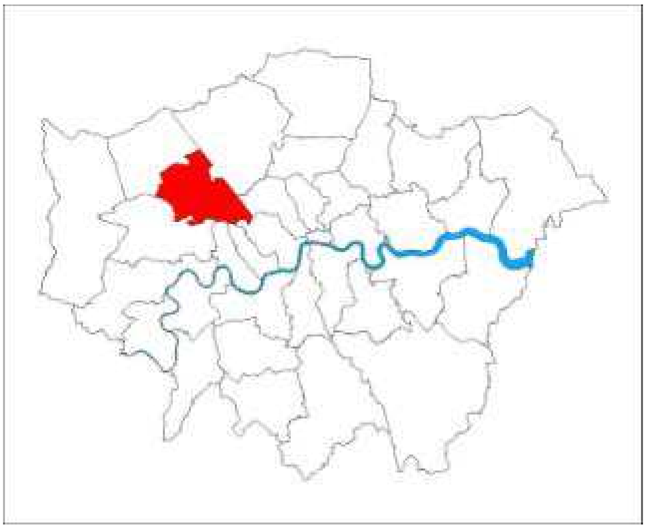
SURFACE WATER MANAGEMENT PLAN
Volume 2 - Appendices



DRAIN LONDON

LONDON BOROUGH OF BRENT

GREATER**LONDON**AUTHORITY

Thames Water

LONDON COUNCILS

Environment Agency

BRENT COUNCIL

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RELATED DOCUMENTS

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5008-UA002334-BMR-02- LB Brent SWMP – Vol 1	Brent SWMP – Main Report	Aoife McNally	12/10/2011	02

CONTENTS

Term	Definition
Aquifer	A source of groundwater comprising water bearing rock, sand or gravel capable of yielding significant quantities of water.
AMP	Asset Management Plan
Asset Management Plan	A plan for managing water and sewerage company (WaSC) infrastructure and other assets in order to deliver an agreed standard of service.
AStSWF	Areas Susceptible to Surface Water Flooding
Catchment Flood Management Plan	A high-level planning strategy through which the Environment Agency works with their key decision makers within a river catchment to identify and agree policies to secure the long-term sustainable management of flood risk.
CDA	Critical Drainage Area
Critical Drainage Area	A discrete geographic area (usually a hydrological catchment) where multiple and interlinked sources of flood risk (surface water, groundwater, sewer, main river and/or tidal) cause flooding in one or more Local Flood Risk Zones during severe weather thereby affecting people, property or local infrastructure.
CFMP	Catchment Flood Management Plan
CIRIA	Construction Industry Research and Information Association
Civil Contingencies Act	This Act delivers a single framework for civil protection in the UK. As part of the Act, Local Resilience Forums must put into place emergency plans for a range of circumstances including flooding.
CLG	Government Department for Communities and Local Government
Climate Change	Long term variations in global temperature and weather patterns caused by natural and human actions.
Culvert	A channel or pipe that carries water below the level of the ground.
Defra	Department for Environment, Food and Rural Affairs
DEM	Digital Elevation Model
DG5 Register	A water-company held register of properties which have experienced sewer flooding due to hydraulic overload, or properties which are 'at risk' of sewer flooding more frequently than once in 20 years.
DTM	Digital Terrain Model
EA	Environment Agency
Indicative Flood Risk Areas	Areas determined by the Environment Agency as indicatively having a significant flood risk, based on guidance published by Defra and WAG and the use of certain national datasets. These indicative areas are intended to provide a starting point for the determination of Flood Risk Areas by LLFAs.
FCERM	Flood and Coastal Erosion Risk Management -
FMfSW	Flood Map for Surface Water
Flood defence	Infrastructure used to protect an area against floods as floodwalls and embankments; they are designed to a specific standard of protection (design standard).

Term	Definition
Flood Forum	Is a charity that provides support and advice to communities and individuals that have been flooded or are at risk of flooding. It is a collective, authoritative voice that aims to influence central and local government and all agencies that manage flood risk.
Flood Risk Area	An area determined as having a significant risk of flooding in accordance with guidance published by Defra and WAG.
Flood Risk Regulations (FRR)	Transposition of the EU Floods Directive into UK law. The EU Floods Directive is a piece of European Community (EC) legislation to specifically address flood risk by prescribing a common framework for its measurement and management.
Floods and Water Management Act	Part of the UK Government's response to Sir Michael Pitt's Report on the Summer 2007 floods, the aim of which is to clarify the legislative framework for managing surface water flood risk in England.
Fluvial Flooding	Flooding resulting from water levels exceeding the bank level of a main river
IDB	Internal Drainage Board
IUD	Integrated Urban Drainage
LB	London Borough
LDF	Local Development Framework
Local Flood Risk Zone (LFRZ)	Local Flood Risk Zones are defined as discrete areas of flooding that do not exceed the national criteria for a 'Flood Risk Area' but still affect houses, businesses or infrastructure. A LFRZ is defined as the actual spatial extent of predicted flooding in a single location
Lead Local Flood Authority (LLFA)	Local Authority responsible for taking the lead on local flood risk management
LiDAR	Light Detection and Ranging
Local Resilience Forum (LRF)	A multi-agency forum, bringing together all the organisations that have a duty to cooperate under the Civil Contingencies Act, and those involved in responding to emergencies. They prepare emergency plans in a co-ordinated manner.
LPA	Local Planning Authority
Main River	A watercourse shown as such on the Main River Map, and for which the Environment Agency has responsibilities and powers
NRD	National Receptor Dataset – a collection of risk receptors produced by the Environment Agency
Ordinary Watercourse	All watercourses that are not designated Main River, and which are the responsibility of Local Authorities or, where they exist, IDBs
Partner	A person or organisation with responsibility for the decision or actions that need to be taken.
PFRA	Preliminary Flood Risk Assessment
Pitt Review	Comprehensive independent review of the 2007 summer floods by Sir Michael Pitt, which provided recommendations to improve flood risk management in England.

Term	Definition
Pluvial Flooding	Flooding from water flowing over the surface of the ground; often occurs when the soil is saturated and natural drainage channels or artificial drainage systems have insufficient capacity to cope with additional flow.
PPS25	Planning and Policy Statement 25: Development and Flood Risk
PA	Policy Area
Policy Area	One or more Critical Drainage Areas linked together to provide a planning policy tool for the end users. Primarily defined on a hydrological basis, but can also accommodate geological concerns where these significantly influence the implementation of SuDS
RBMP	River Basin Management Plan
Resilience Measures	Measures designed to reduce the impact of water that enters property and businesses; could include measures such as raising electrical appliances.
Resistance Measures	Measures designed to keep flood water out of properties and businesses; could include flood guards for example.
Risk	In flood risk management, risk is defined as a product of the probability or likelihood of a flood occurring, and the consequence of the flood.
Risk Management Authority	As defined by the Floods and Water Management Act
RMA	Risk Management Authority
Sewer flooding	Flooding caused by a blockage or overflowing in a sewer or urban drainage system.
SFRA	Strategic Flood Risk Assessment
SMP	Strategic Management Plan
Stakeholder	A person or organisation affected by the problem or solution, or interested in the problem or solution. They can be individuals or organisations, includes the public and communities.
SuDS	Sustainable Drainage Systems
Sustainable Drainage Systems	Methods of management practices and control structures that are designed to drain surface water in a more sustainable manner than some conventional techniques.
Surface water	Rainwater (including snow and other precipitation) which is on the surface of the ground (whether or not it is moving), and has not entered a watercourse, drainage system or public sewer.
SWMP	Surface Water Management Plan
TfL	Transport for London
TWUL	Thames Water Utilities Ltd
WaSC	Water and Sewerage Company

Appendix A – Data Review

Appendix B – SWMP Context

Introduction

In the past, urban surface water management has tended to concentrate on the collection and removal of excess water from the urban environments as quickly and cheaply as possible. This was largely undertaken to avoid flooding of our communities and economic damages being incurred, largely through the development of systems to channel the water within drains, pipes and channels altering the natural catchments and re-aligning the natural streams and rivers.

Additionally, water pollution problems in London have evolved since the days of the Wallbrook Stream, a tributary of the River Thames, which was subject to an Act of Parliament in 13831 to prevent further pollution from latrine discharges. Increasingly, water pollution from discrete polluting sources such as factory pipes are greatly overshadowed by that of overland flows from the roads and rooftops, which rapidly inundate the downstream urban drainage system every time it rains.

Residual pollution within the watercourses has been caused by misconnections of developments and individual homeowners waste water systems to the network. Further sources include a whole series of dual manholes within the current TWUL foul and surface water network which can allow, flow to pass freely between the two systems.

Context

The London Borough of Brent has developed as most of the suburban London Boroughs have, with the intensification of the surrounding village centres and suburbs, largely as a result of an intense transport led development (including the Metropolitan and Jubilee lines) during the early to mid 20th century. This intensification of development has directly affected the status and pollution levels within the watercourses of the Borough.

As this previously undeveloped land is built upon, the amount of water running off roofs, streets, and other impervious surfaces into nearby waterways increases. The increased volume of water runoff and the pollutants carried within it, continue to degrade the quality of the once-natural watercourses. The natural river corridor and natural floodplain is replaced resulting in a significant reduction in the Borough's ability to hold back the water where it falls, this is further exacerbated by the largely impermeable nature of the underlying geology being that of London Clay. This increased imperviousness results in a marked degradation of the quality of the waters within the watercourses as the traditional approaches to drainage result in two main methods:

- Separate Foul and Surface water sewerage system - For most parts of the Borough, domestic and industrial wastewaters and surface water runoff are discharged into separate sewer systems: the foul waste is carried to one of two Wastewater Treatment Works (WwTW) at Modgen or Beckton, while the surface water is channelled directly to local brooks, urban watercourses and main rivers.
- Combined Sewerage Systems - In some areas across the Borough, the domestic and industrial wastewater, rainwater and street runoff are collected in the same sewers and then conveyed together to Mogden WwTW (or Beckton). This is known as a combined sewer system.

Development during the interwar and post war periods was intense and rapid, with the population of the West Middlesex catchment growing from approximately 410,000 to 1.3 million over the 30 years to 1941. Fortunately for the residents of the area, the West Middlesex Drainage Board had the foresight to develop a scheme that would serve (most/part) of the Borough and increase the capacity of the Wastewater Drainage system to accommodate a six time Dry Weather Flow (6DWF) for a domestic population of approximately 2 million people.

The scheme designed, by J.D Watson, during the 1920's would replace 28 smaller WwTW and develop a Trunk Sewer Mains network to transfer the domestic wastewaters through to Mogden WwTW, for parts of Barnet, Brent, Ealing, Harrow, Hillingdon, Hounslow and Richmond.

Figure B-1 Schematic of the West Middlesex Drainage Board plans for Mogden WwTW (after J. Timms)

Unfortunately, although the population has not yet reached that level (the domestic population from the 2001 Census data, draining to Mogden WwTW is approximately 1.7million), all spare capacity of this foul network has been exhausted by the widespread connection of surface water into foul sewers. It appears that as the subsequent development led to increased runoff, the surface water system was not upgraded to cope with it. Instead, the additional surface runoff was diverted into the foul sewers to take advantage of the spare capacity it had at that time.

Another route of surface water entry to foul sewers is via the large numbers of dual manholes in the area. These chambers were designed to allow access to both surface and foul sewers within a common chamber but with the two systems still isolated from each other. If the sealing arrangements between the separate sewers fail or are removed, flow can pass freely between the two systems. Misconnections also occur during property modifications, when rainwater down-pipes and yard drainage are connected to the foul sewers, either by the owners or their tradesmen.

The impact of these factors is that the main foul trunk system is shown to have a very defined response to rainfall, more typical of a combined sewer. The Brent IUD study shows that more than two thirds of the flow in the Wembley Branch Trunk Sewer is not foul or wastewater. This results in widespread flooding from the trunk sewers and vast quantities of untreated sewage being discharged into the local urban watercourses, even for relatively small rain storms.

Finally, a combination of poor historical planning decisions, urban creep and infill development has had a further detrimental impact on the ability of the Borough to hold back the rain where it falls, Thames Water have calculated that there has been a 17% increase since 1971 in impermeable area across North West London, as residents have added extensions or have paved over front gardens. This results in greater volumes of surface water for each rain event entering the system. This effect accumulates further down the system where the increasing volumes create greater pressures on the below ground piped assets, tending to result in overland flood flows, increasing frequencies and levels of discharges at overflows and flooding of peoples properties with contaminated foul and commercial wastewaters.

This steady degradation of drainage capacity in the borough has occurred at the same time that both community expectations for flood protection and pressure from environmental legislation, have placed increasing demands on its performance. Additionally, climate change is expected to increase the frequency of larger storms and higher rainfall intensities, both of which are likely to increase the frequency and impacts of this flooding across the Borough, further impacting the lives of the resident populations.

Objectives

As such, the management of surface water within LBB, is dependent upon the outcomes of the SWMP process, and as such the following objectives are key to helping to resolve the historical issues:

- Stressing the importance of the new LLFA role and employing suitably skilled resources to carry out these duties;
- Education of residents to accept the risk of flooding, change their behaviours and promoting flood resilience within flood risk areas;
- Derivation of a Water Vision for LBB and the surrounding Boroughs

The Surface Water Vision

The water vision for LBB and the emerging North West London Flood Risk Management Partnership over the 30 – 50 year time period will be to achieve a more natural and sustainable approach to coping with rain events across the urban environment.

“An approach that promotes the reversal of historical and current approaches to the drainage system and the watercourses. One that achieves a more sustainable approach to water quality and quantity issues, providing space to flood during the larger events.”

The vision can be achieved through adherence to the following principles whereby:

- Surface water is held back at source and increase the uptake of water re-use activities across the Borough, including the provision of schemes to store water upstream of and throughout the urban environment;
- Surface water is managed above ground, using the topography and infrastructure to deliver safe transport, above ground, of water through the urban environment, for the whole range of events including the extreme events;
- Place making is key to the urban area – through the promotion of natural vegetation to achieve multiple benefits (including improvements in water quality, flooding, biodiversity, public perception and amenity). Stopping the current impermeable trend within our urban areas and reversing the current levels of impermeability across LBB.
- Co-operation across the stakeholders to achieve the best solution for the residents, helping to install greater public confidence in our abilities to manage the issues and safely design our future city through the delivery of an integrated Water Management plan.
- Learning to live with water – preparation for the extreme event is vital as in some cases re-location of people or property may not be viable.

Appendix C – Risk Assessment Technical Details

Introduction

As part of the Drain London Tier 2 project stage, Hyder and AECOM were commissioned to create surface water models to identify key flood risk areas and generate hazard mapping for Group 2 within the Greater London area. The 33 London Boroughs were divided into eight groups (Figure C-1) by the Drain London Forum.

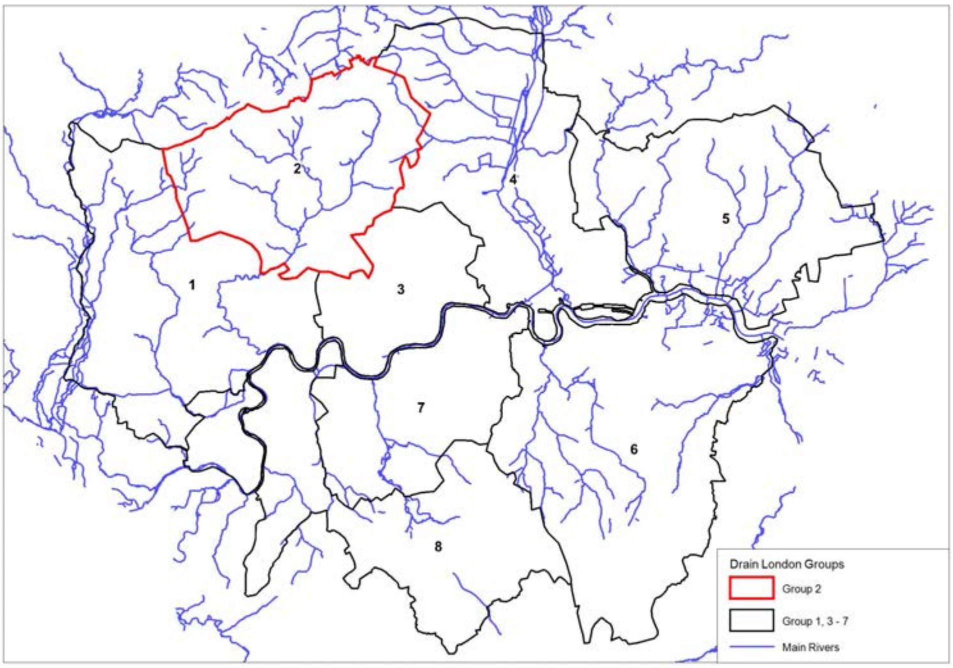

Figure C-1 Drain London Groups

Group 2 comprises three London Boroughs: Barnet, Brent and Harrow (Figure C-2).

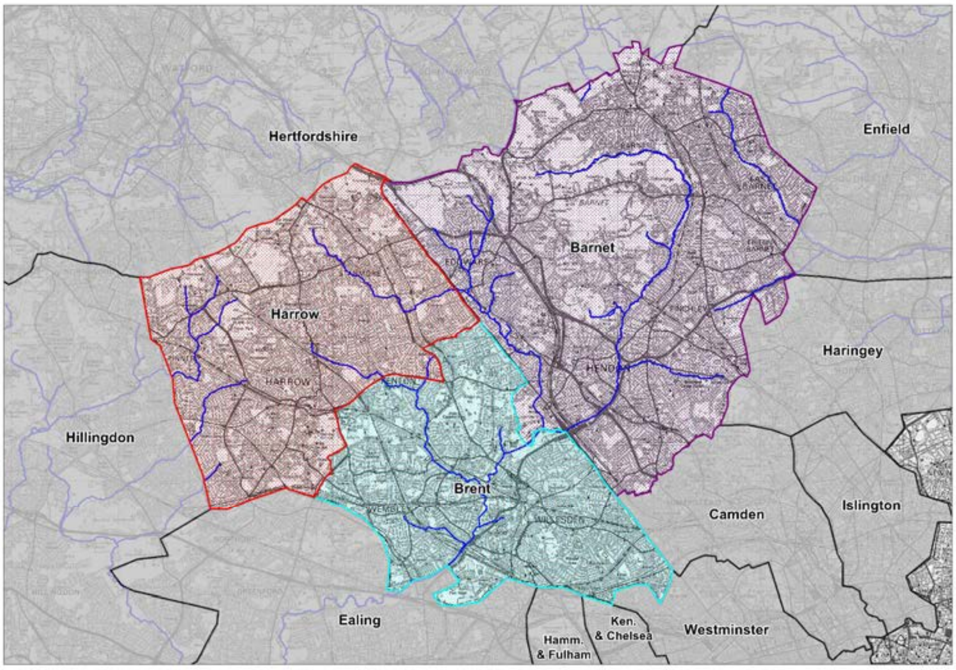

Figure C-2 Group 2 London Boroughs

The three boroughs were divided into hydrological catchments to maximise modelling efficiency and to reduce model run times. The main hydrological catchments provide natural model boundaries. However these model boundaries are not coincident with the borough boundaries.

The London Borough of Brent (LBB) is covered by five model extents (Figure C-3).

