 1 SFRA also identifies that a more detailed analysis of flood risk will be required where it is not possible to allocate all proposed development and infrastructure in accordance with the Sequential Test described in the NPPF. This report is the increased scope SFRA referred to in the Level 1 assessment and fulfils the requirements of the Technical Guidance to the NPPF (paragraph 4). The assessment has been carried out in accordance with the Planning Policy Statement 25: Development and Flood Risk (PPS25) Practice Guide⁴, which describes the objectives and required outputs of a Level 2 SFRA in detail (paragraphs 3.58 to 3.67).

Aims and Objectives

- 1.4 The principal purpose of a Level 2 SFRA is to facilitate application of the Sequential and Exception Tests². This study will make a more detailed and realistic assessment of flood risk by considering the distribution of risk across flood zones and taking account of flood risk management measures such as flood defences. The detailed nature of the flood hazard within a flood zone will be assessed by considering the probability, depth, velocity and rate of onset of flooding. The standard and condition of defences will be assessed, as will the possible effects of failure either by breaching or overtopping. The Level 2 SFRA will identify policies and practices required to ensure that development in flood risk areas satisfies the requirements of the Exception Test.
- 1.5 The Level 2 SFRA will include the following key outputs:
 - an appraisal of the current condition of flood defence infrastructure and of likely future flood management policy with regard to its maintenance and upgrade;
 - an appraisal of the probability and consequences of overtopping or failure of flood risk management infrastructure, including an appropriate allowance for climate change;
 - definition and mapping of the functional floodplain in locations where this is required;

- maps showing the distribution of flood risk across all flood zones from all sources of flooding taking climate change into account;
- guidance on appropriate policies for sites which satisfy parts a) and b) of the Exception Test, and requirements to consider at the planning application stage to pass part c) of the Exception Test;
- guidance on the preparation of FRAs for sites of varying risk across the flood zones, including information about the use of SUDS techniques;
- identification of the location of critical drainage areas and identification of the need for Surface Water Management Plans; and
- meaningful recommendations to inform policy, development management and technical issues.

1.6 Flood risk is a combination of the probability of flooding and the consequences of flooding³. As flooding can arise from a number of different sources this assessment will consider all of the following types of flooding: fluvial flooding from rivers and streams, tidal, surface water, groundwater, sewer and reservoir flooding as well as flooding from other artificial sources. This Level 2 SFRA has been prepared in consultation with the Environment Agency.

The Sequential Test

1.7 One of the aims of the NPPF is to direct development to areas of lower flood risk. This is achieved by adopting a sequential approach to site allocation, requiring planners to seek to allocate sites for future development within areas of the lowest flood risk in the first instance. The NPPF designates certain types of development as permissible in certain flood risk zones. Only where it can be demonstrated that there are no suitable low risk sites should sites with a higher risk of flooding be considered. This is the Sequential Test, it is described in detail in the Technical Guidance to the NPPF. The results of the initial high level Sequential Test carried out for broad development areas in Enfield are described in the following chapter.

The Exception Test

1.8 The NPPF recognises that in some areas it is not feasible or sustainable for development to be located in zones of lower probability of flooding. In these cases the Exception Test should be applied as described in paragraph 102 of the NPPF. The Test provides a method of managing flood risk while still allowing necessary development to occur.

1.9 While the NPPF and accompanying Technical Guidance refer to a two-part Exception Test (parts (A) and (C) below), the PPS25 Practice Guide (extant guidance) includes an additional part (B) to the Exception Test, requiring that *development is on previously developed land*. This additional part of the Exception Test is also discussed in the High Level Sequential Test of the Core Strategy, referred to throughout this document.

Considering that that all development is proposed on previously developed land, the discrepancy in the test components will not impact upon the test results. However, for consistency with the High Level Sequential Test of the Core Strategy, and for clarity of reference, the Exception Test will be considered to comprise the following three components in the remainder of this document:

- A. it must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk, informed by a SFRA where one has been prepared; and
- B. development is on previously developed land; and
- C. a site-specific flood risk assessment (FRA) must demonstrate that the development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall¹.

2.0 THE SEQUENTIAL TEST

Delineation of Flood Risk

2.1 The risk of flooding from rivers is categorised into flood zones, these are defined on maps prepared by the Environment Agency. The flood zones present the worst-case scenario and consequently ignore the presence of all types of flood defences, they are defined as:

- **Flood Zone 1** (low probability) land assessed as having a less than 1 in 1000 annual probability of river flooding (<0.1%) and is therefore not exposed to any practical risk of fluvial flooding;
- **Flood Zone 2** (medium probability) land assessed as having between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% – 0.1%). This means that such an area will on average flood one or more times in a 1000 year period of time;
- **Flood Zone 3a** (high probability) comprises land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%); and
- **Flood Zone 3b** (the functional floodplain) land where water has to flow or be stored in times of flood, Enfield's Level 1 SFRA defines the functional floodplain for Enfield as the land which would flood with an annual probability of 1 in 20 or greater in any year (>5%) in accordance with the Technical Guidance to the NPPF.

Tables 1-3 of the Technical Guidance to the NPPF describe the different types of development that are considered appropriate in each flood zone. For example, residential properties are classed as 'More Vulnerable' and are therefore considered appropriate for Flood Zone 2 but not Flood Zone 3b. An Exception Test is required where such development is proposed in Flood Zone 3a. Shops, restaurants and office buildings by comparison are categorised as 'Less Vulnerable' and are therefore considered appropriate in Flood Zone 3a, provided they do not increase the risk of flooding elsewhere by displacing flood waters or blocking overland flow routes. 'Less Vulnerable' development is not permitted in Flood Zone 3b however.

2.2 Other sources of flooding as well as from rivers and the sea, must also be considered for any sites comprising one hectare or above¹. Consequently if there is evidence that a site allocated for future development is exposed to a significant level of non-fluvial flood risk a more detailed assessment may be required.

2.3 The London Plan⁵ identifies the Lee valley in Enfield as an Opportunity Area, it also requires Enfield to deliver a minimum of 3,950 new homes between 2007/08 and 2016/17. As a consequence, Enfield's Core Strategy does direct some development to areas of the borough that contain zones of high flood risk. A High Level Sequential Test⁶ has been carried out by Enfield, this considers whether there are any alternative development areas which would achieve the objectives of the Core Strategy but are at lower risk, and if not, whether development in the proposed areas is permissible when considered against the provisions of the NPPF.

- 2.4 The High Level Sequential Test describes two 'Place Shaping Priority Areas' (now referred to as priority regeneration areas) in the Lee valley that are exposed to significant levels of flood risk. These are Ponders End and Meridian Water. The report concludes that these sites represent the only viable opportunity for large-scale, strategic development able to help exceed the Mayor's housing targets, reduce the gap between housing demand and provision, and provide significant opportunities for employment to boost the local economy.
- 2.5 Consequently a more detailed Level 2 SFRA is required for these two sites. This must fulfil the requirements of The Exception Test by demonstrating that the development can be safe without increasing flood risk elsewhere as well as considering the potential wider sustainability benefits to the community.

3.0 LEVEL 2 SFRA: PONDER'S END

Site Description

3.1 The River Lee valley was formed by melt waters flowing towards the River Thames at the end of the last ice age. This created a low-lying area of marshes and floodplains. In recent centuries the landscape has been significantly altered to drain the marshes and create usable space. The availability of water required by industrial processes and proximity to water based transport systems offer a significant draw for the industries that have historically thrived in the area. The Ponders End Priority regeneration area is situated in the Lee valley near the eastern boundary of Enfield and is split into three parts. Only that part described in Enfield's Core Strategy as *Ponders End Waterfront* (hereafter referred to as '*Ponders End*') has areas in flood zones 2 and 3, thereby necessitating the application of the Exception Test.

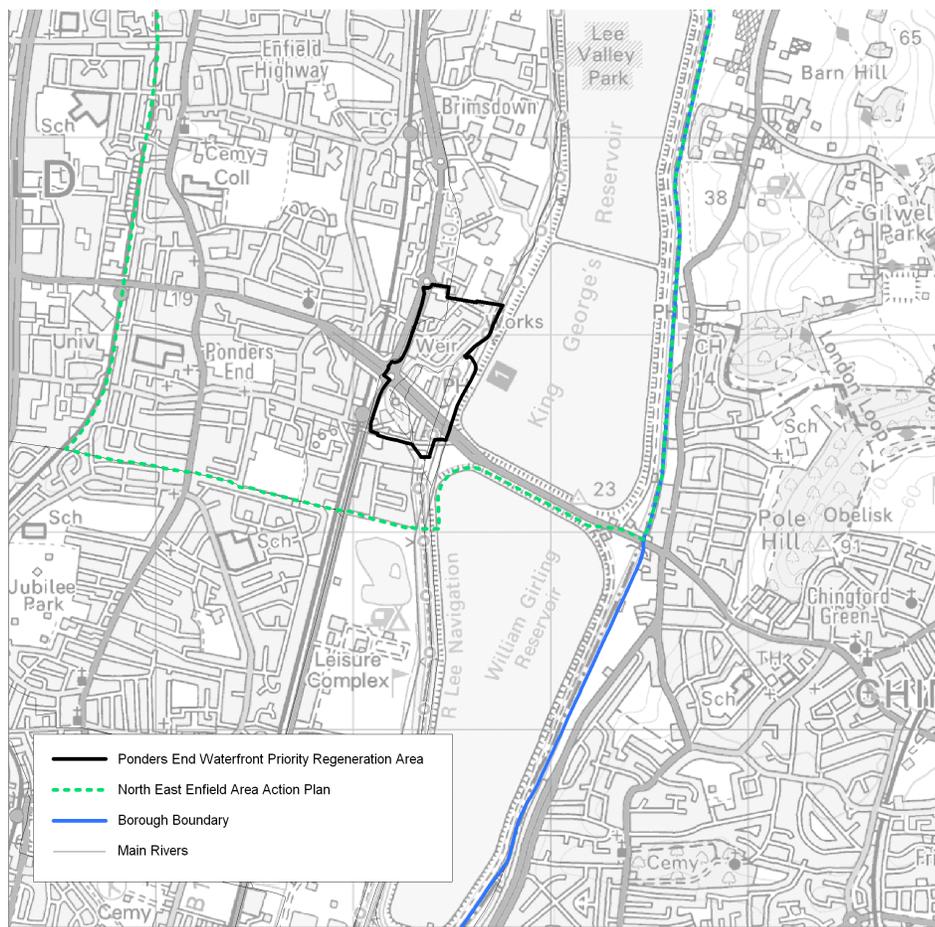


Figure 3.1 Location of Ponders End Waterfront Priority Regeneration Area

- 3.2 The site sits on the west bank of the Lee Navigation at one of only two locations in London where an original loop of the River Lee still exists. The loop serves as a bypass to the nearby canal lock and also feeds a mill chase, which historically powered the water wheel at Wright's Flour Mill. Records show there has been a mill in existence at this site since the 16th century and possibly even the 11th century.
- 3.3 Another main river watercourse, Brimsdown Ditch, crosses the site at its north-west corner. Though now mostly culverted, historical maps show this was once an open watercourse, probably created initially to assist the drainage of the marshes of the Lee valley.

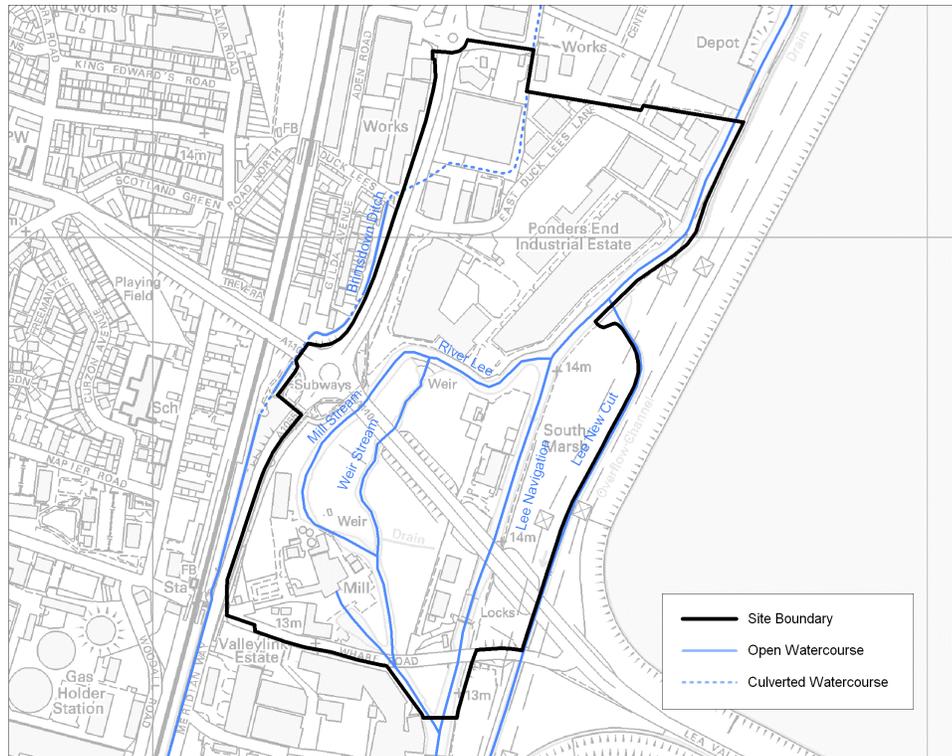


Figure 3.2 Ponders End Site Map

- 3.4 The area is fairly flat rising from 13 metres above sea level at its lowest point to just 15 or so at the highest. The underlying bedrock below the site is the London Clay formation, this precludes infiltration to the confined Chalk aquifer approximately 30 metres below ground. Existing boreholes within the site tap the Chalk aquifer and could be used to provide a sustainable supply of fresh water at the site. The near surface geology of the site consists of substantial drift deposits of Alluvium and Kempton Park Gravel, see drawing PE3 in Appendix A. These deposits are more permeable than London Clay and consequently may have a bearing on groundwater flood risk and opportunities to create infiltration based Sustainable Drainage Systems (SUDS).

- 3.5 The site itself is heavily industrialised although there are significant areas of green space adjacent to and in-between the various channels associated with the River Lee. The Core Strategy (policies 40-41) states that future development will be concentrated on the previously developed areas of the site, at Columbia Wharf and the southern part of the Brimsdown Industrial Estate. It will aim to create a mix-used community combining residential, employment and leisure uses. Further detail is not yet available, but it is likely that development on the remainder of the site will comprise water-compatible leisure uses and therefore will not be subject to the Exception Test. This assumption may need to be revisited as plans for development are progressed.



Figure 3.3 Photograph overlooking Ponders End to the north-east

The Exception Test

- 3.6 Enfield's High Level Sequential Test ⁶ demonstrates that development is necessary within the Ponders End Priority Regeneration Area in order to meet Enfield's strategic objectives. Re-development of the previously-developed land at Ponders End Waterfront is an opportunity to reduce the gap between housing demand and provision and provide significant opportunities for employment to boost the local economy. It also offers opportunities to attain wider sustainability benefits by increasing creating new, mixed-use communities that make the best use of the area's assets, provide green transport links and create a high quality public realm as part of the development. However, it is important to note that the Sequential Test will still need to be applied within the Priority Regeneration Area boundary in order to steer development to areas of lowest flood risk.

- 3.7 Enfield's High Level Sequential Test 6 demonstrates that the Ponders End site passes parts a) and b) of the Exception Test. Re-development also represents an opportunity to create a safe place that can reduce overall flood risk and thereby pass part c) of the Exception Test. Enfield's Level 1 SFRA defines safe development as follows: to be classed as safe, a dry access route above the 100 year plus climate change flood level to and from any residential development should be provided, finished floor levels for these developments should be set at least 300mm above this level. As this study presents new mapped outputs based on improved flood modelling (see paragraph 3.17 below) it is considered appropriate to re-define safe development for the purposes of this report as follows: to be classed as safe, a dry access route above the 100 year plus climate change flood level or, where appropriate modelled data exists, an access route within the 'low hazard' area of the floodplain (as defined by the Environment Agency's Flood Risk Assessment Guidance for New Development R&D Technical Report FD2320⁷) to and from any residential development should be provided, finished floor levels for these developments should be set at least 300mm above the 100 year plus climate change flood level. To achieve this without increasing flood risk elsewhere, it must be shown that there will be no net loss of flood storage and that overland flow routes will not be obstructed. Flood hazard maps for Ponders End are included in Appendix A (see drawing PE15), danger to people is expressed as a combination of flood depth and velocity. The low hazard category typically includes flood depths below 0.25 m and velocities below 0.5 m/s but also includes higher velocities for very shallow depths.
- 3.8 The remainder of this chapter is concerned solely with part c) of the Exception Test. It includes a detailed assessment of the risk of flooding from all sources, considers the effects of flood defences and identifies policies and practices required to ensure that development in flood risk areas satisfy the requirements of the Exception Test.