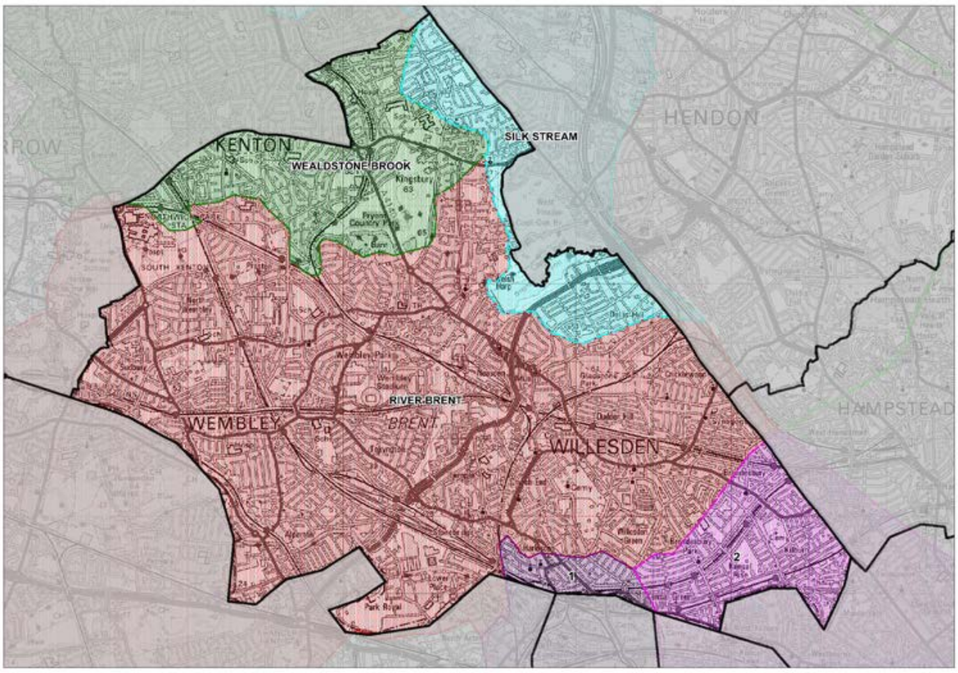

Figure C-3 LBB Model Coverage

The main hydrological catchments provide natural model boundaries. However these model boundaries are not coincident with the borough boundaries. This results in an overlap with one other Drain London Group.

The Southern extent of the Borough overlaps with Group 3. Due to this hydrological overlap Halcrow have modelled the Southern Borough extent as part of their modelling programme. Hyder/AECOM have modelled the River Brent, Wealdstone Brook and Silk Stream.

Model Development

To ascertain a more accurate understanding of the surface water flood risk and hazard across the London Borough of LBB a 2-dimensional (2d) direct rainfall model was created using TUFLOW. TUFLOW is a hydrodynamic modelling package which can be used for 2d modelling of overland flow or as a 1d-2d linked model where there is an interaction with linear flow features.

This approach enables the effect of the topography on overland flood routes to be simulated by direct application of a rainfall profile to a 2d hydraulic model domain. TUFLOW's 2d solution is based on the Stelling solution scheme. It is a finite difference, fixed grid, alternating direction implicit (ADI) scheme solving the full 2d free surface shallow water flow equations.

Hydrological Modelling

The Drain London modelling was designed to analyse the impact of heavy rainfall events across each London Borough by assessing flow paths, velocities and catchment response.

The Drain London Data and Modelling Framework[1] specified that the direct rainfall method should be used in the modelling approach. This method incorporates conservative allowances for the drainage network and infiltration. The following key assumptions were made to generate the model input:

- Initial Loss – None
- Infiltration Loss – None
- Allowance for Drainage System – A constant value of 6.5mm/hr was applied
- No aerial reduction factor applied
- 'Summer' profile was used

Design Rainfall

To comply with the Drain London framework requirements rainfall inputs were generated at a 10km grid square resolution (Figure C-4). As specified in the framework guidance hyetographs for the following rainfall events were generated:

- 1 in 30 year
- 1 in 75 year

[1] Drain London – Data and Modelling Framework v1.0, 10th December 2010

- 1 in 100 year
- 1 in 100 year plus climate change (+30%)
- 1 in 200 year

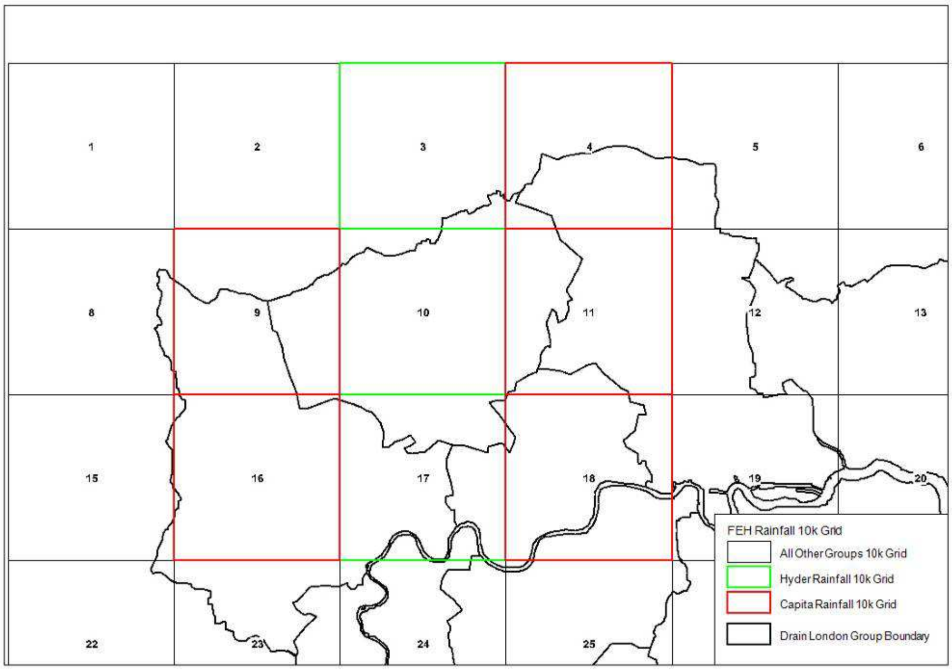

Figure C-4 10k rainfall grid

A two stage process was used to generate the rainfall hyetographs for TUFLOW. The first stage involved the extraction of total rainfall depths at each 10km grid centroid for all required return periods from the FEH CD-ROM (v3) Depth Duration Frequency (DDF) model. A comparison between the peak rainfall depths in adjacent 10km grid squares was completed to confirm the suitability of the 10km grid resolution for modelling purposes. The difference in total rainfall depths between the grid centroids was less than 5% which suggests that the data is suitable for use in TUFLOW. Table C-1 below outlines the peak rainfall depths generated for each 10km grid square by Hyder and Capita Symonds.

	Hyder 10k Grid Rainfall Depth (mm)			Capita 10k Grid Rainfall Depth (mm)				
TUFLOW Rainfall Grid ID	**3**	**10**	**17**	**9**	**16**	**4**	**11**	**18**
10k Grid Centroid ID	**2A**	**2B**	**2C**	**1b**	**1d**	**4a**	**4c**	**4e**
30 year	43.92	42.54	45.32	44.98	47.1	45.45	48.55	48.77
75 year	57.61	55.84	59.18	58.48	61.01	59.82	64.36	64.6
100 year	62.71	60.79	64.33	63.48	66.15	65.18	70.3	70.53
200 year	76.87	74.56	78.60	77.32	80.35	80.11	86.86	87.1

Table C-1 Peak Rainfall Depths for each 10k Grid Centroid

The second stage of input generation involved the use of ISIS which is an industry standard 1d modelling package. Within ISIS an FEH inflow boundary was populated with the DDF rainfall data, a critical storm duration of 3 hours was set and a summer rainfall profile was selected. The 3 hour critical storm duration was predetermined by the Drain London framework guidance document. This process generated the required rainfall hyetographs to apply in each grid square for each return period in TUFLOW.

Critical Storm Duration

Critical duration is a complex issue when modelling large areas for surface water flood risk. The critical duration can change rapidly even within a small area, due to the topography, land use, size of the upstream catchment and nature of the drainage systems. The ideal approach would be to model a wide range of durations. However, this is not always practical or economic when modelling large areas using 2d models which have long simulation times – such as within the Drain London study.

A high level investigation was undertaken to understand the effect of rainfall event duration on the Drain London Study area using a rapid modelling technique. The intention of the investigation was to show variation in critical duration across the study area and thus identify whether it was possible to identify single critical durations for each sub-model. The study used the 1 in 100 year hyetographs for 1, 3, 6 and 12 hour durations along with a simplified terrain model to route overland flow. The key result was that critical duration is highly variable across surface water catchments but the influence was not sufficiently significant to justify considering multiple event durations within the Drain London Study. Therefore, a single duration of 3hrs was selected for all model runs to ensure result consistency and comparability across the Greater London area.

Runoff Coefficients

Runoff coefficients for varying surfaces were standardised and are specified in the Drain London Data and Modelling Framework V1.0. The standardised coefficients were applied to the rainfall event profiles in order to simulate an appropriate level of infiltration for each land use type.

The runoff coefficients were applied in TUFLOW using 2d_rf boundaries which apply rainfall to every active cell in the model.

Software Version

All of the models have been run using the 2010 versions of TUFLOW. The River Brent and Silk Stream models were run using the 64bit version of TUFLOW (2010-10-AA-iDP-w64) due to their size. The 64bit version has been designed to deal with large domain models. The Wealdstone Brook and the two catchments modelled by Halcrow were modelled using the 32bit version of TUFLOW (2010-10-AC-iDP-w32).

Hydraulic Model Parameters

All of the LBB hydraulic models were set up according to the specification in the Drain London Data and Modelling Framework document.

Digital Elevation Model

A key component of the TUFLOW modelling process was the acquisition of a Digital Terrain Model (DTM). TUFLOW utilises standard GIS packages to manage, manipulate and present input and output data. In order to model surface water TUFLOW requires terrain data. This can be from a variety of sources (GPS, LiDAR, photogrammetry etc) but the more detailed and accurate the source of data, the more accurate and reliable the solution is likely to be. High resolution (1m) LiDAR data was provided by Infoterra in two formats:

- Digital Surface Model (DSM) which is unfiltered so buildings and raised objects are maintained
- Digital Terrain Model (DTM) which is filtered with buildings and raised objects smoothed.

Filtered DTM data was used for the Drain London surface water modelling. This provided complete coverage of the Group 2 area (Figure C-5). A TUFLOW topography file, zpt layer, was generated from the DTM at a 5m resolution.

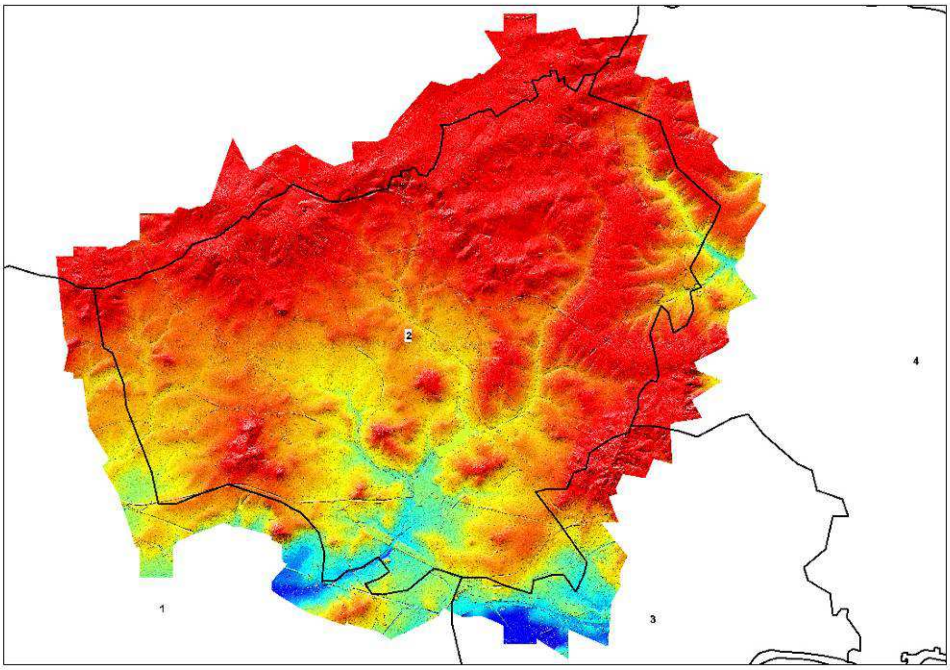

Figure C-5 Group 2 LiDAR

Standard practice for TUFLOW modelling is to use filtered LiDAR as it removes interference and distortion caused by buildings and trees to represent the ‘bare earth’.

While the majority of the Infoterra data provided was of a suitable standard, there were a number of issues identified following initial model runs that required corrective measures. Figure C-6 to C-9 show the main issues identified with the DTM.

Buildings have been poorly filtered leaving anomalous spikes in the ground model which can adversely affect the model results. These buildings have been smoothed using a zshape polygon to mask the building in the DTM. This reduces its impact on the modelled results.

Figure C-6 Poorly filtered buildings in Group 2 LiDAR

Raised structures (e.g. bridges, underpasses and subways) have not been filtered out of the DTM. These features create unnatural barriers to flow where in reality flow would pass beneath or through the structure. To remove these structures from the DTM a 2d zshape was drawn over the structure with node points at all four corners of the polygon. The four points were populated with elevations from the DTM on either side of the structure to effectively cut through the feature. This 2d zshape is then read into TUFLOW where the structure is removed.

Figure C-7 Poorly filtered structures in Group 2 LiDAR

A further issue in the draft modelling identified an error in the filtering process in the DTM creating a speckled model output. This anomaly was referred back to Infoterra for re-filtering of the DTM. A new dataset was issued and has been used to produce the subsequent modelling.

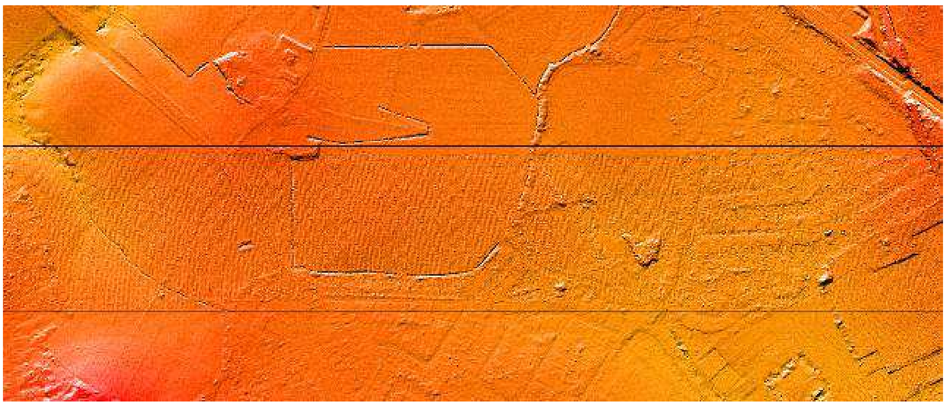

Figure C-8 Speckled LiDAR anomoly

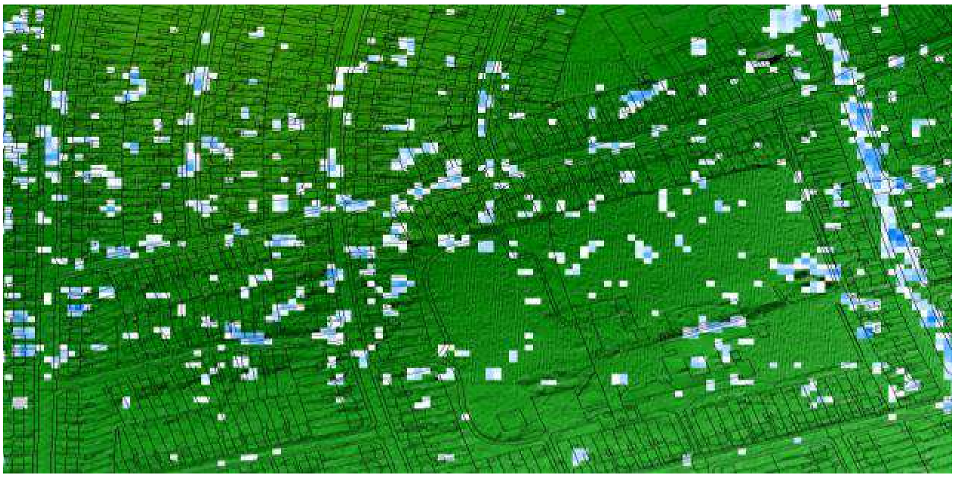

Figure C-9 LiDAR anomaly caused unusual TUFLOW model outlines

Grid Size

The LBB models have all been created at a 5m grid resolution. This grid size was chosen to ensure that key urban features were represented while ensuring a reasonable model run time. This grid size falls within the approved range as specified in the Drain London Data and Modelling Framework.

Building Representation

MasterMap data was used to identify all building footprints within the Group 2 study area. The buildings were separated from the main Master Map dataset and an average ground level within the building footprint was calculated in MapInfo. An 'upstand' of 100mm was applied to the average ground level for each building footprint. Only buildings where the 'upstand' was above the surrounding ground level were applied within the TUFLOW simulation.

A depth varying roughness was applied to all buildings within the model domain. For depths up to 30mm a Manning's n of 0.015 was applied and above this depth, a value of 0.5 was applied.

Floodplain Structures

During the development of the hydraulic models, a number of flow paths through bridges or culverts were identified. Where necessary these structures have been modelled using either a 2d zshape or an ESTRY 1d culvert unit within the 2d TUFLOW domain. No structural information was made available for the Drain London study so the width and invert levels of the structures were estimated using the OS10k map, DTM and Google Maps.

The 2d zshapes were predominantly used for wider structures where the assessment of flow through the structure was not required. The 1d ESTRY units were used where the structures were narrow (less than the 5m grid size) or where an analysis of flow through the structure was seen as beneficial.

Watercourses

All open watercourses within the model domain were assumed to be at bank full throughout each of the model simulations. Bank top levels were determined by using a combination of the Ordnance Survey 10k mapping, Drain London DTM and Google Maps. To represent the bank full watercourses in TUFLOW a 2d zshape polygon was generated at bank top along the length of each watercourse with a node point at each vertex. Each node was populated with an elevation value from the underlying 'bare earth' DTM.

Use of PO lines

In order to analyse the model results at points of interest a series of PO (Point Output) lines were drawn within the TUFLOW model domain to record integral flows, water levels and velocities throughout the simulation. These lines were placed mainly perpendicular to main flow routes. The PO lines can be analysed to determine the total volume of flow passing through it over the simulation. PO lines were not used in all of the LBB models.

Downstream Boundaries

In order to represent flow out of the model domain HQ (Stage vs Flow) boundary lines were added at the edge of the 2d model domain. HQ lines were not used in all of the LBB models.

Cross Boundary Issues

Within the LBB there are several boundary connections between the models. In a majority of cases the model boundaries are located along high topographic features therefore there is minimal flow between the models. Where flow paths between models were identified a downstream boundary as outlined in section 1.2.13 was added. The flow recorded between models was minimal so these flows were not inputted into neighbouring models.

Manning's Values

A common set of Manning's roughness coefficient values were defined in the Drain London Data and Modelling Framework v1.0 to provide consistency between the Borough models. The Manning's values were applied in TUFLOW with in a materials file (.tmf). The Drain London tmf file contained the roughness values along with continuing runoff losses. The tmf file is read in by TUFLOW in conjunction with a 2d_mat.mif file, created based on feature code, and the 2d_rf boundary files.

Model Run Time

All of the LBB models were initially run for six hours as specified in the Drain London Data and Modelling Framework. The model files were checked to ensure that the modelled depths were not increasing and that no further flow paths were being formed. All of the LBB models were run for six hours.

Sensitivity Testing

In order to assess the LBB models sensitivity to changes in drainage the models loss to drainage parameter was amended by +/-25% from 6.5mm/hr to 8.125mm/hr and 4.875mm/hr.

The 0.5% AEP model was re-run with these amended parameters to assess what impact this would have on the modelled extents and depths. The results from the sensitivity analysis were compared with the baseline 0.5% AEP results. A significant impact on results was identified if the percentage change in depth was greater than the percentage change in the parameter.

The LBB models showed minimal sensitivity to changes in the drainage loss parameter. With the sensitivity results showing less than a 25% change in depth from the baseline model results across the Borough. There were several isolated areas which showed larger differences in depth however these were in areas where there were sudden changes in elevation in the underlying DTM (e.g. railway embankments).

Model Stability

An assessment of the LBB models stability was made by analysing the mass balance (cumulative error %) for each model run. The warnings in the model output files were also checked to ensure that these were not highlighting any fundamental issues with the model. This assessment was an important stage in establishing the accuracy of the model outputs.

The Drain London Data and Modelling Framework document suggests that the recommended range of cumulative error should be +/- 5% for a majority of the simulation. All of the models report very high cumulative errors at the beginning of the model simulation. This is caused by TUFLOWs initial wetting process at the beginning of the rainfall event. The models all settle down beyond the one hour mark with the rest of the simulation falling within the recommended range. As the errors occur at the beginning of the simulation at varying times and are not prolonged it is deemed unlikely that they would have an impact on the model results.

The warning messages were also checked for all five of the models. There were repeated warnings in all of the models prior to the start of the simulations. This was caused by the use of very small MasterMap polygons being used in the 2d_rf and 2d_mat files. No further action was taken as this was not likely to impact on the overall model results. Convergence errors occurred in all of the LBB models. A majority of the convergence issues were identified as being caused by areas of poorly filtered LiDAR. As the warnings were in a variety of locations and occurred at differing times during the simulation they were deemed to have a minimal impact on the model results.

Model Summary

The table below summarises the Drain London models run along with a summary of their LBB coverage.

Catchment Name	Model Naming Convention	TUFLOW Build	Grid Size	Storm Duration	Total Run Time	Borough Coverage	Borough Coverage
River Brent	RB_BL_100_180_V12	2010-10-AA-iDP-w64	5m	3hrs	6hrs	29.6km^2	69%
Wealdstone Brook	WB_BL_100_180_V14	2010-10-AC-iDP-w32	5m	3hrs	6hrs	6km^2	14%

Silk Stream	SS_BL_100_180_V3	2010-10-AA-iDP-w64	5m	3hrs	6hrs	3km^2	7%
1		2010-10-AC-iDP-w32	5m	3hrs	6hrs	0.9km^2	2%
2		2010-10-AC-iDP-w32	5m	3hrs	6hrs	3.5km^2	8%

Model Output Files

In order to assess areas at risk of surface water flooding flood depths greater than 0.1m were analysed. The depth grids were broken down into depth bands to allow for the identification of areas at risk of overland flow and deep ponding (>1.5m).

The flood hazard outputs were broken down into bands based on the joint Environment Agency and Defra R&D Technical Report FD2320 (January 2006). This was deemed the most applicable to the heavily urbanised Greater London area. The output was represented by three degrees of critical flood hazard: Moderate (0.75 -1.25) danger for some; Significant (1.25 – 2.0) danger for most; Extreme (>2.0) danger for all. Anything less that 0.75 was not represented as the hazard level was deemed very low.

The velocity outputs were used to assess significant changes in velocity. Velocities above 0.5m/s were analysed as these higher velocity areas were deemed to pose higher risk levels. Velocity vectors were also exported from the models to represent changes in flow direction and magnitude.

The mapped model outputs are included in Appendix D of this SWMP report.

Model Validation

The surface water modelling was validated using the FMfSW shallow and deep outlines, historic flood incidents and Hyder site visits to establish if there was a correlation between the mapped areas identified at risk. There was a good match between the Drain London mapping, historic flood incidents and the EA FMfSW.

The mapping did not correspond with all of the historic flood incidents, however it may be that the source and location of the exact flood incident has not been accurately reported or recorded in the past. The Drain London mapping identified clearer connections between areas of flooding as well as showing flow velocity and hazard.

Model Limitations

There are a number of limitations associated with the modelling methodology:

- The below ground sewerage infrastructure including the combined sewers have not been modelled and therefore their variable capacity has not been taken into account (instead rainfall has been removed at a constant rate of 6.5mm/hour everywhere).

- The modelled topography of the ground is based on a grid of points at a 5 m distance between them and therefore any variations within these have not been modelled.
- Obstructions such as railway embankments have been modelled however culvert crossings beneath them (unless clearly seen on OS maps) have not always been.
- The permeability of the ground has been modelled to a certain extent however only by allowing a limited number of soil categories.
- The capacity of watercourses has not been modelled and therefore there is a tendency of building up of surface water along the river floodplain.

Conclusions and Recommendations

As part of Drain London Tier 2 strategic surface water models were developed for all 33 of the London Boroughs. The models were designed to allow for the assessment of surface water flood risk across each London Borough. Within the LBB the models have helped to identify key flow paths, critical drainage areas (CDAs) and local flood risk zones (LFRZs).

As a result of the surface water modelling the following mechanisms of flooding were identified:

- Ponding of flow in topographical depressions.
- Ponding upstream of structures with small underpasses/subways
- Overland flow along topographical lows and valley channels such as residential streets, gardens and through property

The hazard mapping produced should be treated with caution as inconsistencies in the LiDAR surface received for the study, as a result of inconsistent processing, have resulted in areas where there low depths of surface water are showing to be high hazard rating.

Several recommendations for future improvements to the models are outlined below.

- Develop detailed integrated models in the local flood risk zones to take the underground drainage network and the fluvial network into account
- Re-run the models as and when improved LiDAR becomes available
- Obtain survey data for key structures within LFRZs to improve the accuracy of the modelled output
- Increase the model resolution in LFRZs to improve the accuracy of the modelled flow paths.

Appendix D – Maps

Appendix E – Option Assessment Details

E1 – CDA Descriptions

E2 – Summary of Measures

E3 – Option Assessment (refer to separate spreadsheet)

Appendix E1 – CDA Descriptions

1.1.1 Belvedere Way – Group2_034

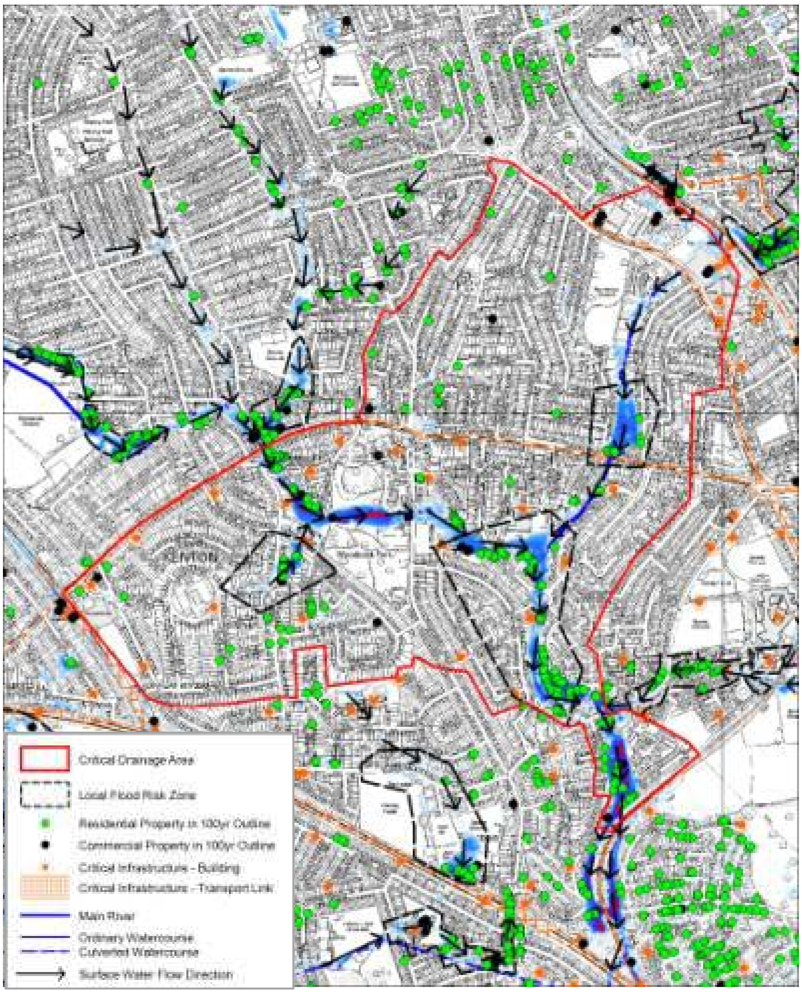

Figure E1-1 Belvedere Way CDA

Group2_034 is located in a densely urbanised area of Kenton in the north of the LBB however the CDA crosses into the London Borough of Harrow (LBH). This is a known area of flood risk with a history of significant flooding from multiple sources. Several studies have focussed in on this area to try to identify the principal mechanism of flooding cause. The most notable, the North Brent IUD Pilot Study (2008), concluded that there was a general lack of capacity in the surface water and sewer network which is exacerbated by the number of cross connections constricting the system.

There were also capacity issues identified in the culverted sections of the Wealdstone Brook upstream of Belvedere Way. This study highlighted that the flood risk issues in this area are caused by system wide constraints therefore any mitigation measures implemented need to ensure that they do not have a negative impact on the system as a whole.

This CDA is approximately 2.55km^2. The 1 in 100 year modelled output indicates that there are 242 non-deprived properties at risk of shallow flooding (<0.5m) and 28 at risk of deep flooding

(>0.5m). There are 37 commercial properties at risk of shallow flooding and two at risk of deep flooding.

There are four 'essential' infrastructure assets at risk of shallow flooding within this CDA: A4006 Kenton Road, two electricity sub stations and Kenton railway station. There are four 'more vulnerable' critical infrastructure sites which are at risk of shallow flooding: Three schools and one electricity installation.

There are several known sources of flood risk within this area: fluvial flooding from Wealdstone Brook, foul sewer flooding and surface water ponding in topographic lows. The surface water modelling has illustrated the key overland flow paths for surface water and the areas at risk of significant ponding. Three LFRZs have been designated within this CDA; these correspond with areas with the largest concentration of property at risk. This CDA was validated against both the EA FMfSW and several historic surface water flooding incidents.

1.1.2 Winchester Avenue – Group2_035

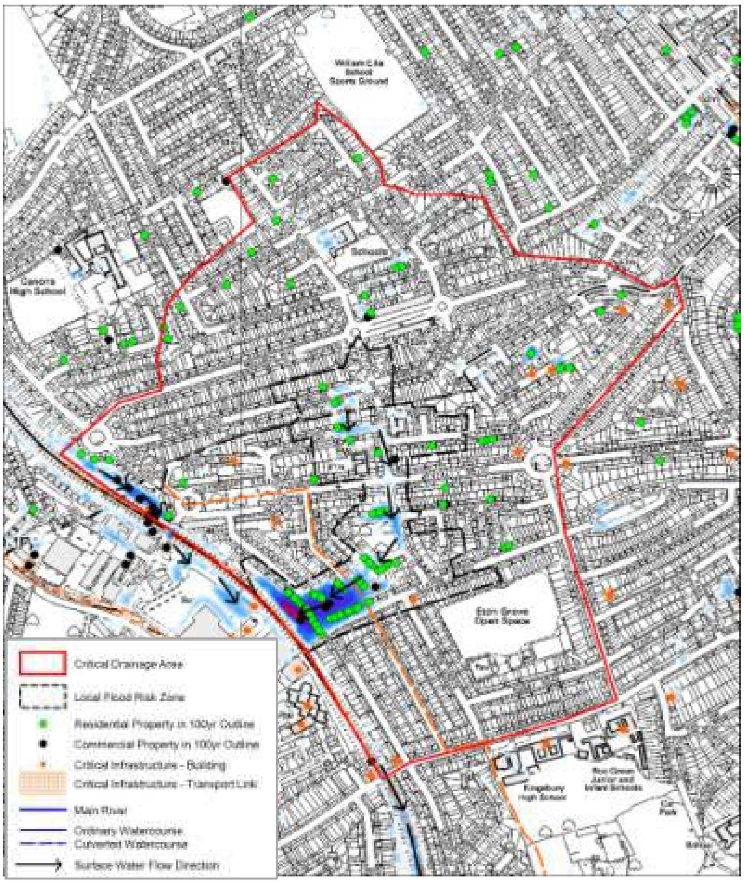

Figure E1-2 Winchester Avenue CDA

Group2_035 is located to the north east of the borough in a densely urbanised area with a small open area to the south. The CDA is approximately 0.7km^2. The 1 in 100 year modelled output indicates that there are 126 non-deprived properties at risk of shallow flooding and 23 at risk of deep flooding. There are 15 commercial properties at risk of shallow flooding and five at risk of deep flooding.

There are three 'more vulnerable' infrastructure assets which are at risk of shallow flooding within this CDA: three electricity installations. The main source of flood risk within this CDA is from overland flow and deep ponding adjacent to the railway embankment. One LFRZ has been designated around the main overland flow route and ponded area within this CDA. There are no visible crossings beneath the embankment in this area. The TWUL sewer network indicates that there are two surface water pipes (approximately 1000mm diameter) crossing beneath the railway line in this location. These surface water sewers would help to alleviate some of the ponding surface water flow. However the specific drainage capacities have not been taken into account in the Drain London modelling.

This CDA was validated against both the EA FMfSW and a historic surface water flooding incident.

1.1.3 Preston Sports Ground – Group2_036

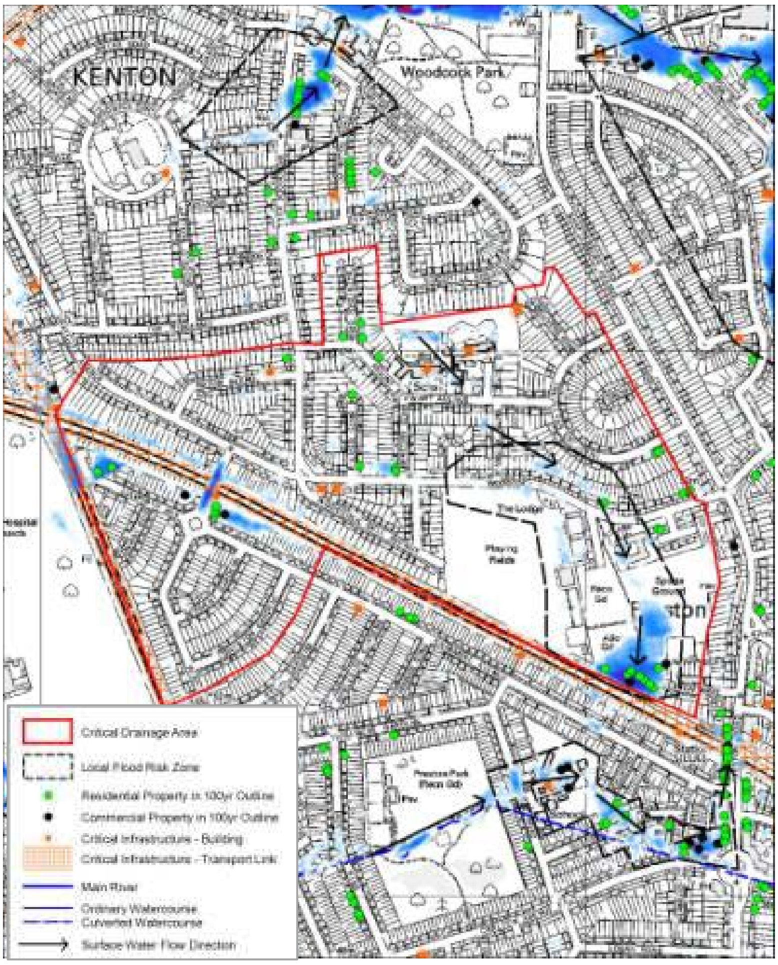

Figure E1-3 Preston Sports Ground CDA

Group2_036 is a mixed use area with an open area to the north and to the south east of the CDA. This CDA is approximately 0.6km^2. The 1 in 100 year modelled output indicates that there are 31 non-deprived properties are at risk of shallow flooding and four are at risk of deeper flooding. There are four commercial properties at risk of shallow flooding and one at risk of deep flooding.

There are two 'essential' infrastructure assets that are at risk of flooding: two electricity sub stations. There are two 'more vulnerable' assets at risk of shallow flooding within the CDA: two schools. The main source of flood risk within this CDA is from overland flow and deep ponding adjacent to the railway embankment at Preston Sports Ground. One LFRZ has been designated around the main overland flow route and ponded area within this CDA. The TWUL surface water network indicates that there is a 900mm diameter pipe crossing under the railway line in this location. The presence of this surface water drain will help to reduce the amount of ponding behind the railway embankment. The Drain London modelling process does not take specific drainage network capacities into account.

This CDA was validated against the EA FMfSW, no historic surface water flooding incidents have been recorded in this area.

1.1.4 Northwick Park – Group2_037

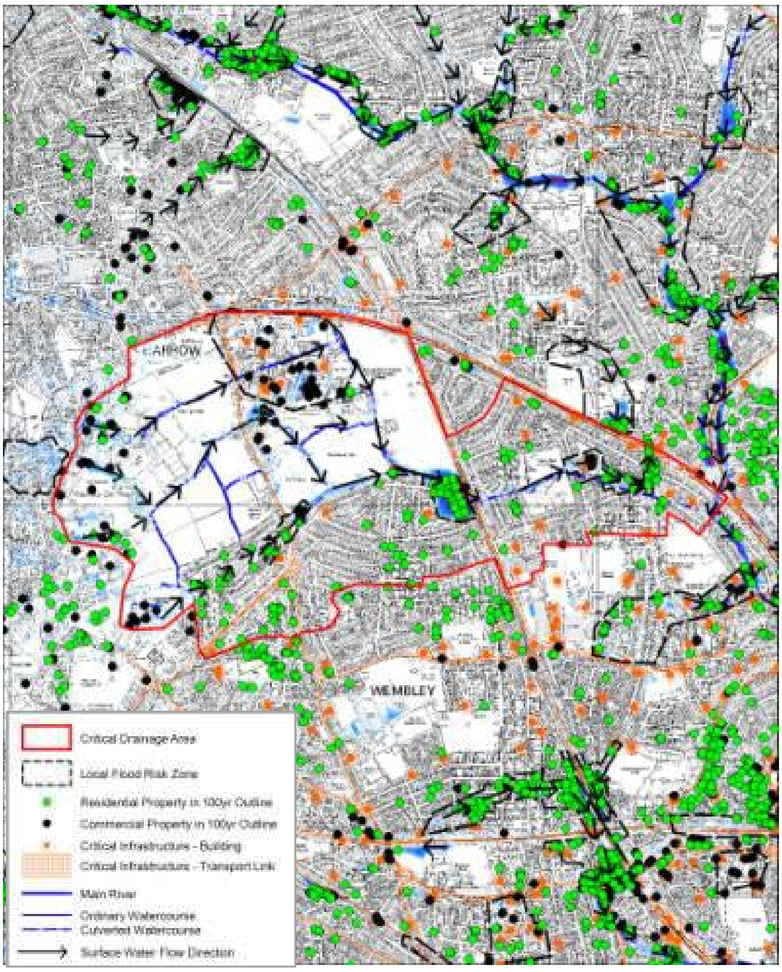

Figure E1-4 Northwick Park CDA

Group2_037 covers a mixed use area to the north west of the borough. There are large areas of open land at Northwick Park to the north and east of the CDA with the remainder of the CDA being densely populated with residential and commercial property. This CDA is approximately 3.4km^2. The 1 in 100 year modelled output indicates that there are 219 non-deprived properties at risk of shallow flooding and 47 at risk of deep flooding. There are 87 commercial properties at risk of shallow flooding and four at risk of deep flooding.

There are four 'essential' infrastructure assets at risk of shallow flooding within this CDA: four electricity sub stations. The sub-station at Nathans Road is at risk of deep flooding. There are seven 'highly vulnerable' assets at risk of shallow flooding: three telecommunication masts and four hazardous waste consent sites. There are 11 'more vulnerable' assets at risk of shallow flooding: four hazardous waste disposal sites, two schools, two hospital sites and three electricity installations.

The main source of risk in this CDA is overland flow and surface water ponding in between open sections of the drainage network. The overland flow is following the old open watercourse valleys. The overland flow is ponding significantly upstream of the railway embankment at Nathans Road as there is only a small subway allowing flow through the embankment in this location. Four LFRZs were designated within this CDA to correspond with areas at most significant risk of flooding. The TWUL surface water network in this area shows an additional pipe crossing under the railway embankment to the south of South Kenton railway station and the subway. This pipe is approximately 1450mm in diameter. This large surface water pipe would help to alleviate the surface water ponding in this area however it has not been taken into account in the Drain London modelling. More information regarding the location of the culverted drain to the north of the Nathans Road would be beneficial to determine if this is being taken into account in the TWUL network.

This CDA was validated against both the EA FMfSW and several historic surface water flooding incidents.