Fluvial Flooding

- 3.9 As fluvial flood risk is the main driver for carrying out a Level 2 SFRA for Ponders End, this form of flood risk will be looked at in detail first. The other forms of flooding described in paragraph 1.6 will then be considered. As tidal flooding does not affect Enfield it has not been further considered in this study.
- 3.10 The extent of the Environment Agency flood zones shown in drawing PE5 in Appendix A demonstrates that fluvial flood risk is a major constraint to the development of this site. These flood zones are based primarily on the Lee Hydrology and Mapping Study⁸, which was completed in March 2007. This study used the Flood Estimation Handbook⁹ methodology and a hydrodynamic flow model in conjunction with a digital terrain model to predict flood flows and the extent of the floodplain across the catchment area. The Environment Agency flood zones are generally based on the undefended flood outlines from this model. The exceptions include Flood Zone 3b, which is based on the defended flood outlines, and Flood Zone 2, which also includes the full extent of the Environment Agency's historical flood records.
- 3.11 The Lee Hydrology and Mapping Study⁸ describes the assumptions made to define the undefended flood outlines:
- flood storage areas assumed full prior to flood event;
 - flow control structures assumed closed such that flood flows are forced to weir over the top; and
 - raised defences assumed to have failed.

This scenario was modelled in such a way that any benefits, such as flood waters being stored upstream due to failure of raised defences, were not accrued downstream.

- 3.12 There are three principal rivers that cross Ponders End, these are:
- River Lee;
 - Lee Navigation; and
 - Brimsdown Ditch.

Refer to paragraph 3.15 below for further information.

- 3.13 The total catchment area of the River Lee is over 140,000 hectares, most of which is outside London and consists of mainly rural areas underlain by permeable Chalk. Consequently the response time of the River Lee to extreme rainfall events at this location is relatively slow. For example the Lee model estimates that the Lee will reach peak flows approximately 24 hours after the start of a flood event. Because of this, any flooding on the River Lee will also be more prolonged.

- 3.14 Following widespread flooding within the Lee valley in 1947 the Flood Relief Channel was constructed in the 1970s. This 20 metre wide concrete channel has a very high conveyance capacity compared to the Lee Navigation and is designed to carry the vast majority of flow during a flood event. As a result of this diversion, for lower order flood events the major component of flow in the Lee Navigation is actually derived from Turkey Brook and the Small River Lee. These are both tributary rivers with highly ruralised catchments approximately thirty times smaller than the Lee (the hydrographs included in Appendix B describe this effect for storms of differing duration and return period). As a result, flows along this section of the Lee Navigation can respond more quickly to extreme rainfall events than those on the Flood Relief Channel. Flow levels on the Lee Navigation are controlled to a certain extent by a series of overflow structures that divert flow to the Flood Relief Channel, such as the one on the east bank of the Navigation opposite the Ponders End Industrial Estate. For extreme events such as the 1000 year storm the capacity of these connections are exceeded and the dominant source of flow on the Lee Navigation becomes the whole Lee catchment.
- 3.15 Within the context of this site, the River Lee refers to the loop of the original River Lee that bypasses the canal lock. According to the Lee model, this loop carries all of the flood flows on the Lee Navigation, downstream of the overflow structure, as demonstrated by drawing PE6 in Appendix A. The model shows that no flow occurs along the stretch of the Navigation between the points at which the River Lee loop bifurcates and returns, even for a 1 in 1000-year event. The River Lee loop then separates into two more channels, commonly referred to as the Mill Stream and the Weir Stream. The Weir Stream is the true continuation of the River Lee loop and takes approximately 90% of the flow. The Mill Stream was created to serve a now defunct water wheel within the Wright's Flour Mill site.
- 3.16 The Brimsdown Ditch catchment is a flat, heavily urbanised area that includes London's second largest concentration of employment land⁶. The catchment is drained almost entirely by the surface water sewer network while the river itself is largely culverted or channelised. Consequently the river is very responsive to rainfall and has a very low dry weather flow; also it has very little capacity for storage of flood flows during a storm event. It does have a relatively high conveyance capacity however, something that has been utilised by the creation of the East Enfield Flood Alleviation Scheme (EEFAS), which was implemented in the late-1970s. This scheme involved the installation of a 1.8 metre diameter pipe running for several kilometres eastwards before outfalling into Brimsdown Ditch close to the point at which it is designated a main river, less than 1 kilometre north of Ponders End. Though the scheme alleviates a well-documented flood problem in the Carterhatch area, near to its head, it does increase flows along the river in the Ponders End area. The scheme was designed for a 1 in 25 year event and since its inception there have been no recorded flood events on EEFAS or Brimsdown Ditch. Refer to Enfield's Level 1 SFRA³ for further information and maps regarding these watercourses and their catchment areas.

- 3.17 Since publication of the Lee Hydrology and Mapping Study⁸ in 2007 a two-dimensional (2D) model covering the breadth of the Lee valley from south of Enfield up to the M25 Motorway has been developed with the aim of providing enhanced flood risk assessment of the Central Leaside Strategic Growth Area. The background to this model and a detailed description of its development can be found in the Central Leaside Baseline Hydraulic Modelling Report¹⁰, completed in November 2008. The new model uses the one-dimensional (1D) ISIS model from the Lee Hydrology and Mapping Study to simulate in-channel flows, this is then linked to a 2D TUFLOW model which represents overland flows in the floodplain. This combined model represents flood flows more realistically than the 1D model alone and is therefore considered a significant improvement. The 2D model provides outputs including flood flow, depth and velocity data in addition to the flood outlines.
- 3.18 The baseline 2D model represents the existing, defended flood risk situation at Ponders End and will form the basis of the fluvial flood risk analysis for this report, it allows detailed consideration of the nature of the flood hazard as required by the PPS25 Practice Guide⁴. Outside of this report the model may be used to test possible scenarios for future re-development of the site; the results of these tests will inform site design and future site-specific Flood Risk Assessments (FRAs) as required by the development process. The outputs from the baseline 2D model are displayed in drawings PE8 to PE15 in Appendix A. The flood maps created using this 2D model show out of bank flooding only as the in-channel flows are represented by the 1D model.
- 3.19 In early 2010 the model was reviewed by the Environment Agency to assess whether outputs from the 2D model could be incorporated into, and thereby improve the accuracy of, the Environment Agency flood zones. Though the model was originally reviewed and approved by the Environment Agency in 2008, the 1D Lee model on which the 2D model is based has since been updated resulting in increased flows on two tributaries of the Lee Navigation for high-order flood events. As these two tributaries join the Lee downstream of Ponders End the required model amendments associated with them have no bearing on this site.
- 3.20 Drawings PE8 to PE11 provide a comparison between the 2D model outputs and the latest Environment Agency defended flood maps. Although the 2D model is a more sophisticated simulation than the older model, the 2D outputs appear more pixelated or 'blocky' than those of the 1D version, this is due to the method used by the two model types to determine the extent of the floodplain. The 2D model is based on a grid with a 15-metre resolution covering the entire model area. There are model nodes at the corner and half-way point of each grid square, hence each block is 7.5 metres wide. The floodplain given by the 1D model is defined by taking a flood level at each model node along each river and using GIS software to determine how far the flooding would extend out of bank based on LiDAR data. This leads to a smoother shape for the 1D model based flood outlines. There is however one aspect of the methodology behind the 2D model that is deficient and needs to be addressed in more detail.

- 3.21 As described in paragraph 3.14, for lower order events the Lee Navigation at Ponders End derives most of its flow from nearby tributaries rather than the whole Lee catchment, however the 2D model results are based on a design storm of critical duration for the Lee catchment rather than the smaller tributaries. For the 100 year plus climate change flood approximately 90% of the peak flow in the Lee Navigation comes from Turkey Brook and the Small River Lee whereas for the 1000 year event this proportion is reduced to 40%. A series of hydrographs provided by the Environment Agency in 2011 are included in Appendix B, they demonstrate the difference in peak flow rates and flood volumes between the these two return periods at a location just upstream of Ponders End. They also chart the predicted flood hydrographs for both the Turkey Brook/Small River Lee critical storm and the Lee catchment wide critical storm.
- 3.22 These hydrographs show that for the 1000 year return period the Lee critical storm leads to the maximum peak flow and maximum volume of flooding. For this return period the 2D model outputs can be taken as the definitive flood maps for the purposes of this assessment. However, for the 100 year plus climate change flood the tributary critical storm gives a slightly higher peak flow rate (though overall volume of flood water is marginally less than for the Lee critical storm). Consequently, the 2D model outputs cannot be said to represent the worst case scenario for this return period and any lower order events modelled.
- 3.23 Consequently, the Environment Agency defended flood outlines are to be taken as the definitive representation of flood extent for all return periods modelled other than the 1000 year. Regarding the 1000 year scenario there is an additional flaw in the 2D model outputs to be considered. The 1D model shows a vast overland flow inundating the area to the west of the Lee Navigation between Turkey Brook and Ponders End (see Figure 3.4 below), this flooding is not predicted by the 2D model. Analysis reveals that the overland flow originates from Turkey Brook. Because the 2D model only considers the Lee catchment wide critical storm it predicts significantly lower 1000 year peak flows on Turkey Brook at the point where it breaks its banks than the 1D model ($31.8\text{m}^3/\text{s}$ rather than $41.1\text{m}^3/\text{s}$). The 2D model does show some out of bank flow at this location but determines that it will stay within the Turkey Brook catchment. Nevertheless the overland flow predicted by the 1D model is believed to be unrealistic. 1D models are known not to represent out of banks satisfactorily, in this case the extent of flooding predicted is not considered realistic based on the analysis presented below.

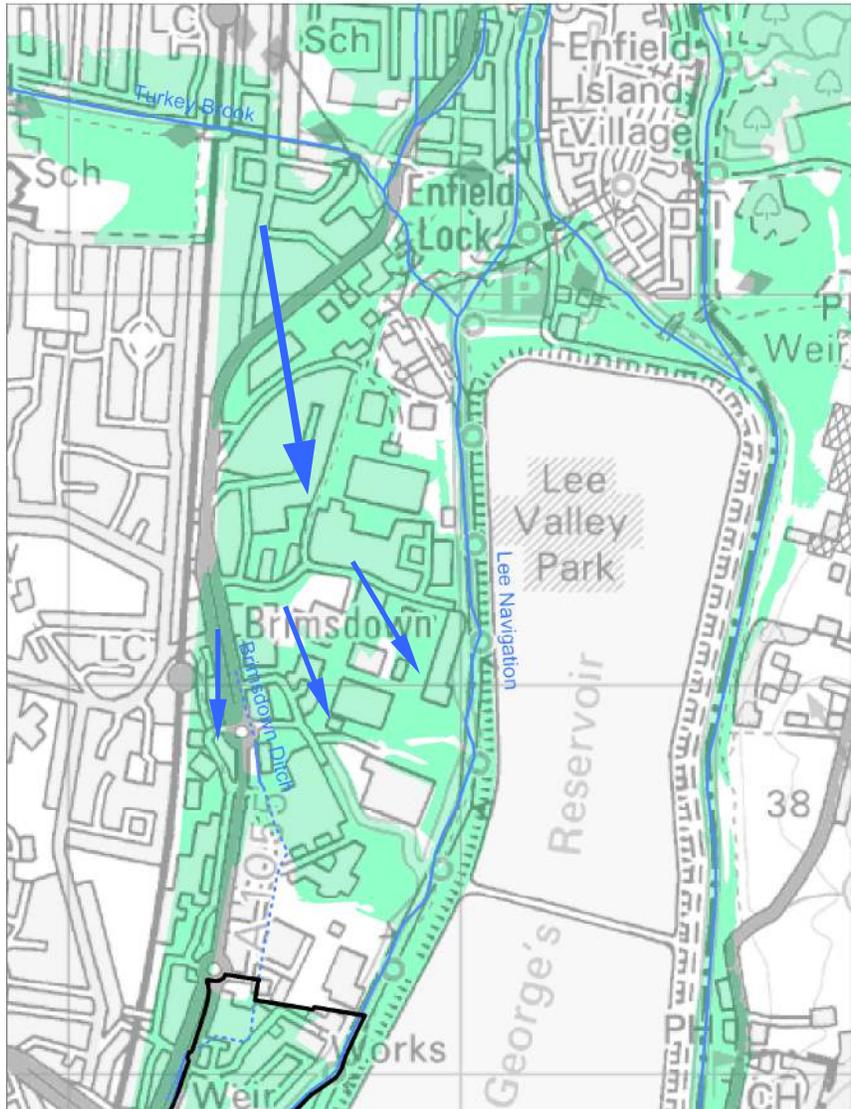


Figure 3.4 Overland flow route predicted by the 1D model for the 1 in 1000 year storm

- 3.24 The overland flow is shown by the 1D model to cross the Turkey Brook catchment boundary to the south and continue flowing for two kilometres all the way to Ponders End. Given that the 2D model shows no such overland flow, it is assumed that the maximum overland flow rate can be estimated by taking the difference between the peak flows predicted by the two models. Hence the excess flow that breaks out of the Turkey Brook catchment can be assumed to peak at a maximum of $9.3\text{m}^3/\text{s}$. Most of the overland flow predicted by the 1D model is shown to pour back into the Lee Navigation before reaching Ponders End (see Figure 3.4), based on the width of the flow path along this proportion would be estimated to be around 90%. If 30% of the original overland flow was conservatively assumed to continue towards Ponders End this would result in a possible peak flow rate of $2.8\text{m}^3/\text{s}$ reaching the site. However, the overland flow would be significantly attenuated as it travelled towards Ponders End. This would reduce the flow rate further, possibly by as much as 50%. Because this flooding occurs 12-14 hours after the start of the storm event it can be assumed that the drainage system will be able to accept much of the runoff as the rainfall will have ceased well before (the 2D model demonstrates adequately that for longer, less intense storms the overland flow does not occur in the first place). In addition the overland flow route is shown to cross the Brimsdown Ditch catchment on its way to Ponders End. Because Brimsdown Ditch is a small, flashy catchment any flooding on this main river will have subsided by the time the overland flow arrives. Flows on Brimsdown Ditch are estimated to return to pre-storm levels within 5 hours of the storm, the capacity of Brimsdown Ditch is in the order of $8\text{m}^3/\text{s}$. As a result there will be significant capacity within this system to soak up excess flows and prevent flooding affecting the Ponders End site. As the 1D model does not include Brimsdown Ditch it takes no account for this effect.
- 3.25 Consequently it is concluded that the overland flow predicted by the 1D model is unrealistic and that the 2D model outputs should be adopted as the definitive flood maps for the 1000 year return period for the purposes of this assessment. It is recommended that prior to any further analysis carried out using the 2D model, such as site-specific FRAs, it will be necessary to update it by including the possible outcomes of the Turkey Brook/Small River Lee critical storm for all return periods.
- 3.26 As described in paragraph 3.5, future development will take place only on the previously developed areas of the site. These include the Ponders End Industrial Estate and the units along the west bank of the Lee Navigation that are inside the River Lee loop; the Wright's Flour Mill site is not planned to be re-developed. Figure 3.5 below shows that while these areas are all outside the defended 100 year plus climate change flood outline, the majority of the Ponders End Industrial Estate (PEIE) is within the undefended 100 year plus climate change flood outline. However, further investigation of this discrepancy reveals that, aside from a small undeveloped portion of the PEIE site in the south-west corner, the ground levels along the right-hand bank of the Lee Navigation and within the site are significantly higher than the 100 year plus climate change flood level for both undefended and defended scenarios – surveyed ground levels are at least 14.70mAOD compared to 100 year plus climate change flood levels of 14.40mAOD . The difference is therefore not due to failure of raised defences. As flood levels are identical for both undefended and defended scenarios the differences cannot be attributed to the failure of off-site defences either. It is concluded that the Flood Zone 3 outline (with or without climate change) is incorrectly represented at the Ponders End Industrial Estate, it should probably be similar to the 100 year defended outline. Hence, although application of the Exception Test will be required for any 'More Vulnerable' development in this area, the test would be passed.

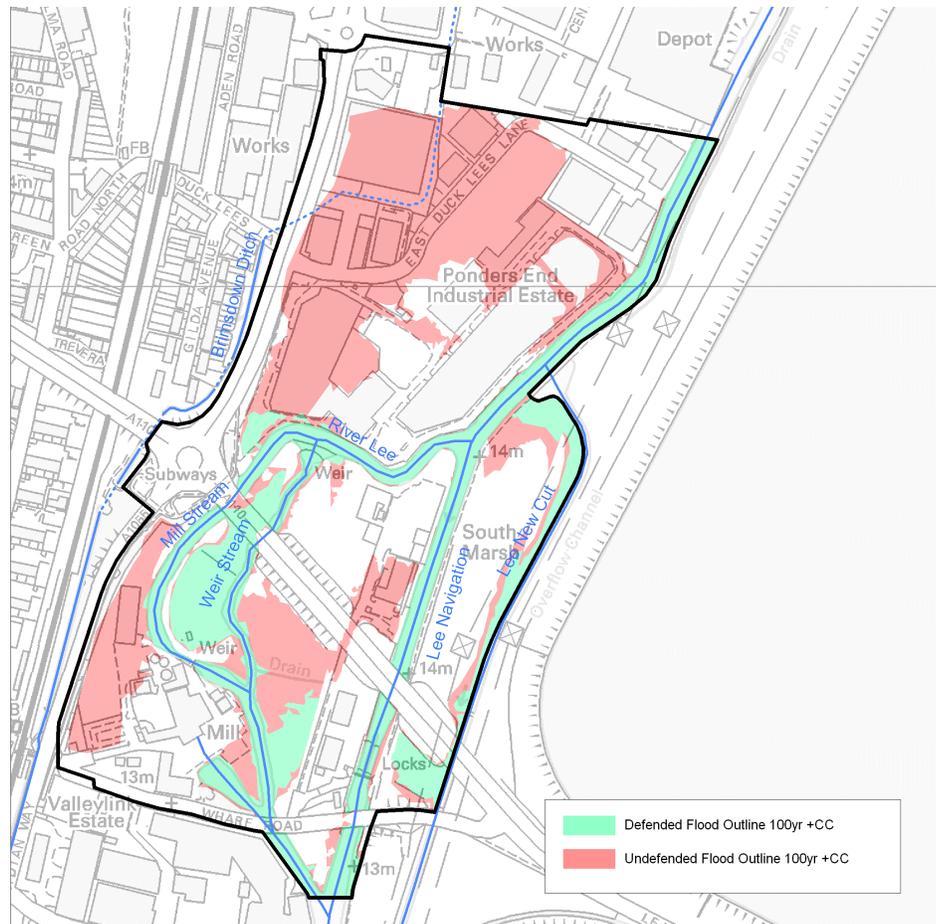


Figure 3.5 Defended and Undefended Flood Outlines for the 100 year plus climate change scenario

- 3.27 In general the defended flood extents shown in drawings PE8 to PE11 demonstrate that for return periods up to a 100 year plus climate change flood event none of the previously developed areas are at risk of flooding. The type of development proposed in Ponders End is predominantly classed as 'Less Vulnerable' or 'More Vulnerable' (Technical Guidance to the NPPF Table 2). Given this, and Enfield's adopted definition of 'safe development' (paragraph 3.7), the 100-year plus climate change flood map is the appropriate scenario under consideration for application of the Exception Test. Outputs from the 2D model including flood depths and velocities are depicted in drawings PE12 to PE15. However, as none of these flood outlines impinge on the areas of proposed redevelopment, further discussion of the implications for future development is not considered necessary.
- 3.28 Brimsdown Ditch has not been included in any of the Lee catchment models developed to date. Discussions with the Environment Agency indicate that this may have been partly due to a lack of construction data and partly to a lack of evidence that this largely culverted main river poses a significant flood risk. However, due to the proximity of this watercourse to the Ponders End site it was considered necessary to develop a better understanding of the potential flood risk for the purposes of this study. A hydraulic model of Brimsdown Ditch was subsequently commissioned by Enfield Council and developed by Halcrow, this work was completed in May 2010. Outputs from this model are in Appendix C and summarised overleaf in Figure 3.6.

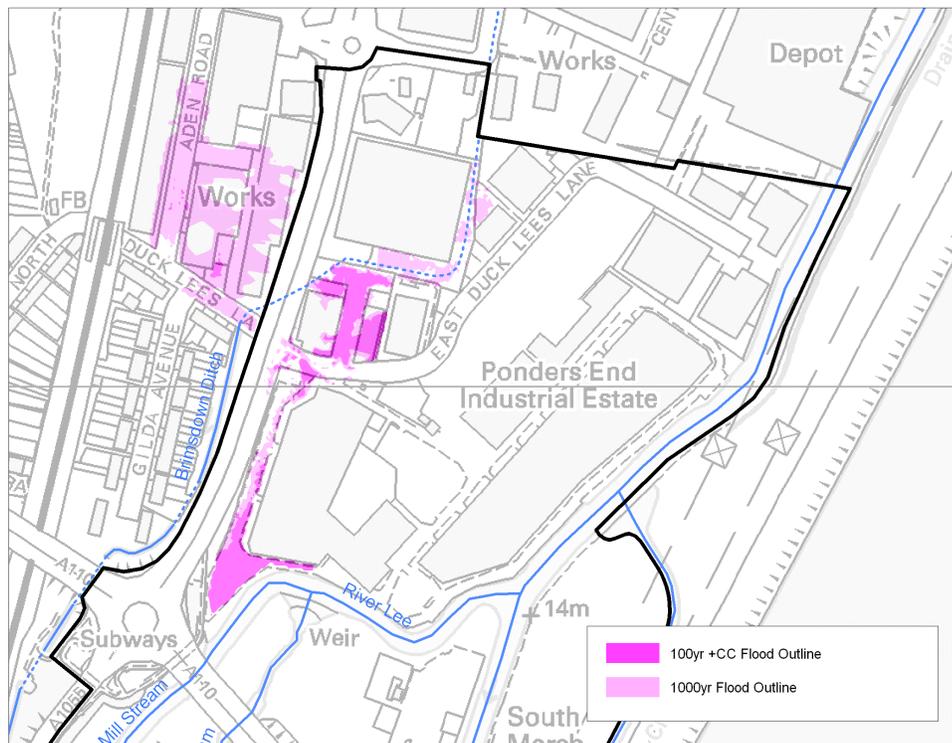


Figure 3.6 Flood extents resulting from surcharging of the Brimsdown Ditch culvert

- 3.29 The flow capacity of Brimsdown Ditch is enhanced by the depth of the culvert, which is typically 3 metres below ground level. This means that flood flows can become significantly pressurised before flooding occurs. Nevertheless, the modelled outputs demonstrate that for the 100 year plus climate change scenario two manholes in Alpha Road (the T-shaped cul-de-sac to the north of East Duck Lees Lane shown in Figure 3.6) surcharge to the extent that an estimated 1000m³ of floodwaters spill out onto the carriageway. About 300m³ of the spilled water ponds in Alpha Road to a maximum depth of 0.3m, the maximum velocity in this area is 0.2 m/s. When the flood level reaches 14.5mAOD water starts to spill over into East Duck Lees Lane creating an overland flow route that continues southwards along a car park access road that runs adjacent to the A1055. The maximum depth and velocity of the water flowing along this route are estimated as 0.1m and 0.6 m/s respectively. The excess water then ponds in a low-point at the south-west corner of the Ponders End Industrial Estate. When this low area has been flooded to a maximum depth of 0.5 metres the remaining water spills over into the River Lee. The maximum flood level within this area is 14.4mAOD compared to a maximum of 14.3mAOD on the River Lee (for a 1000 year event), hence this attenuated spill into the River Lee will occur even when the Lee is at the peak of the flood cycle. Due to the relatively small size and responsive nature of the Brimsdown Ditch catchment, this flooding will occur within 2 to 3 hours of the start of the event. The extent of flooding will recede within a matter of 5 to 6 hours as peak flows dissipate.
- 3.30 To ensure that flood risk posed by the Brimsdown Ditch culvert is mitigated adequately it is recommended that any future development makes allowance for the ponding and overland flows resulting from a 100 year plus climate change event. The area of ponding to the south-west corner of the Industrial Estate should be designated a formal flood storage area.

Flood Defences

- 3.31 The differences between the undefended scenario represented by the Environment Agency flood zones and the defended scenario shown by the flood maps in drawing PE7 and the 2D model outputs are described in paragraph 3.11. There are no flood storage areas or flow control structures within the Ponders End site. There is a single, relatively short raised defence protecting the low triangular area of land at the south-west corner of Ponders End Industrial Estate, see Figure 3.7 below.

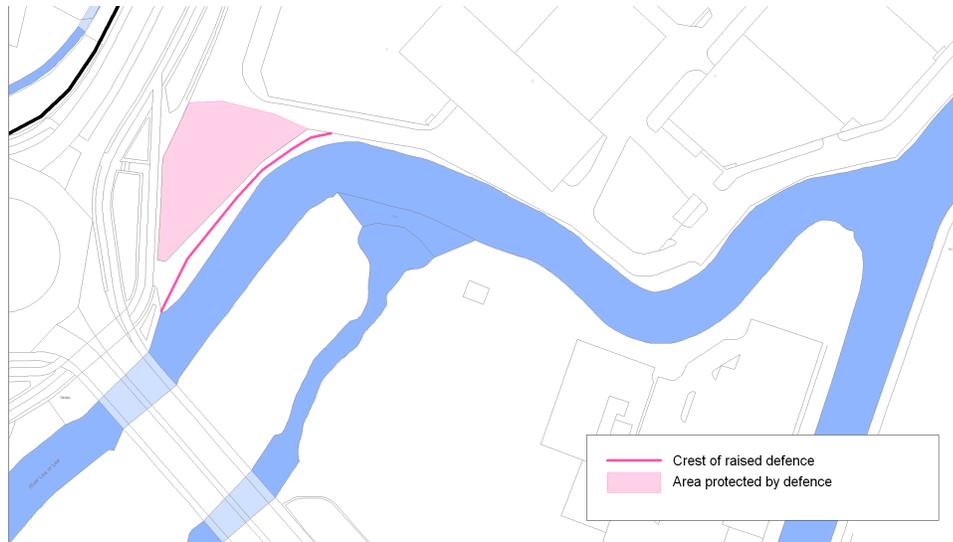


Figure 3.7 Raised defence at south-west corner of Ponders End Industrial Estate

- 3.32 The raised defence consists of an earth embankment reinforced by a low brick wall on the side away from the river, it ranges in height from 0.2 to 0.5 metres. The brickwork is currently in very poor condition. The embankment provides protection against flooding from the River Lee up to a flood level of 14.4mAOD. The lowest point within the defended area is 13.9mAOD. The 100 year plus climate change flood level at this point on the River Lee is 14.1mAOD, the 1000 year level is 14.3mAOD. This defence protects the same low area at the south-west corner of the Ponders End Industrial Estate described in 3.29. As this area is the recipient of any above ground flows spilling out of the Brimsdown Ditch culvert in addition to being the only area within Ponders End protected by a raised defence, and therefore subject to the residual risk posed by its potential failure during a flood event, it is strongly recommended that this area is set aside to be maintained as some form of open space, it is currently in use as a car park. It is also recommended that the access road that runs to this area from Alpha Road is designated a formal overland flow route and modified accordingly to accept exceedance flows originating from the Brimsdown Ditch culvert. As the maximum anticipated depths for a 100 year plus climate change event are 0.1m this should be achievable.

- 3.33 The brickwork element of the defence should be repaired or replaced as part of any redevelopment works. Another option is to remove the flood defence altogether. This would eliminate both the need to maintain the defence and residual risk of the defence failing. However, this area would then become extremely flood prone. Outputs from the Lee model suggest that it would flood at least once every two years on average which may be considered unacceptable. Alternatively the defence could be lowered. Potentially this could provide a balanced solution that reduces the residual risk of failure while maintaining the frequency of flooding at an acceptably low level. Options for altering or repairing the existing defence should be given further consideration during preparation of any future detailed Flood Risk Assessment.
- 3.34 The other flood defences within the site, which would have an adverse impact on flood risk were they to fail, are the channel walls and culverts that have replaced the natural river banks and beds, and the various overflow structures associated with the Lee Navigation. The location, extent and construction type of these structures are shown in drawing PE16 in Appendix A. Figures 3.8 to 3.13 below provide a photographic record of the typical flood defences found on site.



Figure 3.8 Vegetation obscuring concrete retaining wall along Lee Navigation at north end of site



Figure 3.9 Short section of masonry retaining wall on Lee Navigation further downstream



Figure 3.10 Masonry retaining wall outside The Navigation Inn



Figure 3.11 Overlooking weir on River Lee loop



Figure 3.12 Overflow structure on east bank of Lee Navigation



Figure 3.13 Raised defence on River Lee Mill Stream

- 3.35 The Lee Navigation channel is made up of a diverse range of different construction types including sheet piling, reinforced concrete, mass concrete and masonry retaining walls in places. The large size of the channel relative to its flow rates, even a 100 year flood event would only result in a velocity of 0.5 m/s, mean that failures such as collapse of one of the banks due to erosion are both less likely to occur and less likely to have a significant impact on flooding.
- 3.36 The flood defences at Ponders End are generally in good condition. As they are on main rivers they are visually inspected annually by the Environment Agency for structural defects. The Lee Navigation is owned and maintained by British Waterways, whereas the River Lee loop is the responsibility of the relevant riparian owner. Much of the Brimsdown Ditch culvert is classed as a highway structure as it is largely directly below the public highway. Consequently, it is also regularly inspected, typically on a bi-annual basis, by Enfield's Highways Department. Any significant defects that are observed are recorded, monitored and where necessary re-mediated. The available inspection records for these defences have been reviewed; no significant outstanding defects were identified.

3.37 The future management of these defences will to a large extent be determined by the policies set out in two key Environment Agency documents, the Thames Region Catchment Flood Management Plan (CFMP) ¹¹ and the Lower Lee Flood Risk Management Strategy ¹². These documents along with the types of defences that are prevalent in Enfield, and the advantages and disadvantages associated with them, are discussed in greater detail in Enfield's Level 1 SFRA ³. The main messages of these documents are:

- at present it is still possible to maintain existing flood defences;
- climate change will mean that these defences will become less effective in the future, therefore make sure that:
 - any redevelopment reduces the residual flood risk in the areas benefiting from these flood defences using the measures set out in Planning Policy Statement 25: Development and Flood Risk (note: this document has now been superseded by the NPPF);
 - the natural flood plain is used upstream and downstream of these areas to accommodate additional floodwater;
- re-create river corridors so there is more space for the river to flow and flood naturally;
- flood risk management planning needs to be linked closely with regeneration and redevelopment so that the location and layout of development can help to reduce flood risk;
- organisations need to work together to manage all flood sources: fluvial, surface water and sewer flooding.

The Level 1 SFRA also recommends that in general, opportunities should be sought to set back development from the river edge to enable sustainable and cost effective flood risk management options.

3.38 The performance of the overflow structures that control water levels on the Lee Navigation is important but not critical to the management of flood risk across the site. The most vital overflow structure is the one upstream of the River Lee loop bifurcation point, as this protects the Ponders End Industrial Estate. Structurally it is in good condition, however the most likely mode of failure is a blockage caused by floating debris. The high number of small spans that make up this structure (shown in Figure 3.12 and in Figure 3.14 below) increase the likelihood of reduced capacity due to one or more of the openings becoming blocked. Though the chances of a significant number of the openings becoming blocked are negligible, it is worth considering what the consequences would be.

- 3.39 At its lowest point the bank along the Ponders End Industrial Estate (14.70m AOD) is much higher than the left-hand bank of the Lee Navigation upstream of the overflow structure (14.40m AOD), the left-hand bank of the weir stream (14.50m AOD) and the crest level of the lock gates downstream (14.35m AOD). Opposite the overflow structure the 100 year plus climate change flood level for the undefended and defended scenarios is 14.40m AOD. If the overflow structure did fail completely flood levels would increase but not enough to flood the developed land on the right-hand side of the channel. Most of the excess flow would weir over the embankment on the left-hand side as the average bank level for several hundred metres upstream of this point is just 14.40m AOD. The capacity of this 'weir' is huge (in the order of 100m³/s) and as the ground levels below the embankment are much lower the capacity for storage is also ample – any excess flow weiring over this embankment ends up in the same place as it would have if the overflow structure was not blocked. Increased levels will lead to increased flow along the Weir Stream, though this could potentially cause more flooding downstream it would not affect any of the proposed development areas within the study area. Another overflow device potentially affecting the site is an overflow structure downstream of the confluence of the Weir Stream with the River Lee, this latter feature is just outside the site boundary and in any case it would not affect the areas where development is proposed. The Weir Stream weir itself is also an overflow feature, structural failure would lead to significant flooding downstream. It is recommended that the condition and performance of all these assets are assessed and any necessary remedial works completed prior to redevelopment of the site.



Figure 3.14 Overflow structure opposite Ponders End Industrial Estate with ground level spot heights

- 3.40 Flood defences outside the site, such as Fieldes Weir, which controls flows on the Lee Navigation and the Flood Relief Channel, can have a significant bearing on flood risk within the site. Though these defences have not been reviewed in detail they are subject to the policies and practices set out in the CFMP¹¹ and are regularly inspected by the Environment Agency.

Surface Water Flooding

- 3.41 Surface water flooding refers to localised flood events caused by rainfall runoff before or soon after it has entered the local drainage network. Flooding may occur because of the operational failure of drainage infrastructure such as pipes and grilles or because intense rainfall leads to saturation of the ground combined with inundation of sewers and drains. Expected increases in rainfall intensity due to climate change will lead directly to increased risk of surface water flooding³. In areas close to rivers, fluvial flooding can also exacerbate surface water flooding as high river levels prevent surface water outfalls from discharging freely. Consequently the proximity of the various river systems across Ponders End will have a bearing on how surface water is managed on site.
- 3.42 There are two primary sources of data available for assessment of surface water flood risk. These are historical records of surface water flood events and the results of a study conducted for Enfield's Surface Water Management Plan (SWMP) that has been prepared as part of the Drain London project. Drain London is a consortium of organisations led by Greater London Authority and including the Environment Agency, Thames Water, London Councils, Transport for London and London Boroughs. This study assesses surface water flood risk by mapping high-risk areas and identifying Critical Drainage Areas (CDAs) and potential flood alleviation measures.
- 3.43 Enfield's surface water flooding records do not identify any incidents occurring within the Ponders End area. Though Enfield has recently implemented procedures to improve recording of flood events, past events are recorded patchily. It is possible that surface water flood problems exist but are undocumented.
- 3.44 The Drain London surface water flood maps were produced by taking a design storm of 3 hours duration and applying it evenly over an area using topographical data to determine where surface water flows would flow overland and accumulate. The drainage infrastructure was allowed for by removing 6.5mm/h from the rainfall hyetographs. The main use of these maps is to identify areas where further investigation is required. The results for Ponders End are shown in drawings PE17 and PE18 in Appendix A. These show several places across the study area where significant quantities of surface water are estimated to flow and pond. However, the SWMP concludes that these areas do not warrant definition as Critical Drainage Areas as the predicted flood depths are low or only affect open or un-developable spaces. Further analysis of surface water flood risk is outside the scope of this report, however any future site-specific FRAs should address surface water flood risks in greater detail.