1.1.5 Barham Park – Group2_038

Group2_038 is a mixed use area located to the west of the borough. There are large areas of open land to the north and south of the CDA. The CDA is approximately 1.6km^2. The 1 in 100 year modelled output indicates that there are 352 non-deprived properties at risk of shallow flooding and 75 at risk of deep flooding. There are 68 commercial properties at risk of shallow flooding and two at risk of deep flooding.

There are five 'essential' infrastructure assets at risk of shallow flooding: five electricity sub stations. There are six 'more vulnerable' assets at risk of shallow flooding within this CDA: five electricity installations and one residential care home. The main source of flood risk is from overland surface run off which is following a topographic low through the residential area within this CDA. One LFRZ has been designated to correspond with the main overland flow route. The TWUL surface water network in this area shows that there is a 1300mm connecting pipe from St Johns Road (Group2_039) to Lancelot Road and another pipe under the railway embankment running from east to west running parallel to Lancelot Road. The TWUL dataset does not have any pipe diameter information for this crossing.

This CDA was validated against both the EA FMfSW and a historic surface water flooding incident.

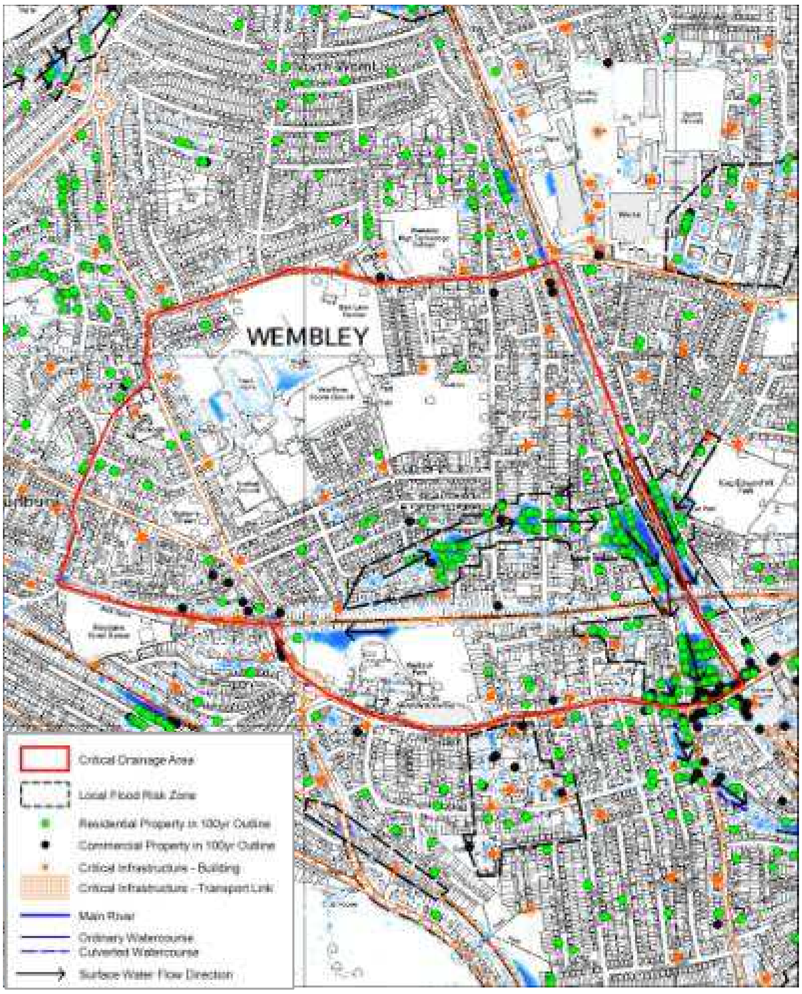

Figure E1-5 Barham Park CDA

1.1.6 King Edward VII Park – Group2_039

Group2_039 is a predominantly urbanised area with an open area of parkland at the centre of the CDA. The CDA is located to the west of the borough and is approximately $0.4km^2$. The 1 in 100 year modelled output indicates that there are 123 non-deprived properties at risk of shallow flooding. There are two commercial properties at risk of shallow surface water flooding.

There are two 'essential' infrastructure assets which are at risk of shallow flooding: two electricity sub stations. There is on 'more vulnerable' asset at risk of shallow flooding: one electricity installation.

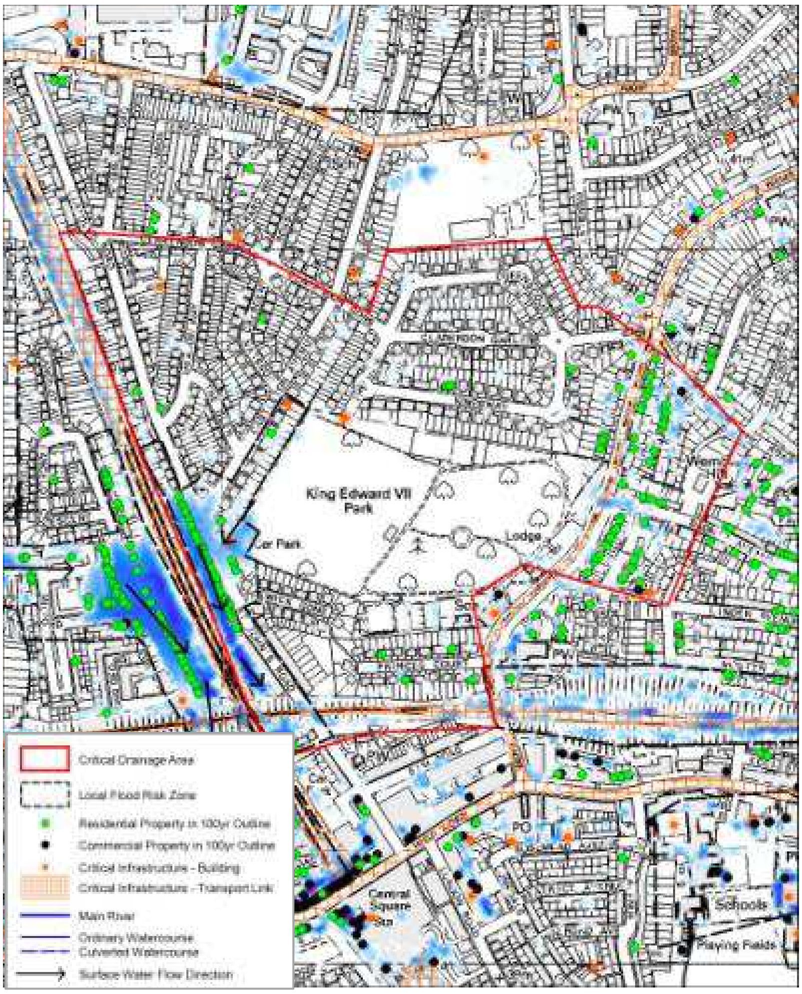

Figure E1-6 King Edward VII Park CDA

The main source of flood risk in this CDA is from ponding surface water in topographic depressions. One LFRZ has been designated in the area at most significant risk of surface water ponding. As mentioned in Group2_038 there is a cross connecting TWUL surface water pipe from St Johns Road to Lancelot Road. The TWUL network suggests that all of the surface water pipes converge in this location and transfer flow over to the pipe network parallel to Lancelot Road. This subterranean cross connection has not been taken into account in this Drain London mapping however it is likely to alleviate some of the ponding surface water in this location.

This CDA was validated against the EA FMfSW, no historic surface water flooding incidents have been recorded in this area.

1.1.7 A4089 – Group2_040

Group2_040 is a densely urbanised area to the south west of the borough. This CDA is approximately 1.2km^2. The 1 in 100 year modelled output indicates that there are 93 non-deprived and 64 deprived properties at risk of shallow flooding, 10 of the deprived properties are at risk of deep flooding. There are 58 commercial properties at risk of shallow flooding, four properties are at risk of deep flooding.

There are two ‘essential’ infrastructure assets that are at risk of shallow flooding within this CDA: two electricity sub stations. There are two ‘highly vulnerable’ assets at risk of shallow flooding: Chaplain Road ambulance station and Harrow Road police station. There are six ‘more vulnerable’ assets at risk of shallow flooding: Wembley Hospital, one residential care home, one GP surgery, one school and two electricity installations.

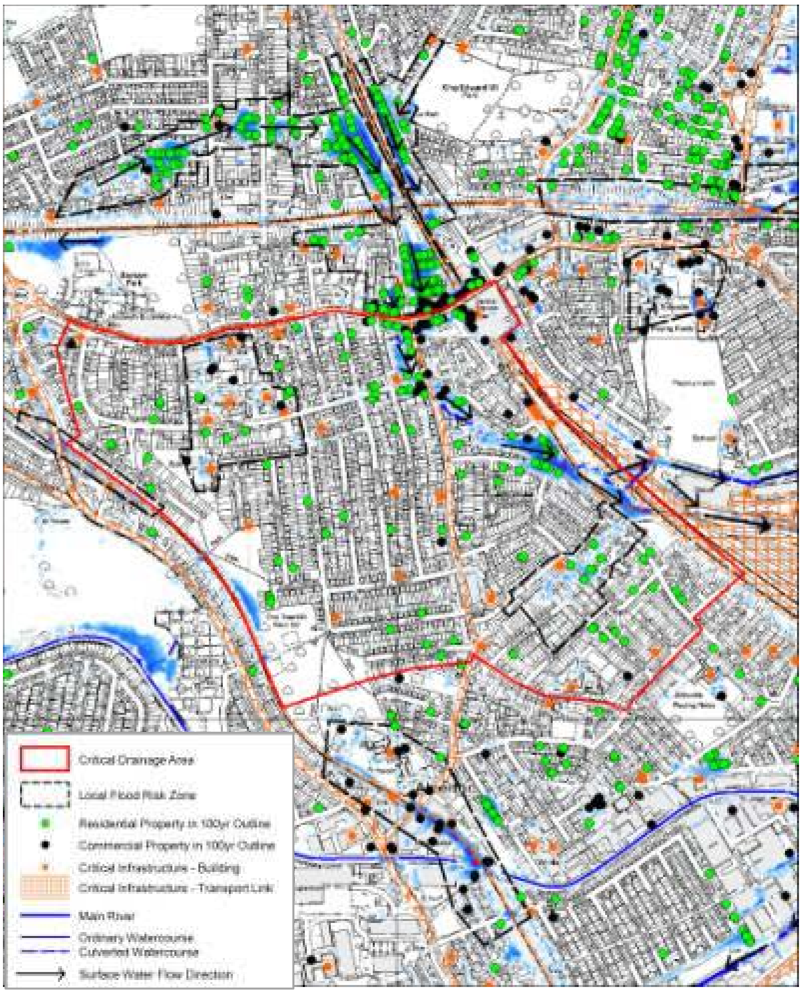

Figure E1-7 A4089 CDA

The main source of flood risk in this CDA is from overland surface water flow and ponding in topographic lows. Two LFRZs have been designated which cover the main overland surface water flow routes.

This CDA was validated against the EA FMfSW, no historic surface water flooding incidents have been recorded in this area.

1.1.8 Alperton – Group2_041

Group2_041 is a mixed use area with open land in the north of the CDA and a mixture of commercial and residential property to the south. This CDA is located to the south west of the borough and is approximately 0.8km^2. The 1 in 100 year modelled output indicates that there are 49 non-deprived properties at risk of shallow flooding and three at risk of deep flooding. There are 44 commercial properties at risk of shallow flooding and 18 at risk of deep flooding.

There are three ‘essential’ infrastructure assets at risk of flooding within this CDA: the A4089 Ealing Road is at risk of deep flooding and Alperton railway station and one electricity sub station are at risk of shallow flooding. There are three ‘more vulnerable’ assets at risk of flooding: one school at risk of shallow flooding and two electricity installations at risk of deep flooding.

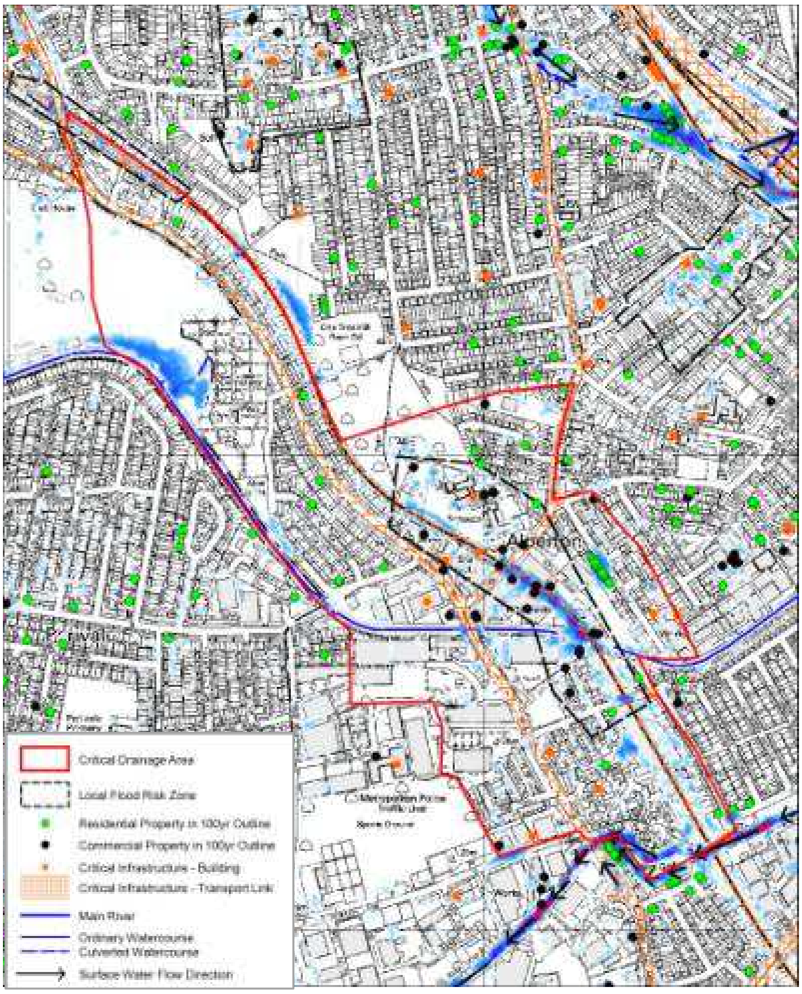

Figure E1-8 Alperton CDA

The main source of flooding in this CDA is surface water ponding in topographic low spots. One LFRZ has been designated in the area at most significant risk of flooding. This CDA was validated against the EA FMfSW, no historic surface water flooding incidents have been recorded in this area.

1.1.9 North Circular – Group2_042

Group2_042 is a predominantly commercial CDA with a small residential area to the north west of the CDA. This CDA is located to the south of the borough and is approximately 1.45km^2. The 1 in 100 year modelled output indicates that there are 53 non-deprived properties at risk of shallow flooding. There are 56 commercial properties at risk of shallow flooding within the CDA.

There are five ‘essential’ infrastructure assets at risk of surface water flooding: four electricity sub stations are at risk of shallow surface water flooding and the A406 north circular is at risk of deep ponding. There are five ‘more vulnerable’ assets at risk of shallow surface water flooding: five electricity installations. The main source of surface water flood risk within this CDA is ponding flow in topographic low spots. One LFRZ has been designated within this CDA this corresponds with the significant area of ponding on the North Circular. This CDA was validated against the EA FMfSW, no historic surface water flooding incidents have been recorded in this area.

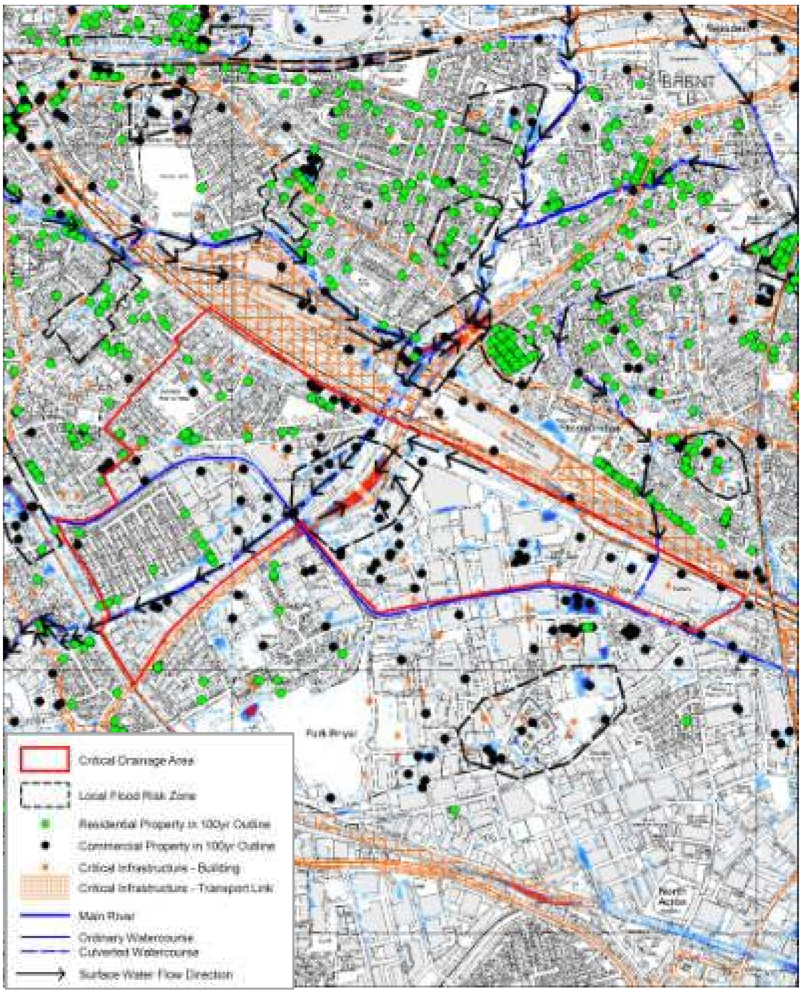

Figure E1-9 North Circular CDA

1.1.10 Park Royal – Group2_043

Group2_043 is located to the south of the borough in a predominantly commercial area. The CDA is approximately 0.5km^2. The 1 in 100 year modelled output indicates that there are 12 non-deprived and 10 deprived properties at risk of shallow surface water flooding. There are 52 commercial properties at risk of shallow flooding within this CDA and three at risk of deep flooding.

There is one 'highly vulnerable' infrastructure asset at risk of shallow surface water flooding: one hazardous waste consent site. There are four 'more vulnerable' assets at risk of shallow surface water flooding: one hazardous waste disposal site, Central Middlesex Hospital and two electricity installations.

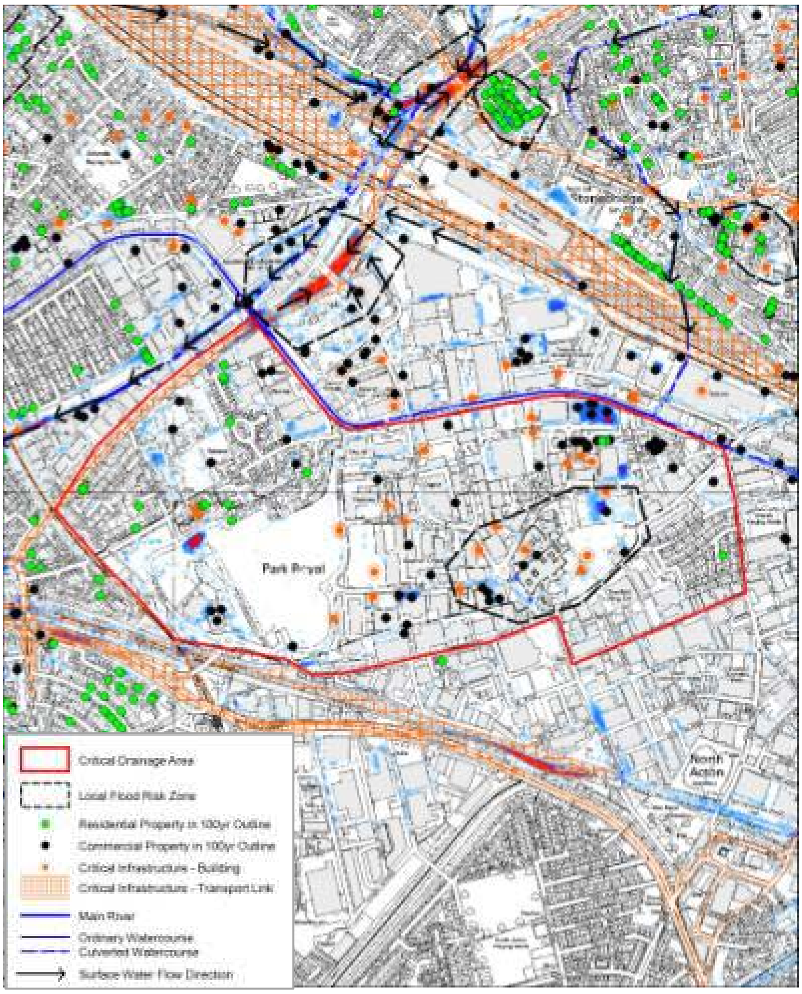

Figure E1-10 Park Royal CDA

The main source of flood risk within this CDA is from ponding surface water in topographic depressions. One LFRZ has been designated in the area at most significant risk of surface water ponding. This CDA was validated against the EA FMfSW, no historic surface water flooding incidents have been recorded in this area.

1.1.11 Tokyngton – Group2_044

Group2_044 is located to the south of the borough in a densely urbanised area. This CDA is approximately 0.5km^2. The 1 in 100 year modelled output indicates that there are 69 non-deprived properties at risk of shallow flooding. There are 11 commercial properties at risk of shallow flooding within this CDA.

There is one 'essential' infrastructure asset at risk of deep flooding within this CDA: A406 North Circular. There are two 'highly vulnerable' assets at risk of shallow flooding: two telecommunications masts. There is one 'more vulnerable' asset at risk of shallow flooding: a residential care home.

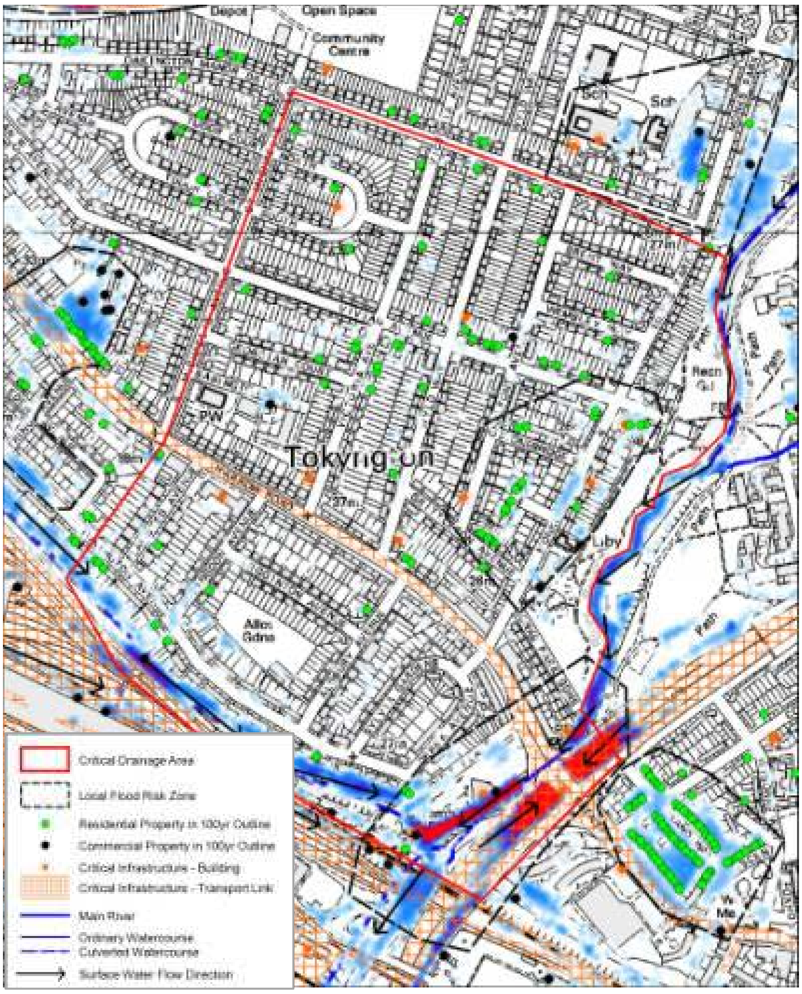

Figure E1-11 Tokyngton CDA

The main source of flood risk within this CDA is ponding surface water flow in topographic depressions. There are two LFRZs designated within this CDA, both LFRZ correspond with the areas at most significant risk of surface water flooding. This CDA was validated against the EA FMfSW and a historic surface water flooding incident in this area.

1.1.12 Brentfield – Group2_045

Group2_045 is located in a densely urbanised area to the south of the borough. This CDA is approximately 0.65km^2. The 1 in 100 year modelled output indicates that there are 141 deprived properties at risk of shallow surface water flooding and three properties at risk of deep flooding. There are 11 commercial properties at risk of shallow surface water flooding.

There is one ‘essential’ infrastructure asset at risk of shallow flooding: one electricity sub station. There are two ‘highly vulnerable’ assets at risk of shallow flooding: two telecommunications masts. There are seven ‘more vulnerable’ assets at risk of shallow flooding: one school, one hazardous waste disposal site and five electricity installations.

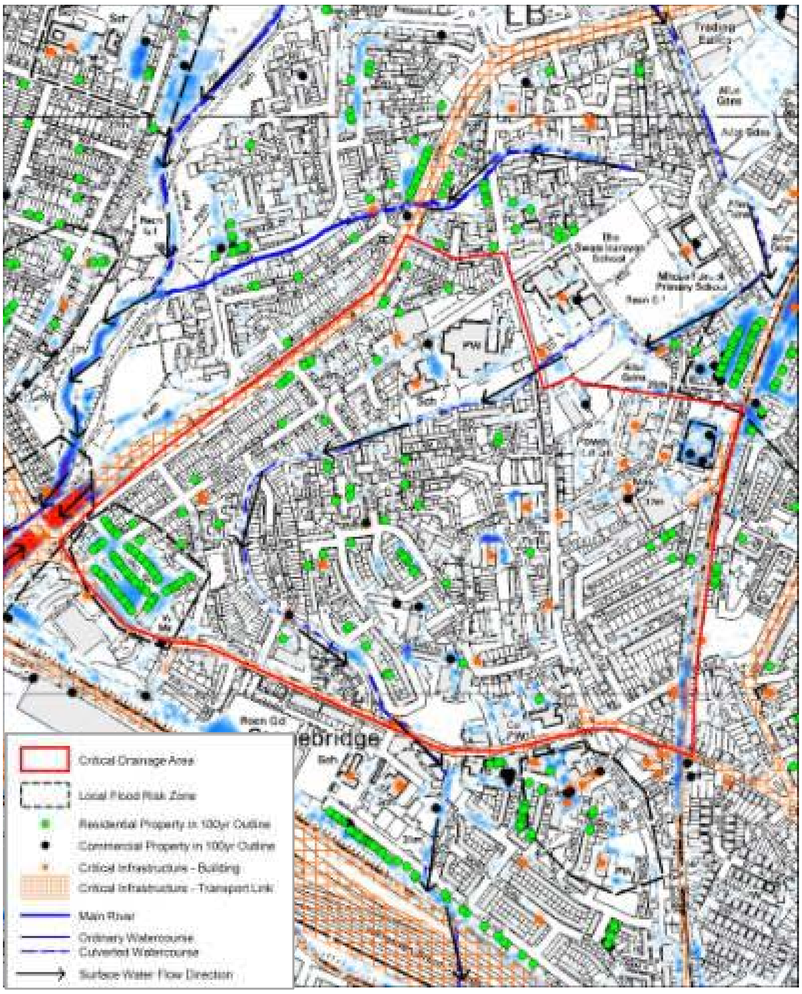

Figure E1-12 Brentfield CDA

The main source of flooding within this CDA is surface water ponding in topographic depressions. One LFRZ has been designated within this CDA, this corresponds with an area of significant ponding to the north west of the CDA. This CDA was validated against the EA FMfSW, no historic surface water flooding incidents have been recorded in this area.

1.1.13 Stonebridge – Group2_046

Group2_046 is a mixed use area with commercial property to the north west of the CDA and residential property to the south east. This CDA is approximately 0.6km^2. The 1 in 100 year modelled output indicates that there are 136 deprived properties at risk of shallow surface water flooding in this CDA. There are 25 commercial properties at risk of shallow flooding with one at risk of deep flooding.

There are three 'essential' infrastructure assets at risk of shallow surface water flooding: two electricity sub stations and Harlesden railway station. There are two 'more vulnerable' assets at risk of shallow flooding: two electricity installations. The main source of flood risk within this CDA is surface water ponding in topographical depressions.

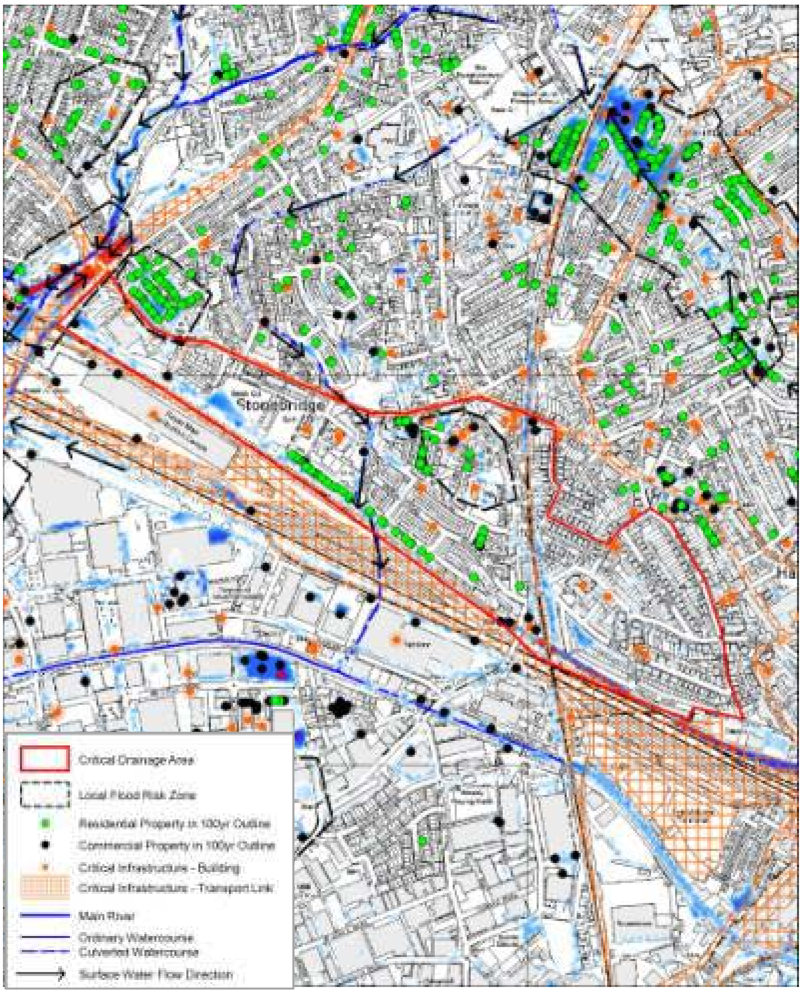

Figure E1-13 Stonebridge CDA

One LFRZ has been designated in an area at significant risk of deeper flooding on Ames Road. This CDA was validated against the EA FMfSW, no historic surface water flooding incidents have been recorded in this area.

1.1.14 Church End – Group2_047

Group2_047 is a densely urbanised area with a large area of open land to the east of the CDA. This CDA is approximately 2.6km^2. The 1 in 100 year modelled output indicates that there are 63 non-deprived and 576 deprived properties at risk of shallow surface water flooding. There are two deprived properties are at risk of deep water flooding. 34 of the non-deprived properties are classified as basement properties. There are 83 commercial properties at risk of shallow surface water flooding and three at risk of deep flooding.

There are six 'essential' infrastructure assets at risk of surface water flooding: A407 Church Road is at risk of deep flooding; four electricity sub stations and a section of gas pipeline are at risk of shallow surface water flooding. There are two 'highly vulnerable' assets at risk of shallow surface water flooding: Harlesden Police Station and Robson Avenue Ambulance Station. There are 19 'more vulnerable' assets at risk of surface water flooding: four GP surgeries, one care home, one health centre, three schools and eight electricity installations are at risk of shallow flooding. Two electricity installations are at risk of deep flooding.

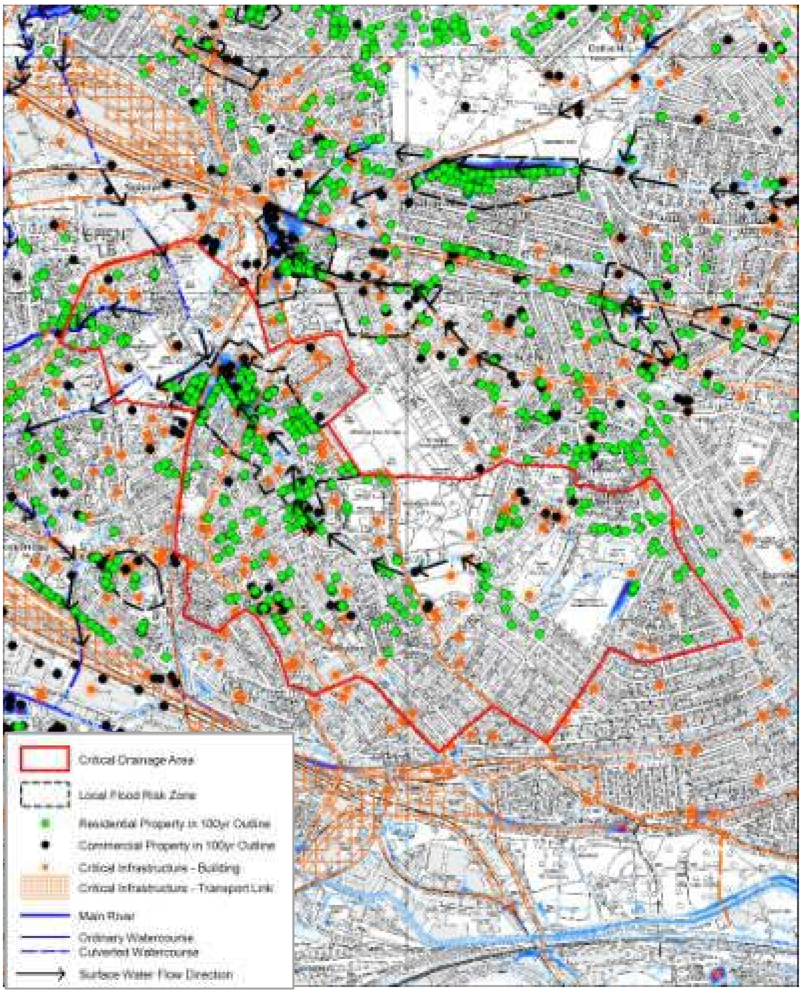

Figure E1-14 Church End CDA

The main source of flooding within this area is surface water runoff and ponding in the urban area. One LFRZ has been designated corresponding with the area at most significant risk of surface water flooding. There are no visible culvert crossings beneath the railway line at Crome Road however the TWUL surface water network shows a large diameter (2290mm) pipe crossing under the railway line. This would help to reduce the surface water ponding locally but it has not been accounted for in the Drain London model.

This CDA was validated against the EA FMfSW and a historic surface water flooding incident.

1.1.15 Neasden – Group2_048

Group2_048 is located in a densely urbanised area to the south east of the borough. This CDA is approximately 0.95km^2. The 1 in 100 year modelled output indicates that there are 52 non-deprived and 189 deprived properties at risk of shallow surface water flooding. 41 deprived properties are at risk of deep flooding. Of these 11 non-deprived and two deprived properties at risk of shallow flooding are classified as basement properties. There are 79 commercial properties are at risk of shallow flooding and 11 properties at risk of deep flooding.

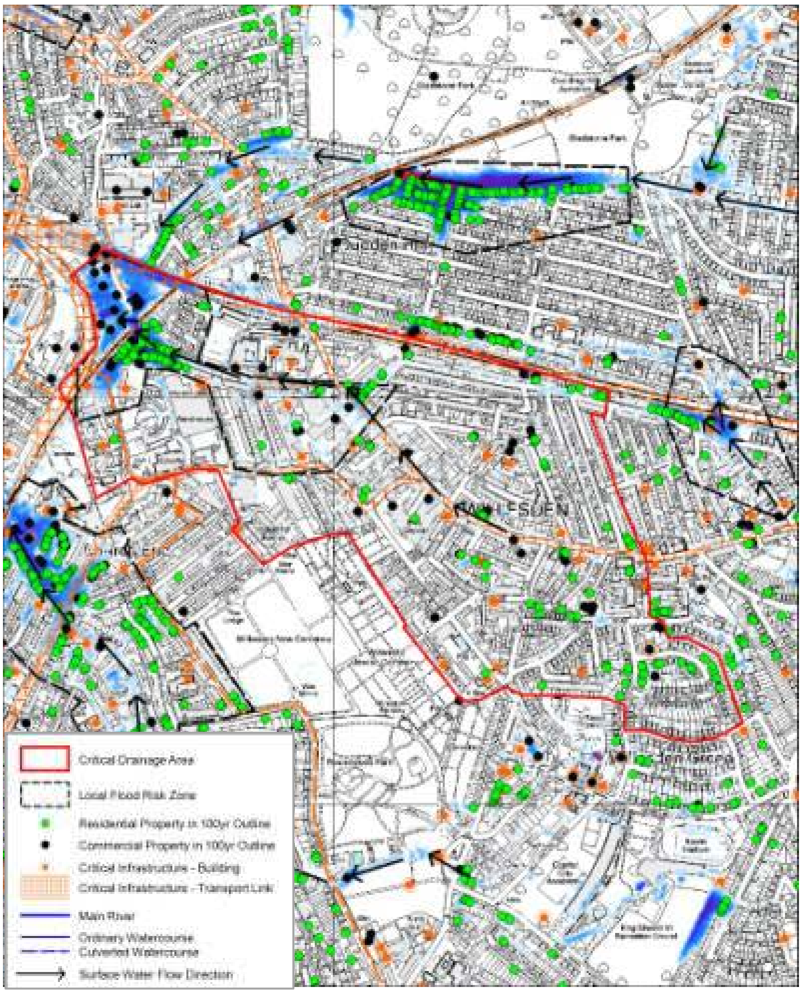

Figure E1-15 Neasden CDA

There are six ‘essential’ infrastructure assets at risk of surface water flooding. Neasden station and the Jubilee railway line are at risk of deep flooding. The A4088 Dudden Hill Lane, two electricity sub stations and a section of gas pipeline are at risk of shallow flooding. There is one ‘highly vulnerable’ asset at risk of shallow flooding: Pound Lane Fire Station. There are six ‘more vulnerable’ assets at risk of shallow flooding: one school and five electricity installations.

The main source of flood risk is the ponding of surface water runoff in topographic low spots to the north-west of the CDA. One LFRZ has been designated in the area of most significant ponding. This CDA was validated against the EA FMfSW, no historic surface water flooding incidents have been recorded in this area.

1.1.16 Dudden Hill – Group2_049

Group2_049 is a densely urbanised area to the west of the borough. This CDA is approximately 2.5km^2. The 1 in 100 year modelled output indicates that there are 548 non-deprived and 94 deprived properties at risk of shallow surface water flooding. One non-deprived and 13 deprived properties are classified as having basements. There are 70 non-deprived properties at risk of deeper flooding. There are 72 commercial properties at risk of shallow surface water flooding and three at risk of deep flooding.