Groundwater Flooding

- 3.45 Groundwater flooding is caused by subterranean water that flows back above ground, this occurs at the interface between the water table and the surface. Groundwater flooding will only occur in or near areas where the underlying rocks and soils are capable of transporting significant quantities of water. Drawing PE3 in Appendix A shows the extent of the various alluvial deposits that cover the Ponders End area. As described in paragraph 3.4 both the Kempton Park Gravel and Alluvium formations can be considered sufficiently permeable to have a bearing on groundwater flood risk, these layers cover the whole site. A new groundwater flood risk dataset has been derived for Enfield's Surface Water Management Plan (SWMP) as part of the Drain London project described in the previous section. The extent of this 'increased Potential for Elevated Groundwater' (iPEG) is shown in Figure 3.15 below.



Figure 3.15 Shaded area shows 'increased Potential for Elevated Groundwater' taken from Enfield's Surface Water Management Plan

- 3.46 The iPEG mapping shows those areas within the borough where there is an increased potential for groundwater to rise sufficiently to interact with the ground surface or be within 2 m of the ground surface. Though all of the site is shown to be within the iPEG area the near surface geology is almost entirely Alluvium which is at the impermeable end of the spectrum of permeable layers. In addition, no groundwater flooding incidents have been recorded within the site by the Environment Agency or Enfield Council. It is therefore considered that groundwater flooding is not a significant risk in this area. Nevertheless the practices and policies regarding groundwater flood risk set out in Enfield's Level 1 SFRA should be followed as appropriate.

Sewer Flooding

- 3.47 The public sewerage network in Enfield is managed by Thames Water Utilities Limited (TWUL). TWUL records show that only 3 foul water sewer-flooding incidents have been reported in the vicinity of Ponders End in the last ten years, no surface water sewer flooding has been reported in this time. Enfield's Level 1 SFRA³ considers the implications of sewer flood risk in further detail. Based on the available evidence it appears that sewer flooding does not represent a significant risk to properties in Ponders End. It is likely that re-development of the site will require considerable re-configuration of the existing sewer network, this will be designed and constructed to modern standards, further reducing the risk.

Reservoirs and Other Artificial Sources of Flooding

- 3.48 There are two large raised reservoirs that represent a significant flood risk to the Ponders End site, these are shown in Figure 3.1 and listed below (reservoir capacity):

- King George's Reservoir (13,970,000m³); and
- William Girling Reservoir (16,500,000m³).

These reservoirs are both owned and maintained by Thames Water. They are classed as high risk reservoirs as they have the potential to cause significant harm to life and property were they to fail. Consequently they are regulated and managed to the highest standard. These reservoirs are regularly inspected for structural defects; safety plans are prepared and maintained. For each reservoir on-site and off-site plans are required as part of the safety procedures.

- 3.49 On-site plans describe the actions that would be undertaken by the reservoir undertaker were a defect or breach to the embankment observed. As raised reservoirs are formed by creating an embankment all the way round the perimeter of the reservoir, a failure could potentially occur anywhere along this line and hence send flood waters in any direction, depending on local topography. On-site plans typically provide information on emergency draw down procedures. As raised reservoirs do not receive water directly from a watercourse there is less likelihood of failure during a flood event.
- 3.50 Off-site plans are prepared and maintained by the Emergency Planning team of the Local Authority within whose area the reservoir is located. Off-site plans are essentially evacuation plans that describe the emergency procedures that would be implemented were a catastrophic failure of the reservoir embankment to occur.
- 3.51 Reservoir flood inundation maps prepared by Defra for high-risk reservoirs are available on the Environment Agency website and show that the entire Ponders End site would be at risk from a reservoir failure. However, it is considered that these risks are adequately managed for the reasons described above. Further discussion and consideration of the risks posed by reservoirs is outside the scope of this report. There are no other artificial sources of flood risk that pose a threat to the Ponders End site.

Flood Risk Management Measures

- 3.52 One of the key messages of the CFMP¹¹ is that any re-development should reduce the risk of flooding. A large, previously developed site with extensive existing flood risk such as this one represents an excellent opportunity to improve flood risk management, benefiting future users of the area and maximising development possibilities.
- 3.53 In making more detailed allocations for development through the Local Plan, the Council will apply the Sequential Test in order to direct development to areas of low flood risk. Where this is not possible, the Council will need to be satisfied that development can meet the provisions of the Exception Test, (where required by the NPPF), and that development can be made safe in accordance with the definition below. It should be noted that there are likely to be multiple ways in which this can be achieved and it will not be possible, or desirable, for the Council to predict the exact form of development, nor the precise way in which the provisions of the Exception Test will be met. During preparation of planning applications for the site, more detailed site-specific Flood Risk Assessments (FRAs) will be required in accordance with the requirements of the NPPF and the recommendations of this study. Where the Exception Test is required, FRAs must demonstrate how the provisions of the Exception Test have been met through the detailed proposals put forward in the planning application. As such, the FRA must demonstrate that the development will be safe without increasing flood risk elsewhere. To be classed as safe, a dry access route above the 100 year plus climate change flood level or, where appropriate modelled data exists, an access route within the 'low hazard' area of the floodplain (as defined by the Environment Agency's Flood Risk Assessment Guidance for New Development R&D Technical Report FD2320⁷) to and from any residential development should be provided, finished floor levels for these developments should be set at least 300mm above the 100 year plus climate change flood level. To achieve this without increasing flood risk elsewhere, it must be shown that there will be no net loss of flood storage and that overland flow routes will not be obstructed (paragraph 3.7).
- 3.54 Drawing PE7 in Appendix A maps the extent of the defended flood outlines for the 100-year plus climate change event and other return periods. This shows that only a small proportion of the site is outside the 1000-year floodplain and therefore considered to be low flood risk. There are no constraints on development due to fluvial flood risk within the low risk area. Outside the 100-year plus climate change outline most types of development are permissible, however finished floor levels may need to be raised to ensure they are at least 300mm above the 100 year plus climate change flood level. It is recommended that a map showing the extent of the '100 year plus climate change flood level plus 300mm' should be prepared for the FRA. Additionally basement dwellings and other types of 'highly vulnerable' development, as defined in Table 2 of the Technical Guidance to the NPPF, should not be considered within this area or within the 1000-year defended flood outline.
- 3.55 As no development is proposed within the 100-year plus climate change outline no additional flood risk management measures are envisaged for this site other than those required to manage surcharging of the Brimsdown Ditch culvert (paragraphs 3.29 to 3.30), failure of the raised defence on the River Lee Mill Stream (paragraphs 3.32 to 3.33), and surface water inundation (paragraphs 3.41 to 3.44).

- 3.56 Where flood defences protecting part of the site lead to a reduction in flood storage, compensatory flood storage corresponding to the volume and level of the lost storage should be provided elsewhere on the site³. Such ‘level for level’ or ‘direct’ compensation is required to ensure that the compensatory flood storage becomes effective at the same point in a flood event as the lost storage would have done¹³. Where direct compensation is not practicable it may be possible to provide indirect compensatory flood storage. Indirect compensation typically consists of an offline flood storage area with an inflow control device such as a weir or sluice gate that only allows water to enter when the flood reaches the level at which compensatory storage is required. A controlled outfall is required to drain the flood storage area as the flood recedes. Schemes involving indirect compensation are more complex and consequently more problematic to design and operate than direct schemes. Therefore, direct compensation is preferred where possible.

Site-Specific Flood Risk Assessments

- 3.57 Guidance on the preparation of site-specific flood risk assessments for sites of varying risk across the flood zones is one of the outputs of a Level 2 SFRA (paragraph 1.5). The requirements for flood risk assessment are described in paragraph 9 of the Technical Guidance to the NPPF. Paragraph 103 of the NPPF defines when a flood risk assessment should be produced as part of a planning application. Further guidance is provided by the PPS25 Practice Guide (paragraphs 3.80 to 3.82) and in Chapter 5 of Enfield’s Level 1 SFRA. Paragraph 3.81 of the PPS25 Practice Guide lists the objectives of an FRA as to establish the following:

- whether a development is likely to be affected by current or future flooding from any source;
- whether it will increase flood risk elsewhere;
- whether the measures proposed to deal with these effects and risks are appropriate;
- if necessary provide the evidence to the LPA so that the Sequential Test can be applied; and
- whether the development will be safe and pass part c) of the Exception Test if this is appropriate.

Given the definition of safe development described in paragraph 3.7 there are two specific additional items that future FRAs in Ponders End should consider.

- 3.58 Firstly the availability of dry or low hazard access routes to all segments of the study area should be assessed for the 100 year plus climate change event. The 100 year plus climate change flood outline in drawing PE10 shows that there are no isolated ‘islands’ within the site as all areas are served by an acceptable escape route (although the EA defended flood outline and the 2D model results show some flooding across the A110 Lea Valley Road and Wharf Road both of these routes are actually elevated well above the flood level and would remain dry). The results of the Brimsdown Ditch hydraulic analysis in Appendix C show that East Duck Lees Lane would be flooded for the 100 year plus climate change event. East Duck Lees Lane provides the only direct vehicular access for the whole of the Ponders End Industrial Estate. However, further analysis reveals that as the maximum anticipated depth of flooding would be 0.1m and the velocity 0.6 m/s the flooding would be classed as low hazard and consequently considered acceptable under the revised definition of safe.

- 3.59 Secondly, it is recommended that site-specific FRAs should identify areas that are not more than 300mm above the 100 year plus climate change flood level (paragraph 3.54) to determine where finished floor levels may need to be raised to ensure development is safe. Where floor levels are required to be raised any related impacts on floodplain reduction and associated increases in flood risk elsewhere must be adequately compensated for. In addition it is recommended that basement dwellings and other types of 'highly vulnerable' development, as defined in Table 2 of the Technical Guidance to the NPPF, should not be considered within this area or within the 1000-year defended flood outline.
- 3.60 Site-specific FRAs should identify areas where residual flood risk remains (for example through the failure of flood risk management infrastructure such as blockage of culverts) and consider whether appropriate measures can be implemented to mitigate these risks. Where such risks remain, parts of developments may need to be designed to be flood resilient or flood resistant. Examples of flood resilient design measures include raising electrical circuits and other services, and using appropriate floor and wall coverings. Flood resistance measures aim to prevent flood waters from entering properties, examples include fitting flood-proof air brick covers and non-return valves to drainage systems.
- 3.61 Any future FRA should update the existing 2D TUFLOW model by including the possible outcomes of the Turkey Brook/Small River Lee critical storm for all return periods prior to carrying out any further analysis. Composite results should be created by combining the model outputs with those for the Lee critical storm. In addition, any future FRA for the Ponders End Industrial Estate should consider the suitability of options for repairing, removing or lowering the raised defence to the south-west corner of this site (paragraphs 3.32 to 3.33).

Guidance on Applicability of SUDS

- 3.62 Information on the use of sustainable drainage techniques is one of the outputs of a Level 2 SFRA (paragraph 1.5). General information on the purpose and use of SUDS can be found in Chapter 6 of Enfield's Level 1 SFRA. The guidance provided here is primarily intended to cover information relevant to the application of SUDS within the Level 2 SFRA study area. An important point to note is that since the publication of the Level 1 SFRA the Flood and Water Management Act 2010 (FWM Act) has re-defined the way that SUDS for new development will be approved and adopted in the future.
- 3.63 Although secondary legislation is required it is anticipated that the new regime for SUDS will be implemented in April 2014 or soon afterwards. Prior to this Defra will publish National SUDS Guidance. Once the new legislation is in force all new developments will be required to implement SUDS designed and constructed in accordance with this guidance. The FWM Act defines all Unitary Authorities such as the London Borough of Enfield as Lead Local Flood Authorities (LLFAs). As well as various new responsibilities related to management of local flood risk, LLFAs will be required to set up SUDS Approval Boards (SABs) who will review all new SUDS proposals. Upon satisfactory implementation the SAB will then adopt the SUDS and takeover responsibility for all future maintenance.

3.64 In relation to the new legislation Enfield are currently preparing a Development Management Document (DMD). A section of the DMD will describe Enfield's policies on SUDS requirements. It is possible that these policies may be superseded in the future by the forthcoming National SUDS Guidance, however the current proposals are as follows:

- All major developments must achieve greenfield run off rates (for 1 in 1 year and 1 in 100 year events);
- All other development should seek to achieve greenfield run off and must maximise the use of SUDS, including at least one 'at source' SUDS measure resulting in a net improvement in water quantity or quality discharging to sewer in-line with any SUDS guidance or requirements.

These policies are in line with the London Plan⁵ and Environment Agency requirements.

3.65 The greenfield mean annual flood flow rate for the whole Ponders End site is calculated as 4.42 l/s/ha using the Institute of Hydrology Report 124¹⁴ method as recommended by The SUDS Manual¹⁵. The associated 1 in 100 year greenfield runoff rate is calculated as 14.09 l/s/ha.

3.66 As described in paragraph 3.4 the area is fairly flat and the underlying bedrock is the London Clay Formation. The near surface geology consists of substantial drift deposits and although these are more permeable than the London Clay they are not necessarily suitable for infiltration based SUDS. Borehole logs taken from the south-west corner of the study area indicate a layer of sand and gravel 2.0-5.0m below ground level which is likely to be suitable for soakaways and other infiltration based SUDS. If this layer extends across the area it is possible that such solutions may be feasible at any location within the site. SUDS design considerations for individual sites will require infiltration test and borehole records. The depth to the water table is another key consideration. Infiltration based techniques are preferable where possible as they confer greater environmental benefits and are often more cost effective to implement than other types of SUDS.

3.67 Another important consideration for drainage design across Ponders End is the close proximity of much of the area to major rivers. Drainage design will have to account for the effects of restricted discharge rates caused by high river levels during storm events. Because much of the site is not much higher than the rivers themselves, as river levels rise the capacity of surface water outfalls will be significantly reduced, possibly even prevented altogether. This is likely to have implications for the amount of storage required.

3.68 Storage capacity can also be enhanced, and therefore reliance on surface water runoff infrastructure reduced, through the use of permeable surfaces throughout a development. As well as buildings opportunities to provide permeable surfaces across car parks and highways should be exploited wherever possible.

Recommendations

- 3.69 The key recommendations made in this report have been summarised below. These are to be read in conjunction with the recommendations of Enfield's Level 1 SFRA, reiterated here in Appendix F.
1. Redevelopment of Ponders End will require a detailed site-specific Flood Risk Assessment (FRA) to be submitted with each individual planning application; these are to be prepared in accordance with the requirements of the NPPF, Enfield's Level 1 SFRA and the recommendations of this study (3.53).
 2. The Sequential Test is to be applied within the site, steering development towards areas of low flood risk (paragraph 3.53).
 3. Where this is not possible the Exception Test will be applied to individual areas within the overall site, this requires that FRA demonstrates the development will be safe without increasing flood risk elsewhere. To be classed as safe:
 - A dry access route above the 100 year plus climate change flood level or, where appropriate modelled data exists, an access route within the low hazard area of the floodplain to and from any residential development should be provided;
 - Finished floor levels for these developments should be set at least 300mm above the 100 year plus climate change flood level;
 - To achieve this without increasing flood risk elsewhere, it must be shown that there will be no net loss of flood storage and that overland flow routes will not be obstructed (paragraph 3.53).
 4. Any FRAs should include a map of the site showing the extent of the area that is within 300mm of the 100-year plus climate change flood level. Basement dwellings and other types of 'highly vulnerable' development, as defined in Table 2 of the Technical Guidance to the NPPF, should not be considered within this area (paragraph 3.54).
 5. Where flood risk management measures are proposed to reduce flood risk and increase the scope for redevelopment of the site, such as those discussed in paragraph 3.55, they must be carried out in accordance with the main messages of the Thames Region Catchment Flood Management Plan¹¹ and the requirements of the Environment Agency.
 6. The 2D TUFLOW model that has been used to represent overland flows in the floodplain must be modified to include possible outcomes of the Turkey Brook/Small River Lee critical storm duration for all return periods prior to any further analysis such as site-specific Flood Risk Assessments (paragraph 3.25).

7. The outline of Flood Zone 3 in the vicinity of the Ponders End Industrial Estate should be reviewed as it is not validated by recently obtained survey data for this site (paragraph 3.26).
8. An overland flow route is required to manage exceedance flows from the Brimsdown Ditch culvert (paragraphs 3.30 and 3.32).
9. The area protected by the raised defence on the River Lee Mill Stream should be maintained as an open space. It is recommended that this defence is repaired or replaced as part of the redevelopment of the site, alternatively consideration could be given to whether it would be more appropriate to lower the defence or remove it altogether (paragraphs 3.32 to 3.33).
10. The condition and performance of all the overflow structures controlling levels on the Lee Navigation should be assessed and any necessary remedial works completed prior to redevelopment of the site (paragraphs 3.38 to 3.39)
11. Where site-specific FRAs identify areas of residual flood risk (for example through failure of flood risk management infrastructure such as culverts), this should be mitigated by implementing flood resilience or resistance measures to individual properties (paragraph 3.60).
12. The proximity of Ponders End to various river channels and the topography of the site signify the importance of ensuring that surface water runoff is controlled on site (paragraph 3.41). Sustainable Drainage Systems (SUDS) are to be employed for all new developments and attenuation is to be provided up to a 1 in 100 year event with climate change (paragraph 3.64). It is likely that overland storage will be required to achieve this, this may create opportunities to provide enhanced green spaces within the site.
13. Future redevelopment of the site must aim to incorporate any relevant measures identified by the Surface Water Management Plan for Enfield (paragraph 3.42).