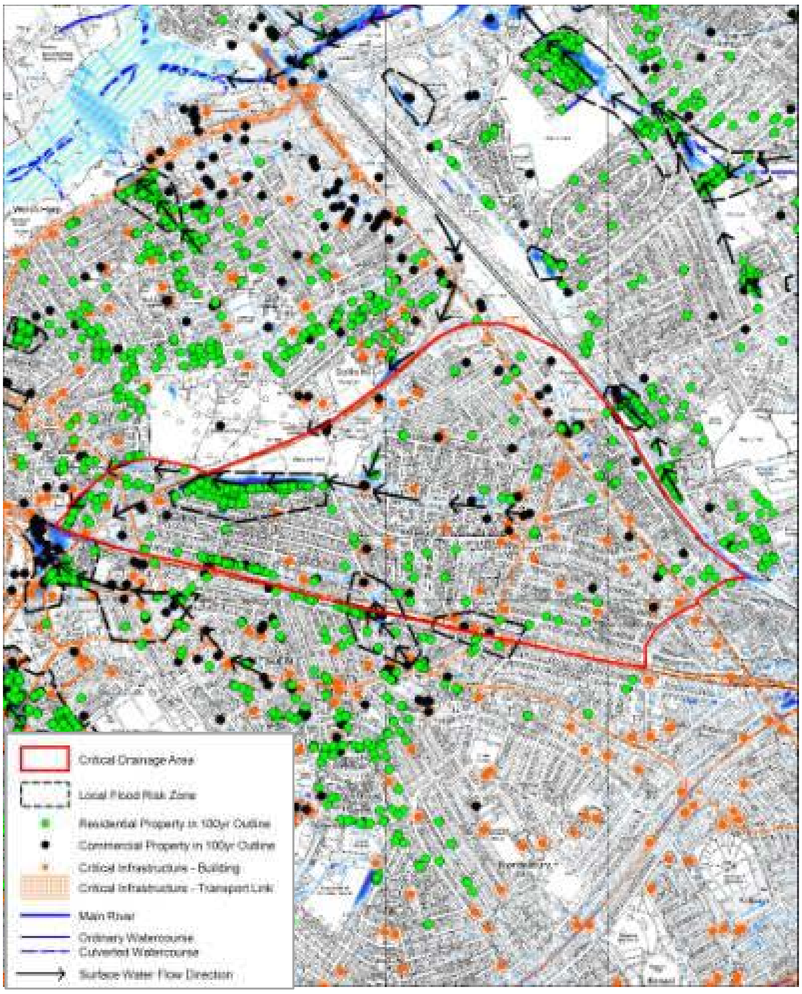

Figure E1-16 Dudden Hill CDA

There are eight 'essential' infrastructure assets at risk of shallow flooding: Seven electricity sub stations and Dollis Hill railway station. There are eight 'more vulnerable' assets at risk of shallow flooding: three schools, one GP surgery and four electricity installations.

The main source of flooding within this CDA is ponding surface water flow in topographic depressions. Three LFRZs have been designated within this CDA, these all correspond with areas at most significant risk of surface water flooding. This CDA was validated against the EA FMfSW and several historic surface water flooding incidents recorded in this area.

1.1.17 A4088 – Group2_050

Group2_050 is located in a densely urbanised area to the east of the borough. The CDA is approximately 0.4km^2. The 1 in 100 year modelled output indicates that there are 14 deprived and 35 non-deprived properties at risk of shallow surface water flooding. There are 12 commercial properties at risk of shallow flooding.

There are two ‘essential’ infrastructure assets at risk of shallow flooding: the A4088 and two small areas on the A406. There is one ‘highly vulnerable’ asset at risk of shallow flooding: a telecommunications mast. There is one ‘more vulnerable’ asset at risk of shallow flooding: one school.

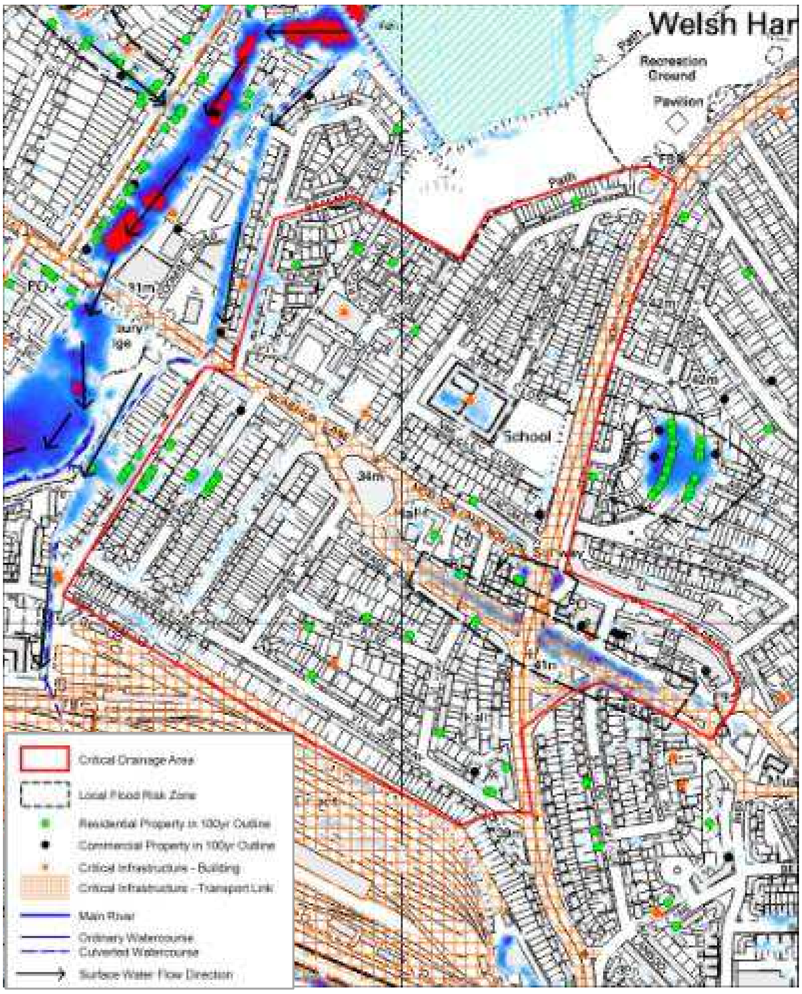

Figure E1-17 A4088 CDA

The main source of flooding within this CDA is surface water ponding on the A4088 as the road drops down below the A406 in this location. Two LFRZs have been designated corresponding with the areas of significant ponding. This CDA was validated against the EA FMfSW, no historic surface water flooding incidents have been recorded in this area.

1.1.18 The Circle – Group2_051

Group2_051 is in a densely urbanised area to the east of the borough. This CDA is approximately 0.24km^2. The 1 in 100 year modelled output indicates that there are 71 non-deprived residential properties and seven commercial properties at risk of shallow surface water flooding.

There are no infrastructure assets at risk of surface water flooding within this CDA.

Figure E1-18 The Circle CDA

The main source of flooding within this CDA is surface water ponding in topographic depressions. One LFRZ has been designated within this CDA; this corresponds with an area of significant ponding to the north west of the CDA. This CDA was validated against the EA FMfSW, no historic surface water flooding incidents have been recorded in this area.

1.1.19 Review Road – Group2_052

Group2_052 is located in an urbanised area to the east of the borough. This CDA is approximately 0.65km^2. The 1 in 100 year modelled output indicates that there are 181 non-deprived properties at risk of shallow surface water flooding and 19 at risk of deep flooding. There are 18 commercial properties at risk of shallow surface water flooding.

There is one ‘essential’ infrastructure asset at risk of shallow flooding: A406 North Circular. There are two ‘highly vulnerable’ assets at risk of shallow flooding: two telecommunications masts. There are two ‘more vulnerable’ assets at risk of shallow flooding: one school and one electricity installation.

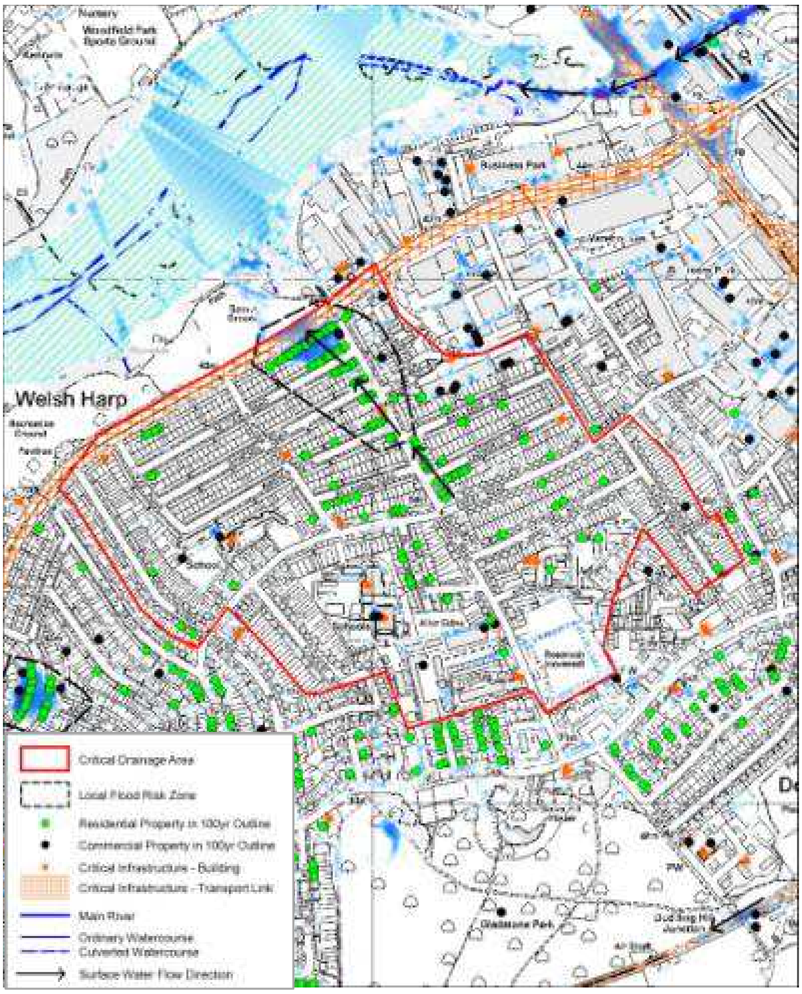

Figure E1-19 Review Road CDA

The main source of flooding within this CDA is surface water ponding between Review Road and the North Circular. One LFRZ has been designated within this CDA; this corresponds with the area of most significant risk. This CDA was validated against the EA FMfSW, no historic surface water flooding incidents have been recorded in this area.

1.1.20 Tudor Gardens – Group2_053

Group2_053 is predominantly urbanised with areas of open land to the north-west of the CDA. This CDA is located to the east of the borough and is approximately 0.8km^2. The 1 in 100 year modelled output indicates that there are 98 non-deprived residential properties at risk of shallow surface water flooding and 4 at risk of deep flooding. There are 11 commercial properties at risk of shallow surface water flooding.

There is one 'essential' infrastructure asset at risk of shallow flooding: one electricity sub-station. There is one 'more vulnerable' assets at risk of shallow flooding: one electricity installation.

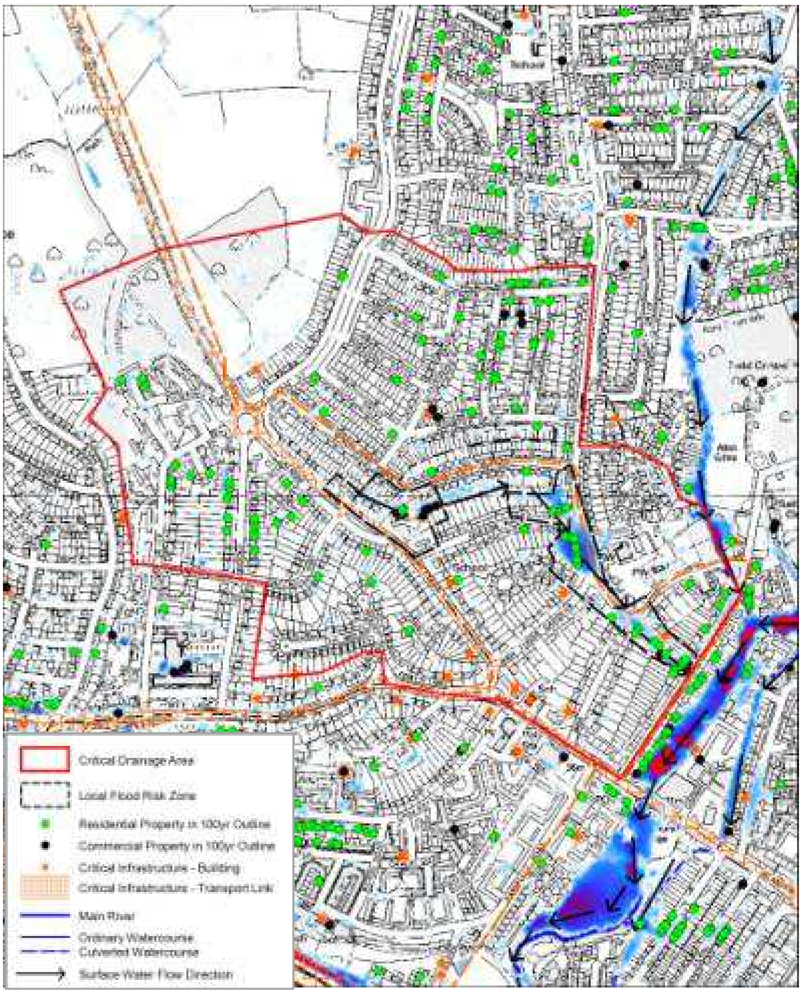

Figure E1-20 Tudor Gardens CDA

The main source of flooding within this CDA is from overland flow and surface water ponding in topographic depressions. Two LFRZs have been designated within this CDA; these correspond with the areas of significant ponding. This CDA was validated against the EA FMfSW, no historic surface water flooding incidents have been recorded in this area.

1.1.21 Forty Bridge – Group2_054

Group2_054 is a mixed use area with dense urban areas to the east and west and a small industrial area towards the centre. There are several recreation grounds distributed through the CDA. The CDA is located to the west of the borough and is approximately 1.3km^2. The 1 in 100 year modelled output indicates that there are 19 deprived and 108 non-deprived properties at risk of shallow surface water flooding. There are two non-deprived properties at risk of deep flooding. There are 30 commercial properties at risk of shallow surface water flooding.

There are two 'essential' infrastructure assets at risk of shallow surface water flooding: two electricity sub stations. There are four 'more vulnerable' assets at risk of shallow flooding: two schools, one nursing home and an electricity installation.

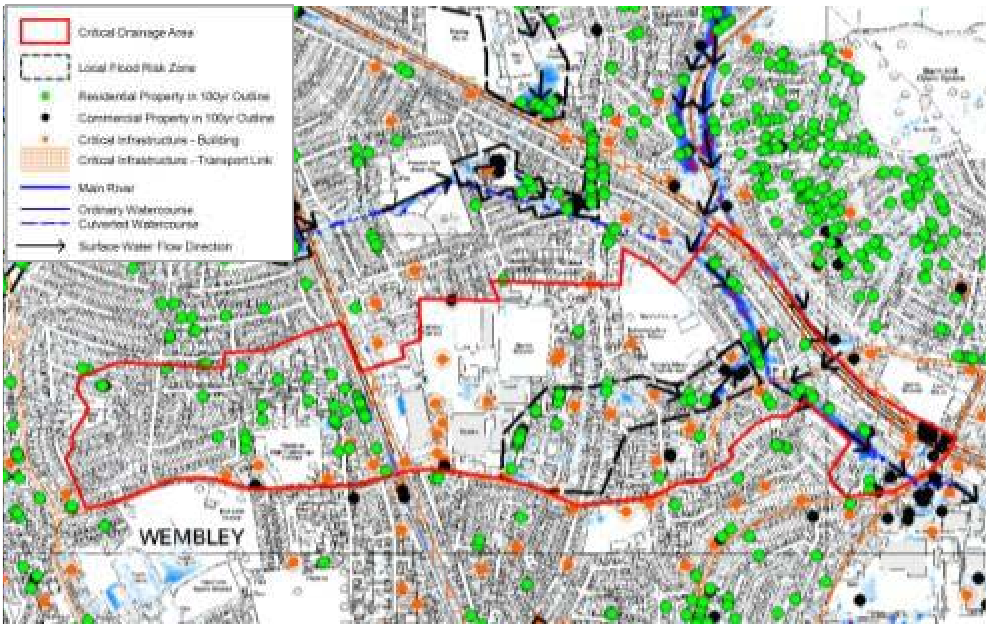

Figure E1-21 Forty Bridge CDA

The main source of flooding within this CDA is overland flow and surface water ponding in topographic depressions. One LFRZ has been designated within this CDA; this corresponds with the predominant overland flow path through the CDA. This CDA was validated against the EA FMfSW and several historic surface water flooding incidents recorded in this area.

1.1.22 Wembley Stadium – Group2_055

Group2_055 is located in a mixed use area with a majority of the CDA being used for commercial purposes with a small area of residential property to the north-west of the CDA. This CDA is approximately 1.35km^2. The 1 in 100 year modelled output indicates that there are 167 non-deprived properties at risk of shallow flooding and one at risk of deep flooding. There are 91 commercial properties at risk of shallow surface water flooding and six at risk of deep flooding.

There are four 'essential' infrastructure assets at risk of shallow flooding: three electricity sub stations and Wembley Stadium railway station and line. There are three 'more vulnerable' assets at risk of shallow flooding: one school and two electricity installations. The main source of flooding within this CDA is surface water ponding in topographic depressions. One LFRZ has been designated within this CDA; this corresponds with the most significant area of ponding to the south of the CDA. This CDA was validated against the EA FMfSW and a historic surface water flooding incident recorded in this area.

Figure E1-22 Wembley Stadium CDA

1.1.23 Harrow Road – Group2_056

Group2_056 is located in a densely urbanised area to the west of the borough. This CDA is approximately 0.43km^2. The 1 in 100 year modelled output indicates that there are 69 non-deprived residential properties and 14 commercial properties at risk of shallow flooding.

There is one 'essential' infrastructure asset at risk of shallow flooding: one electricity sub station. There are two 'more vulnerable' assets at risk of shallow flooding: one school and one electricity installation. The main source of flooding within this CDA is surface water ponding in topographic depressions. One LFRZ has been designated within this CDA; this corresponds with the area of most significant ponding. This CDA was validated against the EA FMfSW and a historic surface water flooding incident recorded in this area

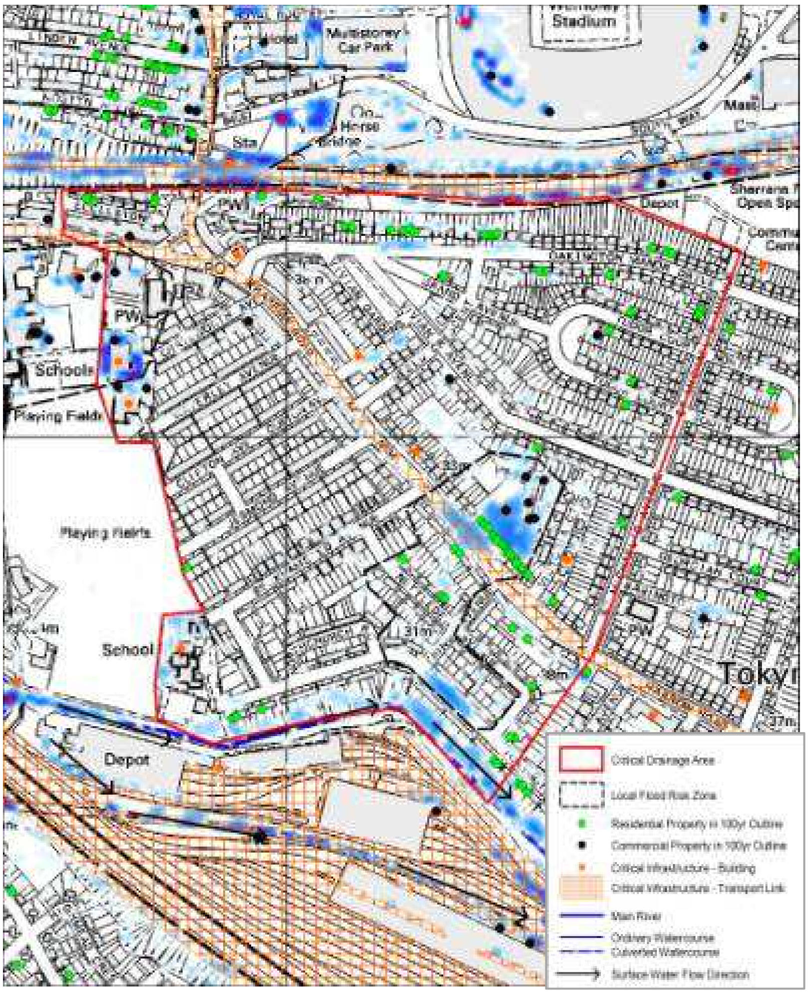

Figure E1-23 Harrow Road CDA

1.1.24 Monks Park North – Group2_057

Group2_057 is a predominantly residential area towards the centre of the borough. This CDA is approximately 0.25km^2. The 1 in 100 year modelled output indicates that there are 12 non-deprived residential properties and 3 commercial properties at risk of shallow surface water flooding.

There are two ‘essential’ infrastructure assets at risk of shallow flooding: two electricity sub stations. There are two ‘more vulnerable’ assets at risk of shallow flooding: two schools. The main source of flooding within this CDA is surface water ponding in topographic depressions. One LFRZ has been designated within this CDA; this corresponds with the area of significant ponding. This CDA was validated against the EA FMfSW, no historic surface water flooding incidents have been recorded in this area.

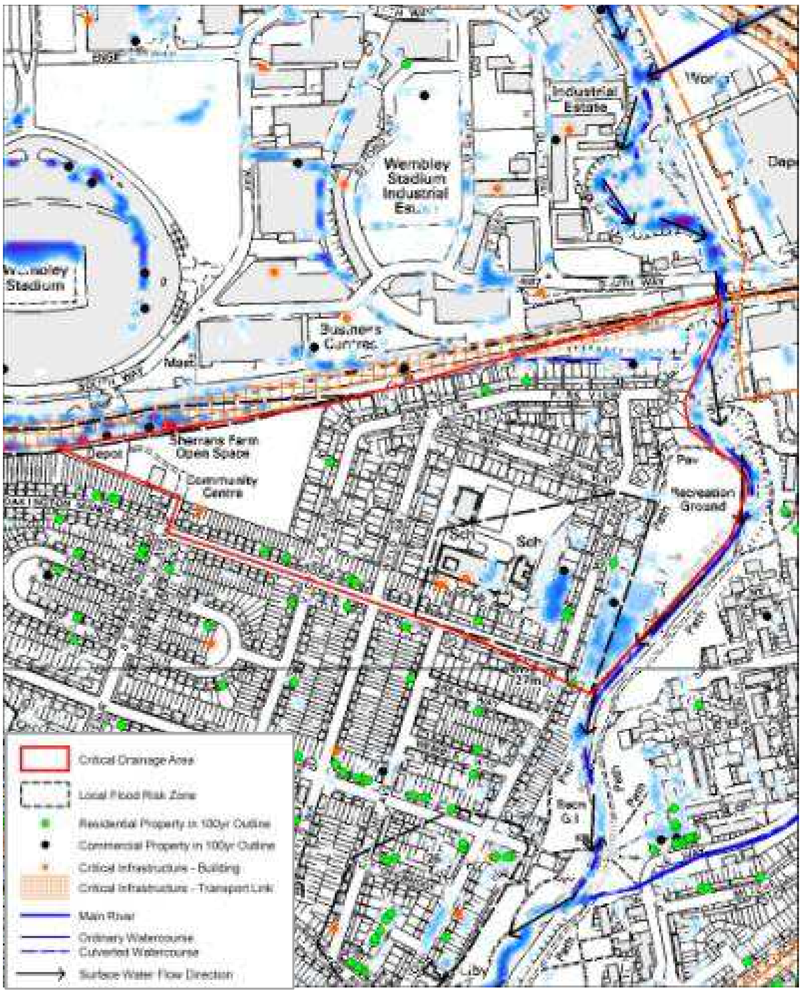

Figure E1-24 Monks Park North CDA

1.1.25 Willesden Junction Station – Group2_058

Group2_058 is a heavily urbanised area to the south of the borough. This CDA is approximately 0.2km^2. The 1 in 100 year modelled output indicates that there are 165 deprived properties at risk of shallow surface water flooding. There are 35 commercial properties at risk of shallow surface water flooding.

There are four ‘essential’ infrastructure assets at risk of shallow flooding: A4000 Station Road, High Street Harlesden, London overland railway line and the Bakerloo Line. There are four ‘more vulnerable’ assets at risk of shallow flooding: two GPs and two electricity installations.

The main source of flooding within this CDA is small areas of shallow surface water ponding in topographic depressions. No LFRZs have been designated within this CDA as the main area of risk is to the railway line which spans more than one CDA. This CDA was validated against the EA FMfSW, no historic surface water flooding incidents have been recorded in this area.

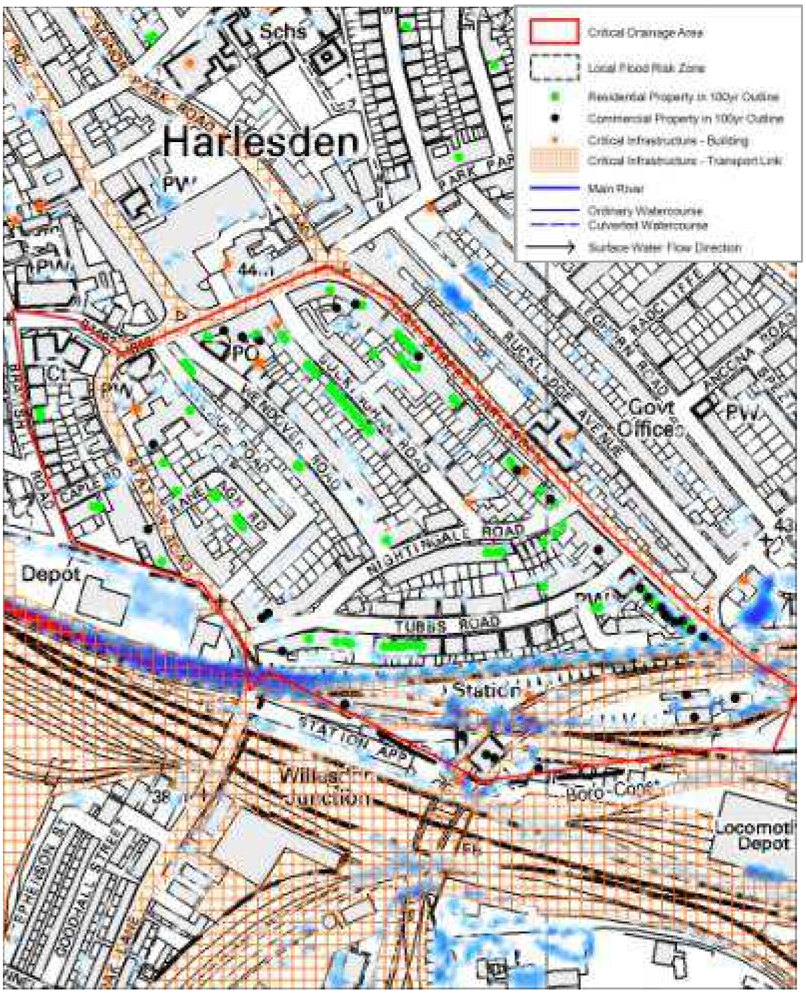

Figure E1-25 Willesden Junction Station CDA

1.1.26 Capitol Way Commercial Area – Group2_059

Group2_059 is a mixed use urbanised area to the north-east of the borough. This CDA is approximately 1.5km^2. The 1 in 100 year modelled output indicates that there are 211 non-deprived residential properties at risk of shallow flooding. There are 39 commercial properties at risk of shallow flooding.

There are two 'essential' infrastructure asset at risk of shallow flooding: two electricity sub stations. There is one 'highly vulnerable' asset at risk of shallow flooding: one telecommunications mast. There are eleven 'more vulnerable' assets at risk of shallow flooding: three schools, one GPs, one nursing home and six electricity installations. The main source of flooding within this CDA is overland flow and surface water ponding in topographic depressions. This CDA was validated against the EA FMfSW and a historic surface water flooding incident recorded in this area.

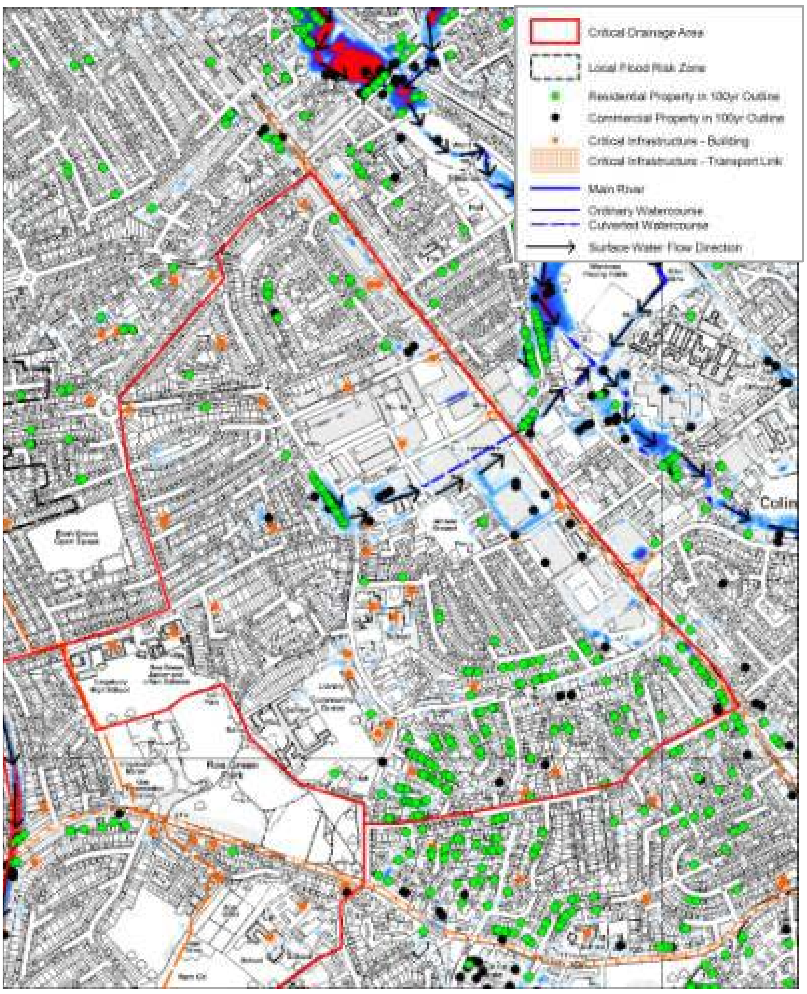

Figure E1-26 Capital Way Commercial Area CDA

1.1.27 Roe Green Park/Fryent Country Park – Group2_060

Group2_060 is a partially urbanised area in the north of the borough. This CDA is approximately 1.5km^2. The 1 in 100 year modelled output indicates that there are 68 non-deprived residential properties at risk of shallow surface water flooding. There are 19 commercial properties at risk of shallow surface water flooding.

There are three 'essential' infrastructure assets at risk of shallow flooding: Kingsbury Railway Station, Jubilee Line and one electricity sub station. There is one 'highly vulnerable' asset at risk of shallow flooding: one telecommunications mast. There is one 'more vulnerable' asset at risk of shallow flooding: one school. The main source of flooding within this CDA is overland flow along the railway line. One LFRZ has been designated within this CDA this corresponds with the area of most significant risk. This CDA was validated against the EA FMfSW, no historic surface water flooding incidents have been recorded in this area.

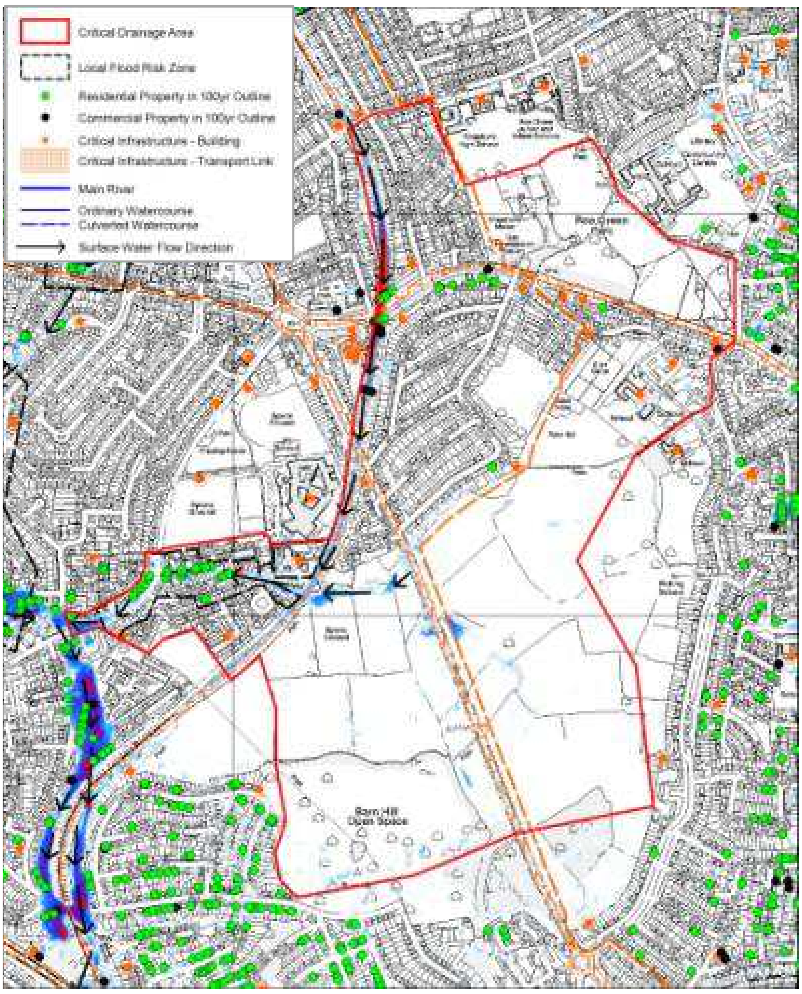

Figure E1-27 Roe Green/Fryent Country Park CDA

Appendix E2 – Summary of Measures

Source

Green Roofs

Green roofs are designed to intercept rainfall and slow down its entry into the ground level drainage system. Vegetation such as grass and small shrubs are added to residential, commercial or shed roofs (Figure E2-1). The green roof systems can improve the quality of the runoff before it enters the drainage system.

Figure E2-1 Example of a residential green roof (Ecotips, 2010[i])

The advantages and disadvantages of green roofs are shown below.

	Advantage / Disadvantage
Advantage	Green roofs are effective at managing and reducing rainfall runoff from property.
	Low maintenance once installed as hardy vegetation is used.
	Management of potential flooding at the source, ‘upstream’ of any high risk areas.
	Water treatment by pollutant removal.
	Does not require extra land space on new development, good for constrained areas.
	Reduces net annual volume required by the storm sewer system.
Disadvantage	Construction on existing properties is disruptive.
	Storage Capacity within green roof can be full prior to commencement of storm
	High associated construction cost on existing properties.
	Challenging to encourage existing homeowners to consider this option.

Table E2-1 Advantages / Disadvantages of Green Roofs

Soakaways

Soakaways are designed to provide an alternative infiltration route for storm water to prevent overburdening the sewerage system. There are several different soakaway options; Figure E2-2 below illustrates a small scale soakaway system within a residential development.

Figure E2-2 Example of a soakaway within a residential development (BCProfiles, 2011[ii])

The advantages and disadvantages of soakaways are shown below.

	Advantage / Disadvantage
Advantage	Management of potential flooding at the source, 'upstream' of any high risk areas.
	Reduces likelihood of property flooding as alternative storm water infiltration route.
	Reduces net volume required by the storm sewer system.
Disadvantage	Installation is disruptive in existing residential areas.
	Not useable in areas underlain by thick clay.
	High associated construction cost.
	Can only be constructed on highways with low traffic volumes where speed restrictions not exceeding 30mph are present.

Table E2-2 Advantages / Disadvantages of Soakaways

Water Butts and Rainwater Harvesting

Water butts are designed to be a low maintenance, easy to install rain water collection receptacle. A large barrel is connected up to a residential property down pipe to collect water for use in the resident's garden (Figure E2-3).

Figure E2-3 Example of a water butt (Water Features Online, 2011[iii])

	Advantage / Disadvantage
Advantage	Management of potential flooding at the source, 'upstream' of any high risk areas.
Advantage	Easy to implement on a property level.
Advantage	Minimal maintenance required to the water butt once it is in place.
Advantage	Reduces net volume required by the storm sewer system.
Disadvantage	May require incentives to encourage residents to install a water butt
Disadvantage	Cannot be guaranteed storage as may be full at the time of a storm.
Disadvantage	In densely urbanised areas may not be applicable if properties do not have gardens as they may not have a use for the water collected.

Table E2-3 Advantages / Disadvantages of Water Butts

Rainwater harvesting is a more comprehensive system that is designed to allow for the re-use of 'grey' water within a property for non-potable purposes (Figure E2-4).

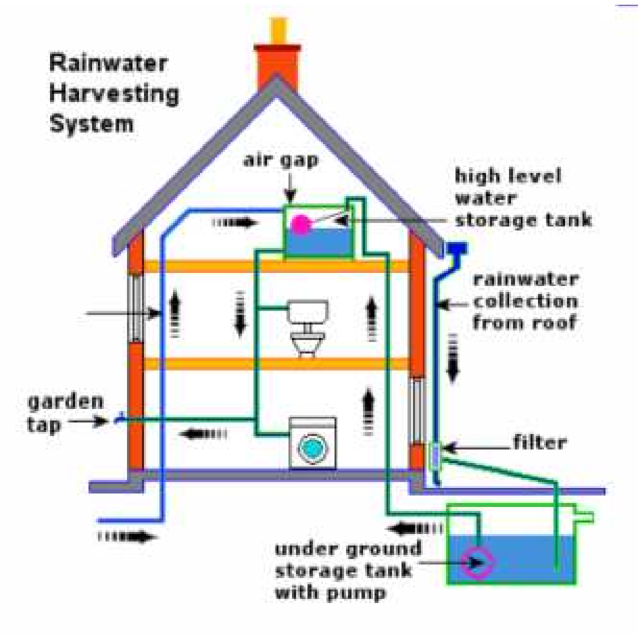

Figure E2-4 Example of a rainwater harvesting system (lowenergyhouse.com, 2011[iv])

	Advantage / Disadvantage
Advantage	Management of potential flooding at the source, 'upstream' of any high risk areas.
	Reduces mains water usage at a property level.
	Reduces net volume required by the storm sewer system.
Disadvantage	Expensive to install this system into an existing residential property.
	Disruptive to install this system into an existing property.
	Maintenance costs would be high.

Table E2-4 Advantages / Disadvantages of Rainwater Harvesting

Permeable Paving

Permeable paving systems are designed to allow water to infiltrate to the underlying granular sub-grade material and eventually provide local groundwater recharge (Figure E2-5). They provide significant benefits in relation to rainfall interception as well an option for removal of surface water volume.

Figure E2-5 Example of permeable paving

The advantages and disadvantages of permeable paving, in combination with filter drains, are shown below.

	Advantage / Disadvantage
Advantage	Permeable paving surfaces have been demonstrated as effective in managing and reducing runoff from paved surfaces.
	Management of potential flooding at the source, ‘upstream’ of any high risk areas.
	Sustainable alternative to creating a larger capacity sewer network.
	Encourage natural groundwater recharge.
	Water treatment by pollutant removal.
	Allows multi-functional use of space.
	Reduces net volume required by the storm sewer system.

Disadvantage	Construction within the road will lead to temporary road closures.
	High associated construction cost
	Can only be constructed on highways with low traffic volumes where speed restrictions not exceeding 30mph are present.
	Annual inspection of permeable pavement will be required.

Table E2-5 Advantages / Disadvantages of Permeable Paving

Roadside Rain Garden

The purpose of the road side rain gardens system is to create a chain of surface water storage areas each connected with a filter / french drain. Surface water is temporarily stored in the soil and granular layer at the base of the structure before being gradually released into the groundwater through infiltration into the ground. Intentionally situated in roadside verges, this will provide areas of storm water infiltration and planting in the smallest area. Roadside rain gardens typically contain hydrophilic flowers, grasses, shrubs and trees.