These recommendations accord with the main messages and objectives of the Thames Region Catchment Flood Management Plan¹¹ and the Lower Lee Flood Risk Management Strategy¹². This document should be reviewed as improved data on flooding becomes available or as government policy updates require.

Conclusions

- 3.70 This Level 2 SFRA has been prepared to investigate in further detail the potential risk of flooding associated with the Ponders End Priority Regeneration Area. It forms a critical element of the evidence base to support the planning process.

4.0 LEVEL 2 SFRA: MERIDIAN WATER

Site Description

- 4.1 The River Lee valley was formed by melt waters flowing towards the River Thames at the end of the last ice age. This created a low-lying area of marshes and floodplains. In recent centuries the landscape has been significantly altered to drain the marshes and create usable space. The availability of water required by industrial processes and the proximity to water based transport systems offered a significant draw for the industries that have historically thrived in the area. The Meridian Water Priority Regeneration Area is situated in the Lee valley at the south-east corner of Enfield.

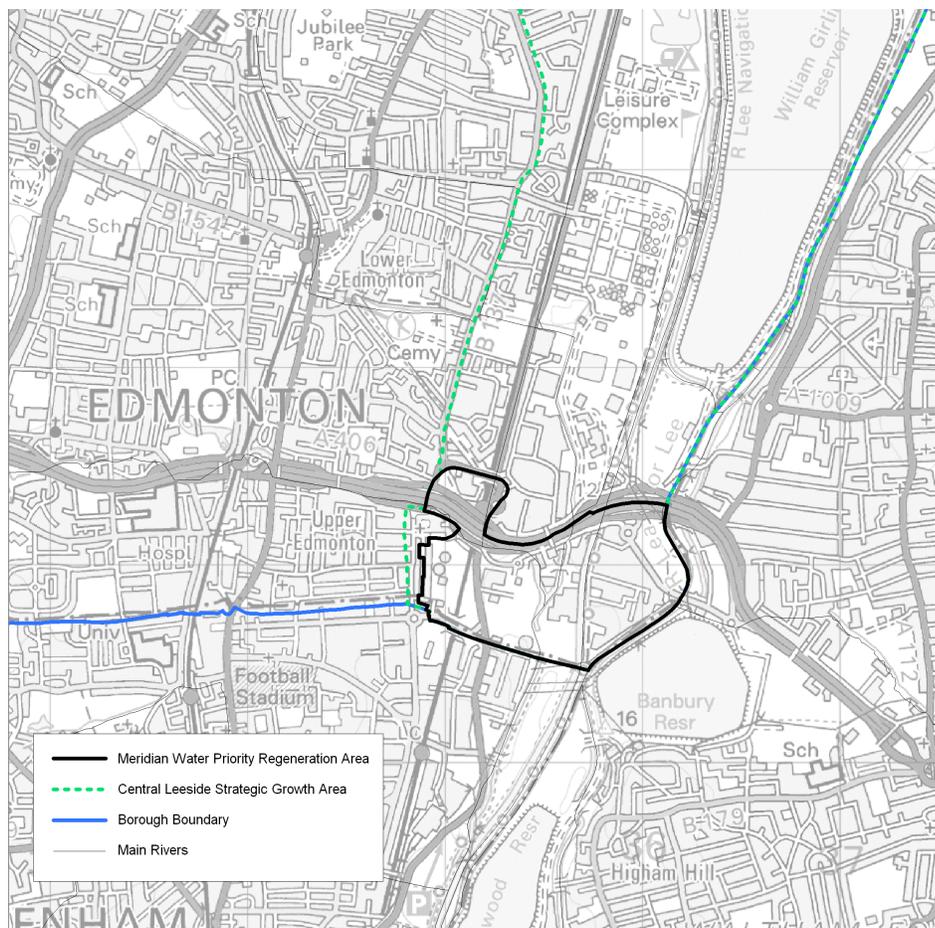


Figure 4.1 Location of Meridian Water Priority Regeneration Area

- 4.2 The site is crossed by several significant watercourses including the Lee Navigation and the River Lee Flood Relief Channel, which forms the east boundary of the site, as well as Pymmes Brook and Salmons Brook which are both tributaries of the Lee. All the rainfall runoff generated in Enfield drains through this site.

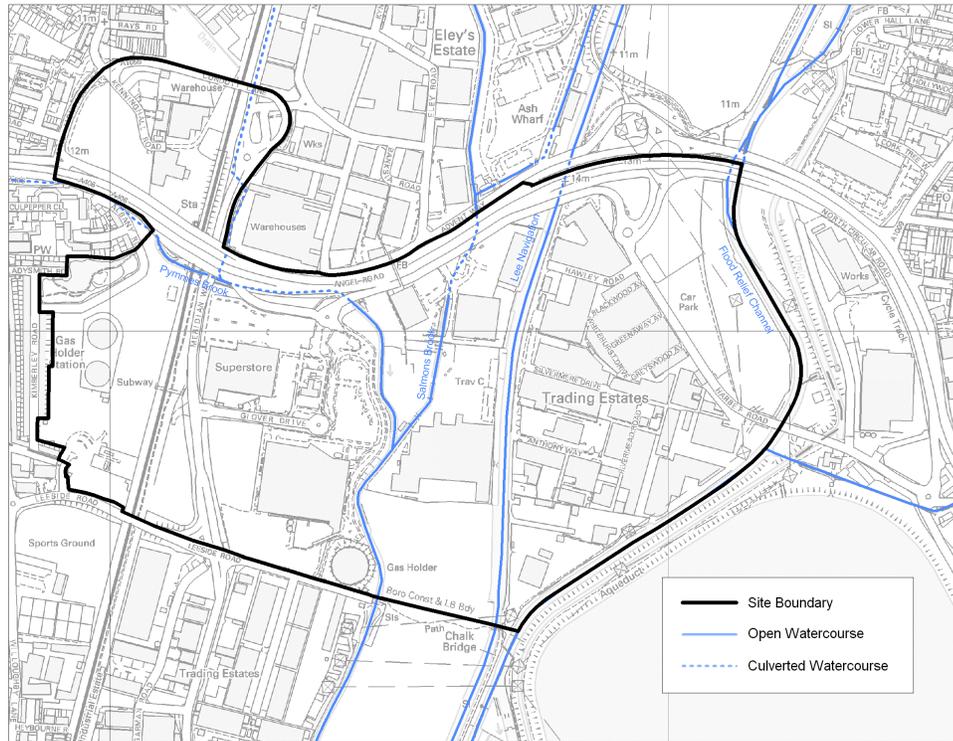


Figure 4.2 Meridian Water Site Map

- 4.3 It is a relatively flat area varying in height from 8 metres above sea level at the lowest point to just 12 metres or so at the highest. The underlying geology of the site, in common with the whole of Enfield, is the London Clay formation. Above this however there are substantial drift deposits consisting of Alluvium, Enfield Silt and Kempton Park Gravel, see drawing MW3 in Appendix D. Though these deposits are far more permeable than London Clay, only the Kempton Park Gravel and Alluvium are considered significantly permeable such that they may have a bearing on groundwater flood risk and opportunities to create infiltration based Sustainable Drainage Systems (SUDS).
- 4.4 In recent years the area has gradually developed from a primarily industrialised space to one that incorporates a significant proportion of large-scale retail units including a Tesco superstore and a branch of Ikea, both of which are visible in Figure 4.3 below. The site is almost completely previously developed, there are some minor areas of green space along the east and west boundaries.



Figure 4.3 Aerial photograph of Meridian Water, looking north with approximate position of site boundary shown (<http://www.dwyer.co.uk>)

- 4.5 Around 20 years ago significant alterations were made to the highway and drainage infrastructure that cross the area as part of upgrade works to the A406 North Circular Road, which forms the north boundary of the site, and the A1055 North-South Route. This involved the creation of multi-span flyovers carrying the North Circular over the North-South Route, Lee Navigation and Flood Relief Channel with associated culverting and channelisation works to Pymmes Brook and Salmons Brook.
- 4.6 Future development of the site will aim to create a mix-used community combining residential properties with employment sites and other commercial buildings.

The Exception Test

- 4.7 Enfield's High Level Sequential Test⁶ demonstrates that the Meridian Water site passes parts a) and b) of the Exception Test. Re-development of the previously-developed land is an opportunity to reduce the gap between housing demand and provision and provide significant opportunities for employment to boost the local economy. It also offers opportunities to attain wider sustainability benefits by creating new, mixed-use communities that make the best use of the area's assets, providing green transport links and creating a high quality public realm as part of the development.

- 4.8 Re-development also represents an opportunity to create a safe place that can reduce overall flood risk and thereby pass part c) of the Exception Test. Enfield's Level 1 SFRA defines safe development as follows: to be classed as safe, a dry access route above the 100 year plus climate change flood level to and from any residential development should be provided, finished floor levels for these developments should be set at least 300mm above this level. As this study presents new mapped outputs based on improved flood modelling (see paragraph 4.18 below) it is considered appropriate to re-define safe development for the purposes of this report as follows: to be classed as safe, a dry access route above the 100 year plus climate change flood level or, where appropriate modelled data exists, an access route within the 'low hazard' area of the floodplain (as defined by the Environment Agency's Flood Risk Assessment Guidance for New Development R&D Technical Report FD2320⁷) to and from any residential development should be provided, finished floor levels for these developments should be set at least 300mm above the 100 year plus climate change flood level. To achieve this without increasing flood risk elsewhere, it must be shown that there will be no net loss of flood storage and that overland flow routes will not be obstructed. The flood hazard maps that have been developed for Meridian Water are described further in paragraph 4.29.
- 4.9 The remainder of this chapter is concerned solely with part c) of the Exception Test. It includes a detailed assessment of the risk of flooding from all sources, considers the effects of flood defences and identifies policies and practices required to ensure that development in flood risk areas satisfy the requirements of the Exception Test.

Fluvial Flooding

- 4.10 As fluvial flood risk is the main driver for carrying out a Level 2 SFRA for Meridian Water, this form of flood risk will be looked at in detail first. The other forms of flooding described in paragraph 1.6 will then be considered. As tidal flooding does not affect Enfield it has not been further considered in this study.
- 4.11 The extent of the Environment Agency flood zones shown in drawing MW5 in Appendix D demonstrates that fluvial flood risk is a major constraint to the development of this site. These flood zones are based primarily on the Lee Hydrology and Mapping Study⁸, which was completed in March 2007. This study used the Flood Estimation Handbook⁹ methodology and a hydrodynamic flow model in conjunction with a digital terrain model to predict flood flows and the extent of the floodplain across the Lee catchment area. The Environment Agency flood zones are generally based on the undefended flood outlines from this model. The exceptions include Flood Zone 3b, which is based on the defended flood outlines, and Flood Zone 2, which also includes the full extent of the Environment Agency's historical flood records. The 'Defended Areas' mapped in drawing MW7 represent the areas outside the 1000 year undefended flood outline defined by the Lee model but within the historical flood outline. The explanation for this apparent discrepancy is that significant enhancements to the network of channels that convey flows on the Lee were carried out following widespread flooding across the valley in 1947, see paragraph 4.17 for more information.

4.12 The Lee Hydrology and Mapping Study⁸ describes the assumptions made to define the undefended flood outlines:

- flood storage areas assumed full prior to flood event;
- flow control structures assumed closed such that flood flows are forced to weir over the top; and
- raised defences assumed to have failed.

This scenario was modelled in such a way that any benefits, such as flood waters being stored upstream due to failure of raised defences, were not accrued downstream.

4.13 There are four principal rivers that cross Meridian Water, these are:

- Pymmes Brook;
- Salmons Brook;
- Lee Navigation; and
- River Lee Flood Relief Channel.

4.14 The Pymmes Brook catchment covers a total area of 4,230 hectares with an urban extent of 44%. It rises just outside Enfield in Barnet and runs for almost 20 kilometres before joining the Lee Navigation at Tottenham. The geology of the catchment is impermeable London Clay with some alluvial deposits. The river is heavily engineered with 2 kilometres of culvert and over 6 kilometres of concrete lined channels. These factors combine to create a relatively flashy river system that has a low baseflow component and responds quickly to rainfall events.

4.15 The Salmons Brook catchment is similar in area, 4,170 hectares, and geology type to Pymmes Brook. However the extent of urbanisation is slightly less at 35% and the upstream sections are more naturalised, though the river does pass through a series of culverts before reaching its confluence with Pymmes Brook within the Meridian Water site. In addition, Salmons Brook is fed by several tributaries such as Saddlers Mill Stream, Houndsden Gutter and Brimsdown Ditch that drain urban areas and are largely culverted or channelised. Consequently Salmons Brook has similar flow characteristics to Pymmes Brook, the main difference being that Salmons Brook derives much of its dry weather flow from the treated effluent discharged by Deephams Sewage Treatment Works at Picketts Lock.

4.16 The total catchment area of the River Lee is over 140,000 hectares, most of which is outside London and consists of mainly rural areas underlain by permeable Chalk. Consequently the response time of the River Lee to extreme rainfall events will be much longer and slower than those of Pymmes Brook and Salmons Brook. Floods on the River Lee will also be more prolonged. Refer to Enfield's Level 1 SFRA³ for further information and maps regarding these watercourses and their catchment areas.

- 4.17 The Flood Relief Channel was constructed in the 1970s as a result of widespread flooding within the Lee valley in 1947, the extent of which is shown in drawing MW4 in Appendix D. This 20 metre wide concrete channel has a very high conveyance capacity compared to the Lee Navigation and is designed to carry the vast majority of flood flows during an extreme event, see drawing MW6 in Appendix D for a visual depiction of the discrepancy in flow rates carried by the two channels during a 100 year plus climate change flood event. Much of the flow in the Lee Navigation is actually derived from Turkey Brook and the Small River Lee, these are tributaries that enter the Lee near the north-east corner of Enfield. Both rivers have highly ruralised catchments similar in size to that of Salmons Brook. Consequently the hydrographs in Appendix E show a double peak for flows on the Lee Navigation. For the 100 year plus climate change storm the first peak (derived primarily from the Turkey Brook and Small River Lee catchments) is larger than the second peak (derived from the whole Lee catchment), whereas for the 1000 year event the second peak is much larger. This is because the standard of protection provided by the Flood Relief Channel is exceeded to such an extent that significantly more flow is diverted down the Lee Navigation and the dominant source of flow becomes the whole Lee catchment. It is worth noting that the critical storm for the Turkey Brook/Small River Lee catchments causes no flooding at Meridian Water. Flow levels on the Lee Navigation are controlled to a certain extent by a series of overflow structures that divert flow to the Flood Relief Channel. As a result of these conditions and the extent of the floodplain across Meridian Water it is broadly accurate to attribute the total risk of fluvial flooding across the area fairly evenly between the River Lee and its two tributary rivers, Pymmes Brook and Salmons Brook.
- 4.18 Since publication of the Lee Hydrology and Mapping Study⁸ in 2007 a two-dimensional (2D) model covering the breadth of the Lee valley from south of Enfield up to the M25 Motorway has been developed with the aim of providing enhanced flood risk assessment of the Central Leaside Strategic Growth Area. The background to this model and a detailed description of its development can be found in the Central Leaside Baseline Hydraulic Modelling Report¹⁰, completed in November 2008. The new model uses the one-dimensional (1D) ISIS model from the Lee Hydrology and Mapping Study to simulate in-channel flows, this is then linked to a 2D TUFLOW model which represents overland flows in the floodplain. This combined model represents flood flows more realistically than the 1D model alone and is therefore considered a significant improvement. The 2D model provides outputs including flood flow, depth and velocity data in addition to the flood outlines.
- 4.19 In early 2010 the model was reviewed by the Environment Agency to assess whether outputs from the 2D model could be incorporated into, and thereby improve the accuracy of, the Environment Agency flood zones. Though the model was originally reviewed and approved by the Environment Agency in 2008 the 1D Lee model on which the 2D model is based has since been updated resulting in increased flows on Pymmes Brook and Salmons Brook for high-order flood events. Consequently, it was necessary to update the original 2D model in line with the latest 1D Lee model. These amendments were completed following advice from the Environment Agency in March 2011. The Meridian Water Master Plan Options and Flood Risk Modelling Report¹⁶ provides further information about how this work was carried out.

- 4.20 The updated baseline 2D model represents the existing, defended flood risk situation at Meridian Water and will form the basis of the fluvial flood risk analysis for this report, it allows detailed consideration of the nature of the flood hazard as required by the PPS25 Practice Guide⁴. Outside of this report the model will be used to test possible scenarios for future re-development of the site; the results of these tests will inform site design and future site-specific Flood Risk Assessments (FRAs) as required by the development process. The outputs from the baseline 2D model are displayed in drawings MW8 to MW15 in Appendix D.
- 4.21 These outputs are based on a composite of model results derived from two different storm durations, one that is critical for the whole Lee catchment and one that is critical for the tributaries Pymmes Brook and Salmons Brook. This method ensures that the maximum possible flood extents for each return period are presented for each catchment.



Figure 4.4 Defence on top of retaining wall on south side of Pymmes Brook at culvert entrance

- 4.22 Drawings MW8 to MW11 provide a comparison between the updated 2D model outputs and the latest Environment Agency defended flood maps. Although the 2D model is a more sophisticated simulation than the older model, the 2D outputs appear more pixelated or 'blocky' than those of the 1D version, this is due to the method used by the two model types to determine the extent of the floodplain. The 2D model is based on a grid with a 15-metre resolution covering the entire model area. There are model nodes at the corner and half-way point of each grid square, hence each block is 7.5 metres wide. The floodplain given by the 1D model is defined by taking a flood level at each model node along each river and using GIS software to determine how far the flooding would extend out of bank based on LiDAR data. This leads to a smoother shape for the 1D model based flood outlines. Other more significant differences exist in certain areas, however as the 2D model has now been updated in line with Environment Agency requirements these discrepancies can be put down to deficiencies in the 1D model used to define the defended flood maps. Consequently, the 2D model outputs will be taken as the definitive flood maps for the purposes of this assessment.

4.23 In general the flood extents shown in drawings MW8 to MW11 demonstrate that while there is very little out of bank flooding for a 1 in 20 year flood event, for higher-order events an extensive proportion of the site is likely to be inundated with floodwaters.

The majority of the Priority Regeneration Area comprises previously developed land. The Core Strategy (policies 37-38) states that future development create a mix-used community combining residential, education, retail, community, employment and leisure uses. Further detail regarding the arrangement of uses is not yet available.

The type of development proposed in Meridian Water is classed as ‘Less Vulnerable’ or ‘More Vulnerable’ (Technical Guidance to the NPPF Table 2). Given this, and Enfield’s adopted definition of ‘safe development’ (paragraph 4.8), the 100-year plus climate change flood map is the appropriate scenario under consideration for application of the Exception Test. Drawing MW10 shows that for this eventuality there are several areas within the site at risk of flooding, including an area to the west of Meridian Way and a wide sweep of land stretching approximately from the confluence of Pymmes Brook and Salmons Brook to the Lee Navigation and continuing onwards to the Flood Relief Channel at the eastern boundary of the site. The flooded areas across the site have been considered as five distinct sites for the purposes of this assessment, these are described below and shown in Figure 4.5:

- Area A – industrial area sandwiched between the North Circular, Conduit Lane and the railway line to the east;
- Area B – land owned by National Grid to the west of the railway line, currently occupied by two disused gas holders;
- Area C – low-lying area between Salmons Brook and the Lee Navigation, roughly in the centre of Meridian Water
- Area D – area of ‘Trading Estates’ to the east of the Lee Navigation;
- Area E – area at risk of flooding from the Flood Relief Channel along the eastern boundary of Meridian Water.

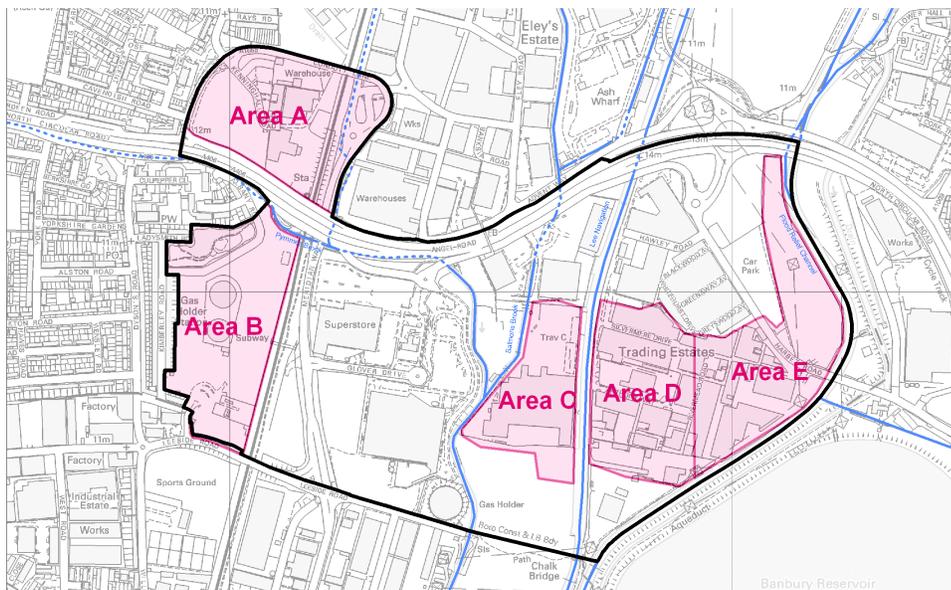


Figure 4.5 Flood risk areas A, B, C, D and E

- 4.24 For the 100-year plus climate change event Area A is flooded extensively by overland flows from Pymmes Brook and Salmons Brook originating outside Meridian Water. Drawing MW12 shows that typical depths are around 0.1 metres though an area in the south-west corner is shown to be under 0.5 metres of water. Though flowing, the water is almost static, maximum predicted velocities for most of the site are in the order of 0.01 m/s; a small area to the north-west experiences velocities up to 0.2 m/s (see drawing MW13). Though flooded by the Lee tributaries, the mechanism of flooding means that this site is inundated fairly late in the cycle. Flooding occurs around 14 hours after the start of the storm event quickly reaching peak levels. By 20 hours the water is starting to recede at a fairly slow rate.
- 4.25 Area B is affected to lesser extent, around a quarter of the land is flooded by overland flows originating from Pymmes Brook just outside of Meridian Water. Typical depths within the flooded area approximately 0.5 metres with an estimated maximum of 0.9 metres (drawing MW12). Velocities are low, predominantly less than 0.1 m/s though one small area experiences speeds up to 1 m/s (drawing MW13). Again flooding commences fairly late in the flood cycle, approximately 16 hours after the start of the event. The full extent is reached by 19 hours, water levels are shown to start receding almost immediately though after 24 hours the extent of flooding is still around 90% of the maximum.
- 4.26 Area C is flooded solely by the Lee Navigation, waters spill out of bank at a low point and flood the area to the west. A 0.6 metre high wall along the western edge prevents spilling to Pymmes Brook or Salmons Brook. Depths here are significant, up to 1.2 metres in the low-lying northern half (drawing MW12). This area starts to flood 20 hours after the start of the event, by 23 hours the entire area is flooded. The extent of flooding is no less severe after two days. This is due to the double flood peak that passes along the Lee Navigation (see hydrographs in Appendix E, also refer to paragraph 4.17). The first peak arrives at 22 hours, the second at 46 hours (flood flows return to normal levels by 66 hours). There are no significant overland flows once the initial inundation is complete, even during this phase velocities are typically less than 0.1 m/s (drawing MW13).
- 4.27 Flood waters inundating Area D on the east side of the Lee Navigation extend towards and converge with water spilling from the Flood Relief Channel further east. The topography of the site means that when the flow capacities of these channels are exceeded the rivers break their banks and rapidly flood wide areas to relatively shallow depths. Analysis suggests there is limited connectivity between the two water bodies, in general flood waters return to source as peak levels on the rivers recede. As there is no significant transfer of flow, flooding from the Lee Navigation and the Flood Relief Channel can be looked at separately. Consequently Area D refers solely to the area flooded by the Lee Navigation – the eastern edge of this area is roughly in line with Rivermead Road. Maximum flood depths are approaching 0.4 metres (drawing MW12). Velocities are near static with typical maximum values less than 0.1 m/s (drawing MW13). For the 100 year plus climate change event flooding occurs from around 17 hours after the start of the storm event, waters reach a maximum extent after 23 hours. After two days the floodwaters have dissipated significantly. This is because the second peak (described above in paragraph 4.26) is of slightly lesser magnitude than the first and does not affect this site to the same extent.

- 4.28 Consequently Area E refers to the area flooded solely by water originating from the Flood Relief Channel, for the 100-year plus climate change event this includes all flooded land east of Rivermead Road. Flood depths range from zero to 1.2 metres (drawing MW12), the deepest areas of flooding are within the green space to the north of Harbet Road. Maximum velocities are predicted to occur just south of Harbet Road close to the banks of the Flood Relief Channel, even here maximum velocities are likely to be not much greater than 1.2 m/s. Values in the order of 0.2 m/s are anticipated in the area north of Harbet Road and less than 0.1 m/s elsewhere (drawing MW13). Flooding occurs approximately 18 hours after the start of the storm event, with most of the area still flooded after two days. Due to the nature of the network of weirs and channels that contribute flow to the Flood Relief Channel the estimated peak flow of around 180m³/s (for the 100 year plus climate change event) is sustained for over 40 hours.
- 4.29 Flood hazard maps for the Meridian Water site have been prepared using the methodology described in section 13.7.2 of Environment Agency's Flood Risk Assessment Guidance for New Development R&D Technical Report FD2320⁷. This technique expresses the danger to people as a combination of flood depth and velocity, thereby dividing the floodplain into the following categories:
- Low hazard – typically flood depths below 0.25 m and velocities below 0.5 m/s but also includes higher velocities for very shallow depths;
 - Moderate hazard (Danger for some) – includes children, the elderly and the infirm;
 - Significant hazard (Danger for most) – includes the general public; and
 - Extreme (Danger for all) – includes the emergency services.

Drawing MW15 demonstrates that for the 100 year plus climate change scenario the areas likely to experience out of bank flooding across Meridian Water fall into the 'low hazard' and 'moderate hazard' categories.

Flood Defences

4.30 The differences between the undefended scenario represented by the Environment Agency Flood Zones and the defended scenario shown by the flood maps in drawing MW7 and the 2D model outputs are described in paragraph 4.12. There are no flood storage areas, flow control structures or raised defences within the Meridian Water site. Consequently the only flood defences within the site, which would have an adverse impact on flood risk were they to fail, are the channel walls and culverts that have replaced the natural river banks and beds. The location and extent of these structures are shown in drawing MW16 in Appendix D.



Figure 4.6 Pymmes Brook at southern boundary



Figure 4.7 Confluence of Pymmes Brook and Salmons Brook



Figure 4.8 Lee Navigation left-hand bank



Figure 4.9 Lee Navigation right-hand bank



Figure 4.10 Flood Relief Channel looking upstream from Harbet Road



Figure 4.11 Flood Relief Channel looking downstream from Harbet Road

- 4.31 These defences are mostly less than 40 years old and are built to modern standards. The Pymmes Brook and Salmons Brook channels were almost entirely re-constructed in the early 1990s as described in paragraph 4.5. The channelised sections of these rivers are primarily composed of reinforced concrete U-shaped channels with some minor sections of sheet piling added more recently. The covered sections are precast concrete box culverts. The reinforced concrete U-shaped channel of the Flood Relief Channel was constructed in the 1970s. The open channel sections of the Pymmes Brook and the Flood Relief Channel are owned and maintained by the Environment Agency.
- 4.32 The Lee Navigation channel is owned and managed by British Waterways. It is made up of a diverse range of different construction types including sheet piling, reinforced concrete, mass concrete and masonry retaining walls in places. Though less robust structurally the large size of the channel relative to its flow rates, even a 100 year flood event would only result in a velocity of 0.5 m/s, mean that failures such as collapse of one of the banks due to erosion are both less likely to occur and less likely to have a significant impact on flooding.
- 4.33 As these flood defences are on main rivers they are visually inspected annually by the Environment Agency for structural defects. Many of these features are also classed as highway structures as they take highway loading or in some way form part of the highway infrastructure. Consequently, they are also regularly inspected, typically on a bi-annual basis, by the relevant highway authority – either the London Borough of Enfield or Transport for London who own and maintain the North Circular Road. Any significant defects that are observed are recorded, monitored and where necessary re-mediated. The inspection records for these defences have been reviewed; no significant outstanding defects were identified.
- 4.34 The future management of these defences will to a large extent be determined by the policies set out in two key Environment Agency documents, the Thames Region Catchment Flood Management Plan (CFMP) ¹¹ and the Lower Lee Flood Risk Management Strategy ¹². These documents along with the types of defences that are prevalent in Enfield, and the advantages and disadvantages associated with them, are discussed in greater detail in Enfield's Level 1 SFRA ³. The main messages of these documents are:
- at present it is still possible to maintain existing flood defences;
 - climate change will mean that these defences will become less effective in the future, therefore make sure that:
 - any redevelopment reduces the residual flood risk in the areas benefiting from these flood defences using the measures set out in Planning Policy Statement 25: Development and Flood Risk (note: this document has now been superseded by the NPPF);
 - the natural flood plain is used upstream and downstream of these areas to accommodate additional floodwater;
 - re-create river corridors so there is more space for the river to flow and flood naturally;
 - flood risk management planning needs to be linked closely with regeneration and redevelopment so that the location and layout of development can help to reduce flood risk;

- organisations need to work together to manage all flood sources: fluvial, surface water and sewer flooding.

The Level 1 SFRA also recommends that in general, opportunities should be sought to set back development from the river edge to enable sustainable and cost effective flood risk management options.

- 4.35 Flood defences outside the site, such as Fieldes Weir, which controls the flows on the Flood Relief Channel, can have a significant bearing on flood risk within the site. Though these defences have not been reviewed in detail they are subject to the policies and practices set out in the CFMP¹² and are regularly inspected by the Environment Agency.
- 4.36 Aside from the channelisation works within Meridian Water there are not known to be any existing flood alleviation schemes within the site. Following severe flooding in October 2000, which affected several hundred properties in the Edmonton area, a flood alleviation scheme for the Salmons Brook has been developed by the Environment Agency. This project is in the planning stages; current proposals involve a flood storage area in the upper part of the catchment and another one close to the area most at risk of flooding. However, it is understood that this scheme will have little impact on the Meridian Water site, as the controlled outflows from the downstream area will not be significantly curtailed.
- 4.37 Given the condition and nature of the existing flood defences at Meridian Water in combination with current and proposed future maintenance policies the risk of structural failure of these defences is considered to be negligible. The presence of culverted watercourses across the site and the residual flood risk associated with the possibility of blockages occurring during an extreme flood event may be significant however. Articles of floating debris transported down river during high water events have been known to form dams within culverts where large items such as tree branches or even trunks can become lodged on protruding elements such as step irons and surface water outfalls. Such occurrences can lead to significant constraints on flow capacities and subsequent overtopping at the upstream end of the culvert. The risk of blockages occurring is exacerbated by the difficulty in identifying and alleviating them prior to or during a flood event.
- 4.38 Within or near Meridian Water there are several culverts and bridges where blockages could potentially occur, these have been individually assessed. The only blockage scenario likely to have a significant effect on the site is the one associated with the Pymmes Brook culvert below Angel Road to the east of Meridian Way. Blockage of this culvert would cause flows to weir over the retaining wall on the right-hand side of the channel potentially flooding a wide area before flowing back into Pymmes Brook downstream of the confluence with Salmons Brook. Consequently, flood risk management measures may be required to ensure that the post-development residual flood risk is controlled adequately. This could be achieved by landscaping the site to create an overland flow route from the upstream end of the culvert to a point on Pymmes Brook further downstream. Alternative options for mitigating residual flood risk include flood resilience measures, such as raising finished floor levels above the natural ground level or raising electrical circuits and other services, or installing telemetry to provide an early warning of rising water levels. Any future site-specific FRAs for this area should address the residual risk represented by possible culvert blockage.

Surface Water Flooding

- 4.39 Surface water flooding refers to localised flood events caused by rainfall runoff before or soon after it has entered the local drainage network. Flooding may occur because of the operational failure of drainage infrastructure such as pipes and grilles or because intense rainfall leads to saturation of the ground combined with inundation of sewers and drains. Expected increases in rainfall intensity due to climate change will lead directly to increased risk of surface water flooding³. In areas close to rivers, fluvial flooding can also exacerbate surface water flooding as high river levels prevent surface water outfalls from discharging freely. Consequently the proximity of the various river systems across Meridian Water will have a bearing on how surface water is managed on site.
- 4.40 There are two primary sources of data available for assessment of surface water flood risk. These are historical records of surface water flood events and the results of a study conducted for Enfield's Surface Water Management Plan (SWMP) that has been prepared as part of the Drain London project. Drain London is a consortium of organisations led by Greater London Authority and including the Environment Agency, Thames Water, London Councils, Transport for London and London Boroughs. This study assesses surface water flood risk by mapping high-risk areas and identifying Critical Drainage Areas (CDAs) and potential flood alleviation measures.
- 4.41 Enfield's surface water flooding records for Meridian Water and the surrounding area are shown in drawing MW4 in Appendix D. There are only two records in this area, both are attributed to operational failure, lack of capacity due to restrictions in the pipework in both cases, rather than extreme rainfall or an inherent capacity issue in the drainage network that would lead to repeated problems. Though Enfield has recently implemented procedures to improve recording of flood events, past events are recorded patchily. It is possible that significant surface water flood problems exist but are undocumented.
- 4.42 The Drain London surface water flood maps were produced by taking a design storm of 3 hours duration and applying it evenly over an area using topographical data to determine where surface water flows would flow overland and accumulate. The drainage infrastructure was allowed for by removing 6.5mm/h from the rainfall hyetographs. The main use of these maps is to identify areas where further investigation is required. The results for Meridian Water are shown in drawings MW17 and MW18 in Appendix D. These show several places across the study area where significant quantities of surface water are estimated to flow and pond. However, the SWMP concludes that these areas do not warrant definition as Critical Drainage Areas. Further analysis of surface water flood risk is outside the scope of this report, however any future site-specific FRAs should address surface water flood risks in greater detail with a focus on the at risk areas identified by the Drain London study.

Groundwater Flooding

- 4.43 Groundwater flooding is caused by subterranean water that flows back above ground, this occurs at the interface between the water table and the surface. Groundwater flooding will only occur in or near areas where the underlying rocks and soils are capable of transporting significant quantities of water. Drawing MW3 in Appendix D shows the extent of the various alluvial deposits that cover the Meridian Water area. As described in paragraph 4.3 both the Kempton Park Gravel and Alluvium formations can be considered sufficiently permeable to have a bearing on groundwater flood risk, these layers cover around two-thirds of the site. A new groundwater flood risk dataset has been derived for Enfield's Surface Water Management Plan (SWMP) as part of the Drain London project described in the previous section. The extent of this 'increased Potential for Elevated Groundwater' (iPEG) is shown in Figure 4.12 below.

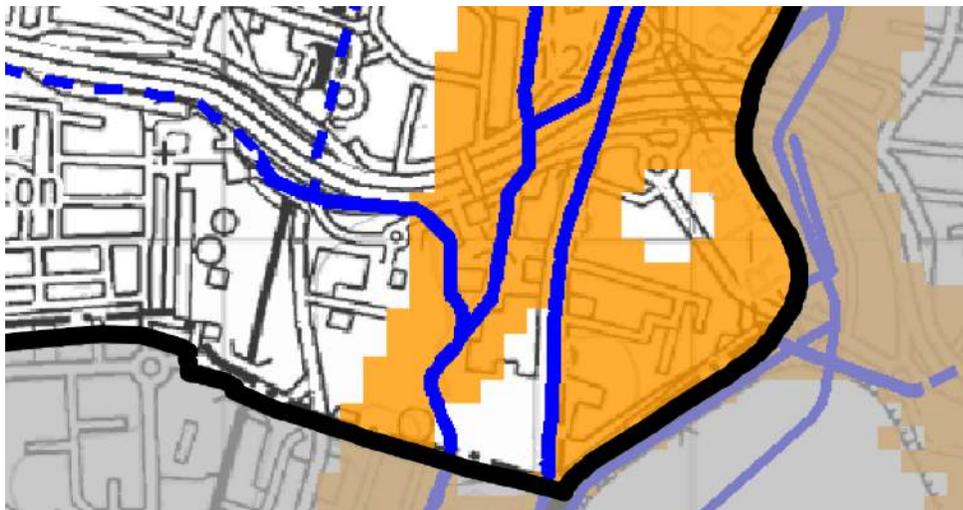


Figure 4.12 Shaded area shows 'increased Potential for Elevated Groundwater' taken from Enfield's Surface Water Management Plan

- 4.44 The iPEG mapping shows those areas within the borough where there is an increased potential for groundwater to rise sufficiently to interact with the ground surface or be within 2 m of the ground surface. Though much of the site is shown to be within the iPEG area the near surface geology within this zone is almost entirely Alluvium which is at the impermeable end of the spectrum of permeable layers. In addition, no groundwater flooding incidents have been recorded within the site by the Environment Agency or Enfield Council. It is therefore considered that groundwater flooding is not a significant risk in this area. Nevertheless the practices and policies regarding groundwater flood risk set out in Enfield's Level 1 SFRA should be followed as appropriate.

Sewer Flooding

- 4.45 The public sewerage network in Enfield is managed by Thames Water Utilities Limited (Thames Water). Thames Water's records show that only 3 foul water sewer-flooding incidents have been reported in the vicinity of Meridian Water in the last ten years, no surface water sewer flooding has been reported in this time. Although sewer flooding incidents are sometimes under reported, based on the available evidence it appears that sewer flooding does not represent a significant risk to properties in Meridian Water. It is likely that re-development of the site will require considerable re-configuration of the existing sewer network; this will be designed and constructed to modern standards, further reducing the risk.

Reservoirs and Other Artificial Sources of Flooding

- 4.46 There are three large raised reservoirs that represent a significant flood risk to the Meridian Water site, these are shown in Figure 4.1 and listed below (reservoir capacity):

- King George's Reservoir (13,970,000m³);
- William Girling Reservoir (16,500,000m³); and
- Banbury Reservoir (capacity unknown).

These reservoirs are all owned and maintained by Thames Water. They are all classed as high risk reservoirs as they have the potential to cause significant harm to life and property were they to fail. Consequently they are regulated and managed to the highest standard. These reservoirs are regularly inspected for structural defects; safety plans are prepared and maintained. For each reservoir on-site and off-site plans are required as part of the safety procedures.

- 4.47 On-site plans describe the actions that would be undertaken by the reservoir undertaker were a defect or breach to the embankment observed. As raised reservoirs are formed by creating an embankment all the way round the perimeter of the reservoir, a failure could potentially occur anywhere along this line and hence send flood waters in any direction. On-site plans typically provide information on emergency draw down procedures. As raised reservoirs do not receive water directly from a watercourse there is less likelihood of failure during a flood event.
- 4.48 Off-site plans are prepared and maintained by the Emergency Planning team of the Local Authority within whose area the reservoir is located. Off-site plans are essentially evacuation plans that describe the emergency procedures that would be implemented were a catastrophic failure of the reservoir embankment to occur.
- 4.49 Reservoir flood inundation maps prepared by Defra for high-risk reservoirs are available on the Environment Agency website and show that the entire Meridian Water site would be at risk from a reservoir failure. However, it is considered that these risks are adequately managed for the reasons described above. Further discussion and consideration of the risks posed by reservoirs is outside the scope of this report. There are no other artificial sources of flood risk that pose a threat to the Meridian Water site.

Flood Risk Management Measures

- 4.50 One of the key messages of the CFMP¹¹ is that any re-development should reduce the risk of flooding. A large, previously developed site with extensive existing flood risk such as this one represents an excellent opportunity to improve flood risk management, benefiting future users of the area and maximising development possibilities.
- 4.51 In making more detailed allocations for development through the Local Plan, the Council will apply the Sequential Test within the Meridian Water area in order to direct development to areas of low flood risk. Where this is not possible, the Council will need to be satisfied that development can meet the provisions of the Exception Test, (where required by the NPPF), and that development can be made safe in accordance with the definition below. It should be noted that there are likely to be multiple ways in which this can be achieved and it will not be possible, or desirable, for the Council to predict the exact form of development, nor the precise way in which the provisions of the Exception Test will be met. During preparation of planning applications for the site, more detailed site-specific Flood Risk Assessments (FRAs) will be required in accordance with the requirements of the NPPF and the recommendations of this study. Where the Exception Test is required, FRAs must demonstrate how the provisions of the Exception Test have been met through the detailed proposals put forward in the planning application. As such, the FRA must demonstrate that the development will be safe without increasing flood risk elsewhere. To be classed as safe, a dry access route above the 100 year plus climate change flood level or, where appropriate modelled data exists, an access route within the 'low hazard' area of the floodplain (as defined by the Environment Agency's Flood Risk Assessment Guidance for New Development R&D Technical Report FD2320⁷) to and from any residential development should be provided. Finished floor levels for these developments should be set at least 300mm above the 100 year plus climate change flood level. To achieve this without increasing flood risk elsewhere, it must be shown that there will be no net loss of flood storage and that overland flow routes will not be obstructed (paragraph 4.8).
- 4.52 Drawing MW7 in Appendix D maps the extent of the defended flood outlines for the 100-year plus climate change event and other return periods. This shows that approximately half the site is outside the 1000-year floodplain and is therefore considered to be low flood risk. There are no constraints on development due to fluvial flood risk within the low risk area. Outside the 100-year plus climate change outline most types of development are permissible, however finished floor levels may need to be raised to ensure they are at least 300mm above the 100 year plus climate change flood level. It is recommended that a map showing the extent of the '100 year plus climate change flood level plus 300mm' should be prepared for the FRA. Additionally basement dwellings and other types of 'highly vulnerable' development, as defined in Table 2 of the Technical Guidance to the NPPF, should not be considered within this area or within the 1000-year defended flood outline.

4.53 Within the 100-year plus climate change outline most types of development will require significant flood risk management measures (see the Technical Guidance to the NPPF Tables 2 and 3 for further information on Flood Zone compatibility). These measures could include modifications to the existing flood risk management infrastructure or alteration of the site topography. The main options considered viable for the Meridian Water site are outlined below:

1. Raising and lowering ground levels in key areas to increase safety in some places while creating compensatory flood storage elsewhere – due to the requirement for level for level compensatory flood storage, see paragraph 4.55, if this is only carried out within the site there will be no net increase in the space available for development, however this method can be used to control the shape of the floodplain and therefore allocate development in accordance with non-flood risk related requirements.
2. Widening and restoration of the Pymmes Brook, Salmons Brook or Flood Relief Channel rivers – natural flood management techniques such as this set space aside for water by creating additional flood storage along the edges of the watercourse and provide biodiversity enhancements by creating a green corridor along the riverbank. The rectangular shape of the existing reinforced concrete channels running through Meridian Water means that the rivers break their banks suddenly and flood the large flat areas either side to low depths. If these rivers were naturalised, perhaps implementing a wider two-stage channel, the rivers would start flooding earlier in the cycle but would only flood a controlled buffer zone either side of the river. Such alterations to the river channels would have to be carefully designed to ensure that flood risk was not increased up or downstream of the site. Any additional future maintenance requirements would have to be accounted for, particularly with regard to the sections owned and managed by the Environment Agency (see paragraph 4.31).
3. Create flood storage upstream and downstream – where opportunities exist it may be possible to use the natural floodplain upstream and downstream of the site to accommodate additional floodwater. Modifications such as these would require large-scale landscaping works, however the benefits to flood risk on site may ensure they are justifiable. Such measures could potentially also reduce flood risk at nearby sites also. For example, increasing conveyance on Salmons Brook and providing storage further downstream could benefit Eley's Estate to the north of Meridian Water (see Figure 4.13). The feasibility of this option depends largely on the proximity of available land. Figure 4.13 on the following page shows two possible sites that could be used to store additional floodwaters.
4. Increase attenuation of tributaries – the flood risk posed by Pymmes Brook and Salmons Brook could potentially be alleviated by creating flood storage areas higher up in the catchment. This would reduce peak flows and thereby reduce the risk of flooding at Meridian Water. However, opportunities to provide flood storage along these rivers are extremely limited. Where they are available they are more likely to be implemented for the purposes of reducing flood risk to existing developments within these catchments, for example the Salmons Brook flood alleviation scheme described in paragraph 4.36 (the feasibility of developing a similar scheme for Pymmes Brook is also being investigated). Consequently, the possibility of utilising upstream storage to attenuate flooding and reduce risk at Meridian Water should be discounted.

- 4.54 Several of these techniques could be implemented in partnership with each other to provide the optimum solution for the Meridian Water site. These types of opportunities are positively aligned with the main messages of the CFMP¹¹ such as using natural floodplain upstream and downstream to accommodate additional floodwater and re-creating river corridors so that there is more space for rivers to flow and flood naturally, these messages are described more fully in paragraph 4.34.
- 4.55 Where flood defences protecting part of the site lead to a reduction in flood storage, compensatory flood storage corresponding to the volume and level of the lost storage should be provided elsewhere on the site³. Such 'level for level' or 'direct' compensation is required to ensure that the compensatory flood storage becomes effective at the same point in a flood event as the lost storage would have done¹³. Where direct compensation is not practicable it may be possible to provide indirect compensatory flood storage. Indirect compensation typically consists of an offline flood storage area with an inflow control device such as a weir or sluice gate that only allows water to enter when the flood reaches the level at which compensatory storage is required. A controlled outfall is required to drain the flood storage area as the flood recedes. Schemes involving indirect compensation generally make more effective use of any space that is available for flood storage however they are more complex and consequently more problematic to design and operate than direct schemes. Therefore, the Environment Agency advise that indirect compensation is unlikely to be acceptable and that direct compensation is strongly preferred where possible.

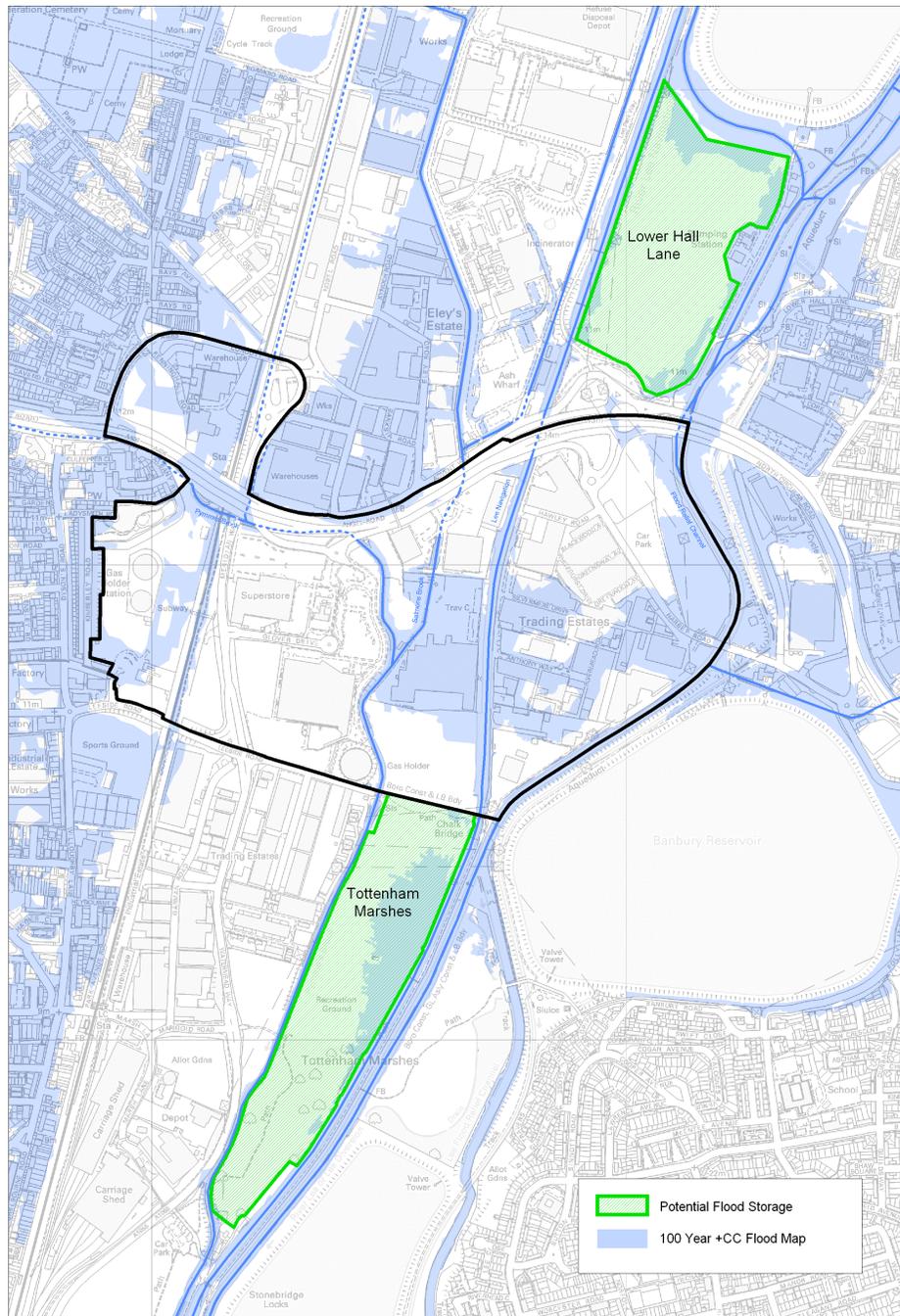


Figure 4.13 Potential compensatory storage areas upstream and downstream of Meridian Water

4.56 The Meridian Water Master Plan Options and Flood Risk Modelling Report¹⁶ considers flood risk management options for the five discrete areas described in paragraph 4.23. The findings and recommendations are summarised below, refer to the report for further details including potential site layouts. The measures described overleaf may be subject to future amendments, the fundamental criteria is that all developments must be safe and must not increase flood risk elsewhere. Note that most of the proposals are to provide level for level on site storage and hence the proposed compensation areas are equal to the areas currently at risk of flooding.

Area A

It is proposed to mitigate flood risk by reshaping the land thereby providing 5.1 ha of flood compensation on-site and creating a raised, developable area adjacent to A1055 Conduit Lane that will be considered safe for flood risk. The existing overland flow to the south-east of this area across the railway line must be maintained.

Area B

A potential solution to allow development to take place is to provide level for level on-site storage covering the same area as the current floodplain but re-configured to facilitate development. The proposed compensatory flood storage area will be 3.2 ha in size. Existing overland flow routes to the south are to be maintained.

Areas C and D

As described in paragraph 4.26-27 flooding to these areas originates solely from the Lee Navigation locally overtopping its banks. The preferred mitigation option presented in the options study for Areas C and D is to provide flood compensation storage of 10.6 ha off-site on a level for level basis. Combining this with appropriate flood defence measures will make the whole of Areas C and D available for development, this is a key aspiration of the masterplanners as these sites are central to the overall development.

Potentially available sites within the vicinity of Meridian Water include Lower Hall Lane (LHL) and Tottenham Marshes (TM), refer to Figure 4.13. LHL is owned by Thames Water, as it covers 13.2 ha it could potentially provide the full compensation required for mitigation purposes. It is unlikely to be wholly available, however it is currently anticipated that 3.5 ha of land at LHL can be set aside for flood storage. Utilising further compensatory storage at TM could provide an additional 6.9 ha bringing the total up to 10.4 ha – the land here is thought likely to be contaminated, this issue needs to be investigated thoroughly as part of any future flood storage proposals at this site. The compensation flood storage areas can only be provided in areas of these sites that are currently outside the floodplain, see Figure 4.13. The shortfall of 0.2 ha could be absorbed by other sites that may become available during the lifespan of the proposals. If not it is likely that significantly more than 0.2 ha will be available on-site in any case. This approach is described in more detail in the Meridian Water Masterplan Options and Flood Risk Modelling Report¹⁶ and was agreed in principle by the Environment Agency, see Appendix B of that report.

Alternatively, it would be feasible to provide all of the required compensatory storage at LHL if indirect rather than direct (or ‘level for level’ – see paragraph 4.55) compensation were used. With this approach a flood storage area is created that compensates the volume of flooding lost due to defences rather than the area. This is achieved by excavating the flood storage area below the natural ground level to make better use of the available space. The total volume of flooding to Areas C and D is estimated to be 65,000m³, hence a 5.0 ha flood storage area in LHL with an average depth of 1.3 metres (this is considered feasible given the flood levels and requirement to drain the flood storage area positively) would be adequate. Positive drainage of this area would require an outfall to the Flood Relief Channel rather than the canal. The area required could be reduced if some of the compensatory storage required to make Areas C and D developable were provided on-site.

Area E

It is proposed to landscape this area to create a distinct area of flooding on the north-east side of Harbet Road, this will allow development on the opposite side of the road. The compensation area is 6.5 ha which is larger than the 6.0 ha currently exposed to flooding.

Site-Specific Flood Risk Assessments

4.57 Guidance on the preparation of site-specific flood risk assessments for sites of varying risk across the flood zones is one of the outputs of a Level 2 SFRA (paragraph 1.5). The requirements for flood risk assessment are described in paragraph 9 of the Technical Guidance to the NPPF. Paragraph 103 of the NPPF defines when a flood risk assessment should be produced as part of a planning application. Further guidance is provided by the PPS25 Practice Guide (paragraphs 3.80 to 3.82) and in Chapter 5 of Enfield's Level 1 SFRA. Paragraph 3.81 of the PPS25 Practice Guide lists the objectives of an FRA as to establish the following:

- whether a development is likely to be affected by current or future flooding from any source;
- whether it will increase flood risk elsewhere;
- whether the measures proposed to deal with these effects and risks are appropriate;
- if necessary provide the evidence to the LPA so that the Sequential Test can be applied; and
- whether the development will be safe and pass part c) of the Exception Test if this is appropriate.

Given the definition of safe development described in paragraph 4.8 there are two specific additional items that future FRAs in Meridian Water should consider.

4.58 Firstly the availability of dry or low hazard access routes to all segments of the study area should be assessed for the 100 year plus climate change event. The 100 year plus climate change flood outline in drawing MW10 shows that there are several isolated 'islands' that would potentially be cut off during an event of this magnitude. Although the EA defended flood outline and the 2D model results show some flooding across the A406 North Circular this route is actually elevated well above the floodplain and would remain dry, even taking this into account some areas remain at risk of being cut-off. The other main access routes are Meridian Way and Harbet Road, both of these are potentially affected by flooding. Drawing MW15 shows that most of the isolated areas are eliminated when low hazard access routes are brought under consideration. Nevertheless site-specific FRAs must consider this in greater detail.

4.59 Secondly, it is recommended that site-specific FRAs should identify areas that are less than 300mm above the 100 year plus climate change flood level (paragraph 4.52) to determine where finished floor levels may need to be raised to ensure development is safe. Where floor levels are required to be raised any related impacts on floodplain reduction and associated increases in flood risk elsewhere must be adequately compensated for. In addition it is recommended that basement dwellings and other types of 'highly vulnerable' development, as defined in Table 2 of the Technical Guidance to the NPPF, should not be considered within this area or within the 1000-year defended flood outline.

- 4.60 Site-specific FRAs should identify areas where residual flood risk remains (for example through the failure of flood risk management infrastructure such as blockage of culverts) and consider whether appropriate measures can be implemented to mitigate these risks. Where such risks remain, parts of developments may need to be designed to be flood resilient or flood resistant. Examples of flood resilient design measures include raising electrical circuits and other services, and using appropriate floor and wall coverings. Flood resistance measures aim to prevent flood waters from entering properties, examples include fitting flood-proof air brick covers and non-return valves to drainage systems. The specific residual risk represented by possible blockage of the Pymmes Brook culvert below Angel Road to the east of Meridian Way should be addressed separately by any FRAs that relate to the site between Meridian Way and Pymmes Brook (paragraph 4.38).

Guidance on Applicability of SUDS

- 4.61 Information on the use of sustainable drainage techniques is one of the outputs of a Level 2 SFRA (paragraph 1.5). General information on the purpose and use of SUDS can be found in Chapter 6 of Enfield's Level 1 SFRA. The guidance provided here is primarily intended to cover information relevant to the application of SUDS within the Level 2 SFRA study area. An important point to note is that since the publication of the Level 1 SFRA the Flood and Water Management Act 2010 (FWM Act) has re-defined the way that SUDS for new development will be approved and adopted in the future. Although secondary legislation is required it is anticipated that the new regime for SUDS will be implemented in April 2014 or soon afterwards. Prior to this Defra will publish National SUDS Guidance. Once the new legislation is in force all new developments will be required to implement SUDS designed and constructed in accordance with this guidance. The FWM Act defines all Unitary Authorities such as the London Borough of Enfield as Lead Local Flood Authorities (LLFAs). As well as various new responsibilities related to management of local flood risk, LLFAs will be required to set up SUDS Approval Boards (SABs) who will review all new SUDS proposals. Upon satisfactory implementation the SAB will then adopt the SUDS and takeover responsibility for all future maintenance.
- 4.62 In relation to the new legislation Enfield are currently preparing a Development Management Document (DMD). A section of the DMD will describe Enfield's policies on SUDS requirements. It is possible that these policies may be superseded in the future by the forthcoming National SUDS Guidance, however the current proposals are as follows:
- All major developments must achieve greenfield run off rates (for 1 in 1 year and 1 in 100 year events);
 - All other development should seek to achieve greenfield run off and must maximise the use of SUDS, including at least one 'at source' SUDS measure resulting in a net improvement in water quantity or quality discharging to sewer in-line with any SUDS guidance or requirements.

These policies are in line with the London Plan⁵ and Environment Agency requirements.

- 4.63 The Greenfield mean annual flood flow rate for Meridian Water is calculated as 3.88 l/s/ha using the Institute of Hydrology Report 124¹⁴ method as recommended by The SUDS Manual¹⁵. The associated 1 in 100 year Greenfield runoff rate is calculated as 12.37 l/s/ha.
- 4.64 As described in paragraph 4.3 the area is fairly flat and the underlying bedrock is the London Clay Formation. The near surface geology consists of substantial drift deposits and although these are more permeable than the London Clay they are not necessarily suitable for infiltration based SUDS. Borehole logs taken from the north-west corner of the study area indicate a layer of sand and gravel 1.5-3.5m below ground level which is probably suitable for soakaways and other infiltration based SUDS. If this layer extends across the area it is possible that such solutions may be feasible at any location within the site. SUDS design considerations for individual sites will require infiltration test and borehole records. The depth to the water table is another key consideration. Infiltration based techniques are preferable where possible as they confer greater environmental benefits and are often more cost effective to implement than other types of SUDS.
- 4.65 Another important consideration for drainage design across Meridian Water is that the close proximity of much of the site to major rivers. Drainage design will have to account for the effects of restricted discharge rates caused by high river levels during storm events. Because much of the site is not much higher than the rivers themselves, as river levels rise the capacity of surface water outfalls will be significantly reduced, possibly even prevented altogether. This is likely to have implications for the amount of storage required.
- 4.66 Storage capacity can also be enhanced, and therefore reliance on surface water runoff infrastructure reduced, through the use of permeable surfaces throughout a development. As well as buildings opportunities to provide permeable surfaces across car parks and highways should be exploited wherever possible.

Recommendations

- 4.67 The key recommendations made in this report have been summarised below. These are to be read in conjunction with the recommendations of Enfield's Level 1 SFRA, reiterated here in Appendix F.
1. Redevelopment of Meridian Water will require a detailed site-specific Flood Risk Assessment (FRA) to be submitted with each individual planning application; these are to be prepared in accordance with the requirements of the NPPF, Enfield's Level 1 SFRA and the recommendations of this study (paragraph 4.51).
 2. The Sequential Test is to be applied within the site, steering development towards areas of low flood risk (paragraph 4.51).
 3. Where this is not possible, in making their allocations the Council will need to be satisfied that the Exception Test can be passed. FRAs accompanying individual planning applications must demonstrate how this will be achieved in each instance, including how the development will be safe without increasing flood risk elsewhere, to be classed as safe:
 - A dry access route above the 100 year plus climate change flood level or, where appropriate modelled data exists, an access route within the low hazard area of the floodplain to and from any residential development should be provided;
 - Finished floor levels for these developments should be set at least 300mm above the 100 year plus climate change flood level;
 - To achieve this without increasing flood risk elsewhere, it must be shown that there will be no net loss of flood storage and that overland flow routes will not be obstructed (paragraph 4.51).
 4. Any FRAs should include a map of the site showing the extent of the area that is within 300mm of the 100-year plus climate change flood level. Basement dwellings and other types of 'highly vulnerable' development, as defined in Table 2 of the Technical Guidance to the NPPF, should not be considered within this area (paragraph 4.52).
 5. Where flood risk management measures are proposed to reduce flood risk and increase the scope for redevelopment of the site, such as those described in paragraph 4.53, these must be carried out in accordance with the main messages of the Thames Region Catchment Flood Management Plan¹¹ and the requirements of the Environment Agency.
 6. Any future site-specific FRA for the area between Meridian Way and Pymmes Brook should address the residual risk of a blockage in the Pymmes Brook culvert potentially causing significant flooding (paragraph 4.38).
 7. Where site-specific FRAs identify areas of residual flood risk (for example through failure of flood risk management infrastructure such as culverts), this should be mitigated by implementing flood resilience or resistance measures to individual properties (paragraph 4.60).

8. The proximity of Meridian Water to various river channels and the topography of the site increase the importance of ensuring that surface water runoff is controlled on site (paragraph 4.39). Sustainable Drainage Systems (SUDS) are to be employed for all new developments and attenuation is to be provided up to a 1 in 100 year event with climate change (paragraph 4.62). It is likely that overland storage will be required to achieve this, this may create opportunities to provide enhanced green spaces within the site.
9. Future redevelopment of the site must aim to incorporate any relevant measures identified by the Surface Water Management Plan for Enfield (paragraph 4.40).

These recommendations accord with the main messages and objectives of the Thames Region Catchment Flood Management Plan ¹¹ and the Lower Lee Flood Risk Management Strategy ¹². This document should be reviewed as improved data on flooding becomes available or as government policy updates require.

Conclusions

- 4.68 This Level 2 SFRA has been prepared to investigate in further detail the potential risk of flooding associated with the Meridian Water Priority Regeneration Area. It forms a critical element of the evidence base to support the planning process.

GLOSSARY AND ABBREVIATIONS

Glossary of Terms

Annual probability The estimated probability of a flood of a given magnitude occurring or being exceeded in any year, usually expressed as the 100 year flood, 1 in 100 or 1%.

Attenuate To reduce in force or intensity.

Brownfield site Any land or site that has been previously developed.

Catchment The area contributing runoff or baseflow to a particular point on a watercourse.

Catchment Flood Management Plan A high-level planning strategy through which the Environment Agency works with other key decision-makers within a river catchment to identify and agree policies to secure the long-term sustainable management of flood risk.

Climate change Long term variations in global temperature and weather patterns.

Culvert Covered channel or pipe that forms a watercourse below ground level.

Development The carrying out of building, engineering, or other operations in, on, over or under land or the making of any material change in the use of any buildings or other land.

Flood defence Infrastructure, such as flood walls and embankments, intended to protect an area against flooding, to a specified standard of protection. Also includes assets that convey flood water such as culverts and channels.

Flooding Inundation by water whether this is caused by breaches, overtopping of banks or defences, inadequate or slow drainage of rainfall, underlying groundwater levels or blocked drains and sewers.

Floodplain Area of land adjacent to a watercourse, an estuary or the sea, over which water flows in time of flood, or would flow but for the presence of flood defences where they exist.

Floodplain compensation The provision of new floodplain storage capacity to replace lost natural floodplain due to development.

Flood probability The estimated probability of a flood of given magnitude occurring or being exceeded in any specified time period.

Flood risk An expression of the combination of the flood probability and the magnitude of the potential consequences of the flood event.

Flood Risk Assessment A study to assess the risk of a site or area flooding, and to assess the impact that any changes or development in the site or area will have on flood risk.

Flood Risk Management Combines the functions of mitigating and monitoring flood risks and may include pre-flood, flood-event or post-flood activities.

Flood storage The temporary storage of excess runoff or river flow in tanks, ponds, basins, reservoirs or on the floodplain.

Fluvial Relating to a river or rivers.

Fluvial flooding Flooding from a river or other watercourse.

Functional floodplain Unobstructed areas of the floodplain where water regularly flows in time of flood. The Technical Guidance to the NPPF defines this as land which would flood with an annual probability of 1 in 20 (5%) or greater.

Greenfield runoff rate The rate of runoff that would occur from the site in its undeveloped (and therefore undisturbed) state.

Groundwater Water in the saturated zone of the ground below the water table.

Groundwater flooding Flooding caused by groundwater escaping from the ground when the water table rises to or above ground level.

Main river A watercourse designated on a statutory map of main rivers maintained by Defra.

Major Development For dwellings, a major development is one where the number of residential units to be constructed is greater than 10, or where the number of dwellings to be constructed is not known, the site area is greater than 0.5 hectares. For all other uses a major development is one where the floor space to be created by the development is more than 1,000 square metres or the site area is greater than 1 hectare.

Ordinary watercourse A watercourse that is not a designated main river, a private drain or a public sewer.

Residual risk The risk that remains after risk management and mitigation. It may include, for example, risk due to very severe storms (above design standard) or risks from unforeseen hazards.

Return period A term used to express the frequency of extreme events. It refers to the estimated average time interval between events of a given magnitude.

Runoff The flow of water from an area on the catchment surface, caused by rainfall.

Sequential Test A risk based approach to assessing flood risk, its aim is to steer new development to areas at the lowest probability of flooding (Zone 1).

Sewer flooding Flooding caused by the blockage or overflowing of sewers or urban drainage systems.

Strategic Flood Risk Assessment An assessment of flood risk carried out for forward planning purposes.

Sustainable drainage system A sequence of management practices and control structures, often referred to as SUDS, designed to drain surface water in a more sustainable manner than some conventional techniques. Typically, these techniques are used to attenuate rates of runoff from development sites.

List of Abbreviations and Acronyms

AOD Above Ordnance Datum

CC Climate Change

CFMP Catchment Flood Management Plan

CDA Critical Drainage Area

CIRIA Construction Industry Research and Information Association

Defra Department of the Environment, Food and Rural Affairs

DCLG Department for Communities and Local Government

DMD 

DPD Development Plan Document

EEFAS East Enfield Flood Alleviation Scheme

FRA (Site-Specific) Flood Risk Assessment

FWM Act Flood and Water Management Act 2010

iPEG increased Potential for Elevated Groundwater

LDD Local Development Document

LDF Local Development Framework (historic name for the Local Plan)

LHL Lower Hall Lane

LLFA Lead Local Flood Authority

NPPF National Planning Policy Framework

PEIE Ponders End Industrial Estate

SAB SUDS Approval Board

SFRA Strategic Flood Risk Assessment

SPD Supplementary Planning Document

SUDS Sustainable Drainage Systems

SWMP Surface Water Management Plan

TM Tottenham Marshes

TWUL Thames Water Utilities Limited

REFERENCES

1. National Planning Policy Framework, DCLG, March 2012
2. Technical Guidance to the National Planning Policy Framework, DCLG, March 2012
3. Strategic Flood Risk Assessment, London Borough of Enfield, February 2008
4. Planning Policy Statement 25: Development and Flood Risk Practice Guide, DCLG, December 2009
5. The London Plan, Greater London Authority, July 2011
6. High Level Sequential Test: Core Strategy Submission Document, London Borough of Enfield, May 2010
7. Flood Risk Assessment Guidance for New Development R&D Technical Report FD2320/TR2, Defra/Environment Agency, October 2005
8. The Lee Hydrology and Mapping Study, Halcrow, March 2007
9. The Flood Estimation Handbook, Institute of Hydrology, 1999
10. Central Leaside Baseline Hydraulic Modelling Report, Buro Happold, November 2008
11. Thames Region Catchment Flood Management Plan, Environment Agency, July 2008
12. The Lower Lee Flood Risk Management Strategy, Environment Agency, June 2006
13. CIRIA Report 624: Development and Flood Risk - Guidance for the Construction Industry, CIRIA, January 2004
14. Flood estimation for small catchments, Institute of Hydrology Report 124, 1994
15. C697 The SUDS Manual, CIRIA, 2007
16. Meridian Water Master Plan Options and Flood Risk Modelling Report, Atkins Ltd, March 2011