Figure E2-6 Typical example of a roadside rain garden in Seattle USA[v]

The advantages and disadvantages of using road side rain gardens are shown in the table below.

	Advantage / Disadvantage
Advantage	Roadside rain gardens have been demonstrated as effective in managing and reducing runoff conveyed by highway surfaces.
	Sustainable alternative to creating a larger capacity sewer network.
	Encourage natural groundwater recharge.
	Reduces net volume required by the storm sewer system.
	Contribution to aesthetic appeal and habitat in urbanised areas.
	Flexible for use in areas of various shapes and sizes.

Disadvantage	Regular maintenance of vegetation, such as weeding, soil replacement and watering during dry periods.
	Inspection following large rainfall events. This includes clearing of the access channel from the road to the soil.
	Periodic replacement of planting is required.
	Retrofitting costs are high and would be disruptive in heavily urbanised areas

Table E2-6 Advantages / Disadvantages of Roadside Rain Gardens

Swales

Swales are landscape features designed to remove silt and pollution from surface water runoff (Figure E1-7) constructed with shaped sloped sides and filled with vegetation. The water's flow path, along with the wide and shallow ditch, is designed to maximize the time water spends in the swale, which traps pollutants and silt. Depending upon the geometry of land available, a swale may have a meandering or almost straight channel. A common application is around car parks or alongside roads, where substantial automotive pollution is collected by the paving and then flushed by rain. The swale treats the runoff before releasing it to the watershed or storm sewer.

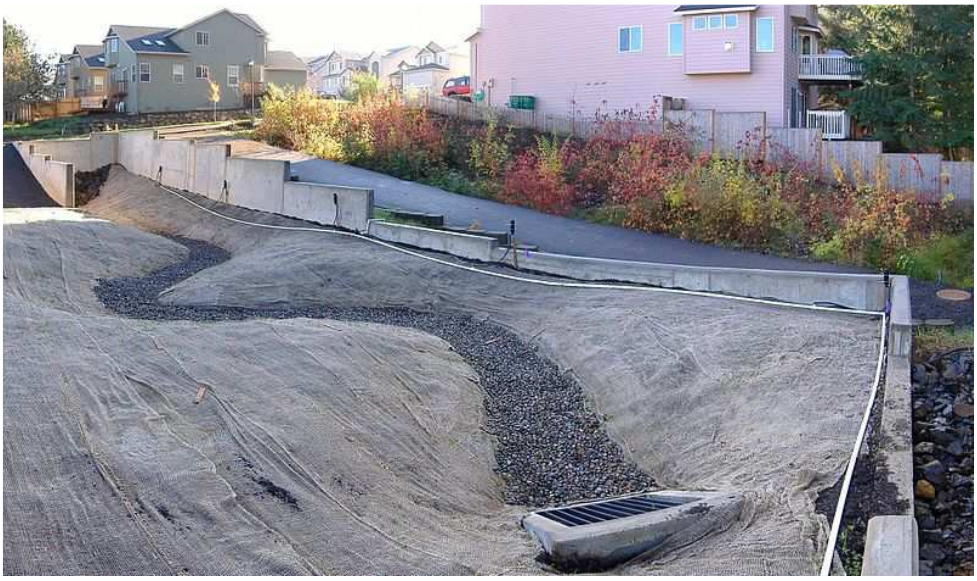

Figure E2-7 Example of swale under construction (completed swale shown in background)

	Advantage / Disadvantage
Advantage	A decreased conveyance of overland flow of flood water toward an area with historical records of flooding.
	Manage the rate of runoff and reduce flooding caused by urbanisation.
	Encourage natural groundwater recharge

Disadvantage	Temporary closure of the areas during construction.
	Swales to route flow in to structures will need regular maintenance.

Table E2-7 Advantages / Disadvantages of Swales

Detention Basins

A detention basin is a large area of ground laid to grass which is dry for the majority of the time and fills up with water during periods of heavy rainfall, which it releases slowly. Permanent ponds may be incorporated towards inlets and outlets for visual amenity and settlement of silts. They can also act as offline storage structures when positioned alongside existing watercourses, which fill when river levels are high. This can help to alleviate pressure on the drainage network elsewhere in the catchment.

Figure E2-8 Example of Detention Basin © Copyright BJ Smur[vi]

The following Figure shows an offline basin during construction.

Figure E2-9 Example of an offline storage structure under construction

The advantages and disadvantages of providing this form of flood mitigation measure are as follows: -

	Advantage / Disadvantage
Advantage	Attenuation of storage of flood water when water levels are high
	Manage the rate of runoff and reduce flooding caused by urbanisation.
	Encourage natural groundwater recharge
Disadvantage	Potential health and safety implications of adding flood storage areas in and around schools without significant costs associated with education and warning requirements. However the CIRIA W12 Sustainable Water Management in Schools provides guidance on overcoming these health and safety issues.
	Temporary closure of parkland/open space during construction and when water levels are high.

Table E2-8 Advantages / Disadvantages of Detention Basins

Ponds and Wetlands

Ponds and wetlands can be used to manage storm water runoff, prevent flooding and downstream erosion. They can also be used to improve water quality in an adjacent river, watercourse or lake and to encourage biodiversity through the creation of new habitats. They can vary in size but they are essentially areas that are designed to accommodate and intercept storm water slowing their entry into nearby watercourses and/or drainage systems. They can be designed to discharge into watercourses with overflow structures pipes or weirs that only operate during flood conditions.

	Advantage / Disadvantage
Advantage	A decreased conveyance of overland flow of flood water toward an area with historical records of flooding.
	Manage the rate of runoff and reduce flooding caused by urbanisation.

	Encourage biodiversity and habitat creation
Disadvantage	Temporary closure of the areas during construction.
	Usage dependent on underlying ground conditions / soil type
	Swales to route flow in to structures will need regular maintenance.

Table E2-9 Advantages / Disadvantages of Ponds and Wetlands

Pathway

Improved Maintenance Regimes

This option involves the implementation of an effective maintenance regime to ensure that blockage by vegetation or deposition will not reduce the hydraulic capacity of the existing drainage infrastructure including the public drains, ordinary watercourses, highway gullies, storm and foul sewers. Maintenance would include regular inspection, treeworks, jetting and clearance of debris, gravel and silt where required.

In the context of blockage by trees, the “maintaining to a better standard” option would entail implementing good arbori-cultural practice including:

- surveys for root-plate stability of the larger specimens,
- selective thinning and coppicing of the developing scrub to increase vigour,
- thinning for better specimens,
- removal of non-native species,
- improvement of the stand for amenity, bank stability and biodiversity purposes,
- removal of major fallen dead-wood, obstacles and other debris.

The objective of these works would be to reduce the amount of woody debris liberated in flood conditions which could accumulate on bridges or in sewers.

Maintenance also assumes enforcement of notices served under the Land Drainage Act[vii]. It would be beneficial to identify assets that are more at risk of blockage than others to allow for a more pragmatic approach to setting maintenance regimes. Therefore if an asset is considered at greater risk then it should be maintained more frequently than others in the borough.

The advantages and disadvantages of providing an effective maintenance regime are:

	Advantage / Disadvantage
Advantage	Clearance of drains and swale networks will ensure that water drains freely and to the best of its design capacity.
	Regular and effective maintenance and record keeping could help to support flood defence funding decisions.

Disadvantage	Inspection of the flood defence systems and assets should take place prior to and after potential significant rainfall events, representing a burden on the asset owners, both in terms of cost and time

Table E2-10 Advantages / Disadvantages of Maintaining Existing System

Increase Capacity in Drainage System

Drainage network improvements involve upsizing of sewer pipes, increased gully entry point locations, construction of off/on-line storage tanks etc. Their advantages and disadvantages are shown below.

	Advantage / Disadvantage
Advantage	Manage the rate of runoff and reduce flooding caused by urbanisation.
	Reduce the risk of manhole surcharging.
Disadvantage	Temporary closure of the roads during construction causing disruption.
	Network improvements are generally expensive to carry out.
	Could lead to an increase in flood risk downstream of the system improvements

Table E2-11 Advantages / Disadvantages of Network Drainage Improvements

Separation of Foul & Surface Water Sewers

Historically foul and surface water sewer networks were combined into one piped system. In areas where urbanisation has significantly increased along with the expanse of impermeable surface this combined network is not always capable of dealing with the associated increase in surface water runoff. This can lead to an increase of sewer surcharging events resulting in effluent spilling above ground which poses a significant risk to public health. The separation of the two networks ensure that if the surface water network does surcharge there is no effluent mixed with the overflow (Figure E2-10).

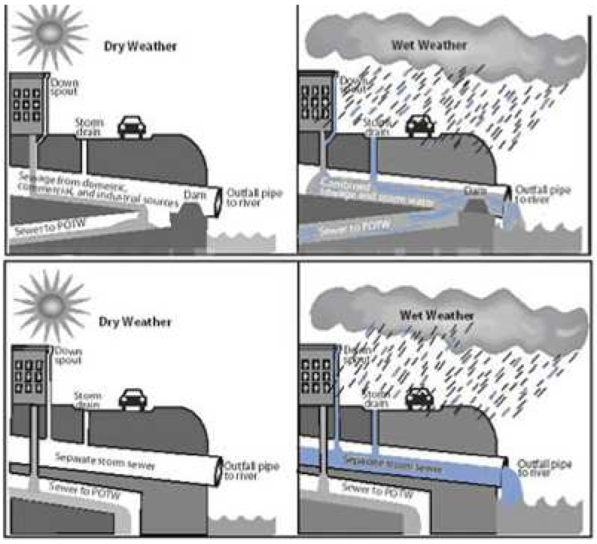

Figure E2-10 Example of a combined sewer system at the top and a separated sewer system at the bottom (Department for Environmental Protection, 2011[viii])

The advantages and disadvantages of sewer separation are provided below.

	Advantage / Disadvantage
Advantage	Manage the rate of runoff and reduce flooding caused by urbanisation.
	Significant reduction in the likelihood of effluent flooding.
	Reduce the risk of manhole surcharging.
Disadvantage	Temporary closure of the roads during construction causing disruption.
	Network improvements are generally expensive to carry out.

Table E2-12 Advantages / Disadvantages of Sewer System Separation

Managing Overland Flows

This option involves the installation of raised features to manage overland flow through an area. Raised features such as high kerbs and full width speed humps can be used to divert flow along carriageways when the sewer system is overburdened (Figure E2-11).

Figure E2-11 Example of a speed hump (Geograph, 2011[ix]) and of raised kerbing (Barkingside, 2009[x])

The advantages and disadvantages of overland flow management are provided below.

	Advantage / Disadvantage
Advantage	Contain surface water runoff in the road carriageway preventing property flooding.
Advantage	Speed humps will also have a traffic calming effect.
Advantage	Would be quick to implement, depending on scale of management required.
Disadvantage	This setup can cause the temporary closure of the roads during a flood event.
Disadvantage	Disruption caused during the initial installation of both overland flow options.
Disadvantage	Depending on the scale of management required this can be quite an expensive option to implement.

Table E2-13 Advantages / Disadvantages of Overland Flow Management

Land Management Practices

Through the masterplanning of strategic growth areas or large development sites, modification of land contours, profiles and ground levels may be used to channel surface water flows away from property and infrastructure. The advantages and disadvantages of land management practices are provided below.

	Advantage / Disadvantage
Advantage	Highly effective method for surface water flooding of property and/or infrastructure.
Disadvantage	This can be a disruptive option to implement particularly in areas where there is existing occupied development.
	This will be a costly option to implement and may require on-going management to ensure modifications which adversely affect the effectiveness of the measure are not subsequently made by occupiers.

Table E2-14 Advantages / Disadvantages of Land Management Practices

Receptor

Improved Weather Warning

In key flood risk areas this could be a beneficial option to ensure that residents with temporary/demountable defences have time to prepare their properties prior to an event. . The EA already have several telemetry stations on the river catchments across the LBB to allow for flood monitoring. More monitoring stations could be put in place by both the EA and TWUL in areas that are particularly prone to flooding. An alarm system or call centre contact approach could be used to alert residents prior to an event.

The advantages and disadvantages of weather warning are provided below.

	Advantage / Disadvantage
Advantage	Will give local residents more time to prepare their property for an event.
	Will allow for better monitoring of frequency of flood events and may allow for the identification of key causes.
	Would be relatively straight forward to put the monitors in place.
Disadvantage	Requires a system to be in place for contacting the local residents, this can be costly and disruptive depending on the system.
	Can be a costly option depending on the number of monitors required.

Table E2-15 Advantages / Disadvantages of Improved Weather Warning

Planning Policy

In preparing this Surface Water Management Plan consideration has been given to the potential of policy as well as engineering interventions to contribute to flood risk mitigation. In developing its Development Management and other local planning policies, in support of the Local Flood Risk Management Strategy, it is recommended that Brent give consideration to the following matters:

- the need to avoid 'urban creep';
- using redevelopment opportunities to improve the drainage characteristics of the site over those which currently exist;
- using water corridors to achieve sustainability and where appropriate public access benefits;
- deculverting of watercourses;
- improving the surface water management through the design and layout of development; and
- realisation of the All London Green Grid (ALGG).

Urban creep is the term used to refer to the cumulative impact on towns and cities of gradual increases of impermeable areas. The Pitt Review discussed the risks relating to urban creep and through Recommendation 9 expressed the view that urban creep should be minimised. Recommendation 9 of the Pitt Review recommended that: "Householders should no longer be able to lay impermeable surfaces as of right on front garden and the Government should consult on extending this policy to back gardens and business premises". To date this has not been extended to back gardens and business premises but this study highlights the importance of considering such initiatives within the CDAs assessed.

As a minimum all new development in Brent that go through a Flood Risk Assessment process must provide betterment to greenfield run off rates in the existing site. The SWMP can be used as part of the Local Development Framework evidence base to support local policies and provide additional evidence base for the CDAs identified. Local policies should be developed to deculvert sections of local watercourses and safeguard river corridors from future development to reduce flood risk and maximise environmental benefits.

Development design and layout should be considered in terms of making efficient use of land and ensuring that the resulting urban form achieves sustainable management of surface water.. There are opportunities to work with the natural topography for cost effective and sustainable developments that minimise engineering land movement.

There are opportunities to provide new outdoor amenity space, areas of biodiversity, and new recreational uses within areas of higher flood risk. The key SuDS features such as swales, detention and wetlands areas should be located within public open spaces. Where this is not possible due to the extent of current urbanisation, suitable easement land strips should be incorporated within the design layout development and land covenants to avoid potential access and riparian ownership issues to safeguard long-term maintenance.

It is also considered that flood risk can be mitigated through a progressive policy on planning and urban design. This would include rolling out design policies associated with:

- The use of SuDS on all new developments to reduce overall flood risk and to remove surface water from the storm sewer system.
- Encouraging the use of green roofs in new development.
- Incorporation of SUDS and highway source control measures within highway, traffic calming and community schemes.
- Minimisation of the use of hard landscaping in conjunction with the use of positive drainage systems to remove surface water.

The All London Green Grid (ALGG) is a "strategic framework for creating, improving and managing high quality Green Infrastructure"[xi]. The ALGG provides an opportunity to not only improve the aesthetics of LBB but also to incorporate methods of flood risk mitigation into areas being re-greened. One of the objectives within the expanded ALGG is to manage flood risk so it is important that LBB liaises with the ALGG team to ensure that the where possible the most appropriate flood risk mitigation measures are incorporated. This collaborative approach could lead to significant benefits between as well as within boroughs.

Social Change, Education and Awareness

As part of education and awareness, it is important that residents within key flood risk areas are made aware of what to do when a flood occurs, who they should contact and the information that they should provide. It is also important that Council staff can respond swiftly and appropriately when alerted to a flood event. LBB in conjunction with the EA could hold meetings in key risk areas and/or produce information leaflets for local residents to outline this information.

Within LBB any staff that may possibly be contacted by the general public should be made aware of the most appropriate method for recording a flood incident within the borough. Staff should be made aware of what key information is required to ensure that the event is fully logged and that it is passed onto the relevant person within LBB for resolution. Even if the flooding incident is not from a source within the administrative area of LBB, staff should still record the incident and refer the member of the public to the relevant body responsible.

Collaboration between LBB, the EA and TWUL to educate local residents to make them more aware of the impact small property level changes can have on local flood risk. Introducing property level options that residents could implement themselves such as green roofs, water butts and permeable paving to reduce localised flood risk would be beneficial. Informing local residents of the available property level protection measures will improve general awareness and may encourage residents to make their own preparations to protect their properties against future floods.

Improved Resilience and Resistance Measures

Property resistance measures are those which prevent flood water from entering a property. Resistance measures include:

- Flood resistant gates
- Periscope air vents
- Waterproof wall renders and facings

- Non return valves in waste pipes and outlets
- Temporary measures such as free standing barriers, door boards, flood skirts and airbrick covers
- Water resistant external doors and windows

The advantages and disadvantages of this option are outlined below.

	Advantage / Disadvantage
Advantage	Installation of these measures will help to minimise the likelihood of flow entry into property.
	Allows for faster community recovery following an event.
	Gives residents peace of mind at low return period events
Disadvantage	Many of these measures are temporary so need to be fitted by the residents prior to a flood so require the resident to be at home to put up/install the resistance measures.
	Sufficient warning needs to be provided to ensure the residents have time to respond.
	To be most effective several resistance measures need to be implemented which can be quite costly
	Only provides protection to property for low return period events

Table E2-16 Advantages / Disadvantages of Property Resistance Measures

Property resilience measures are those that are carried out within a property to minimise internal floodwater damage. Resilience measures include:

- Tanking
- Concrete floors
- Raised electrical sockets
- Horizontal plasterboard replacement
- Flood resilient kitchens – plastic, stainless steel, free standing removable units
- Water resistant internal walls (rendered or tiled)
- Plastic skirting boards
- Pump and sump systems in place
- Water resistant internal doors

The advantages and disadvantages of this option are outlined below.

	Advantage / Disadvantage
Advantage	Minimises property damage during a flood event
	Quicker recovery of property after an event
	Gives peace of mind to residents during an event
Disad vanta	This is a costly option for a property owner to have to implement

	Relies on all adjoining properties implementing resilience measures to ensure the scheme is effective.

Table E2-17 Advantages / Disadvantages of Property Resilience Measures

Raising Doorway/Access Thresholds

This is a permanent resistance measure which involves the raising of property access points through the incorporation of steps or a ramped access.

The advantages and disadvantages of this option are outlined below.

	Advantage / Disadvantage
Advantage	Installation of these measures will help to minimise the likelihood of flow entry into property.
	Allows for faster community recovery following an event.
	Permanent measure so there is no need for the resident to be in place to install the measure.
	Gives residents peace of mind at low return period events
Disadvantage	This is a costly measure to implement into existing residential properties.
	This option alone will not completely protect a property other measures may also be necessary.
	Only provides protection to property for low return period events

Table E2-18 Advantages / Disadvantages of Raising Doorway/Access Thresholds

Temporary or Demountable Flood Defences

This option involves the installation of fittings to allow for the placement of temporary/demountable flood defences at a property level.

The advantages and disadvantages of this option are outlined below.

	Advantage / Disadvantage
Advantage	Installation of these measures will help to minimise the likelihood of flow entry into property.
	Allows for faster community recovery following an event.
	Gives residents peace of mind at low return period events.

	Sufficient warning needs to be provided to ensure the residents have time to respond.
Disadvantage	This measure is temporary so needs to be fitted by the residents prior to a flood which requires the resident to be at home to put up/install the resistance measures.
	To be most effective several resistance measures need to be implemented which can be quite costly
	Only provides protection to property for low return period events.

Table E2-19 Advantages / Disadvantages of Temporary/Demountable Flood Defences

Appendix E3 – Summary of Measures

1.1.28 Northwick Park – Group2_037

The Drain London mapping identified several areas of significant risk within this CDA. These areas of risk have been discussed in Section E1. The main flood risk issues in this area relate to deep surface water ponding to the south of a stretch of culverted watercourse adjacent to the railway line. The area in the east of this CDA has a history of flooding.

There are approximately 219 non-deprived residential properties at risk of surface water flooding. Of those, 47 fall within the deep (>0.5m) surface water mapping which indicates significant risk to health and safety.

To mitigate the flood risk in this area, the following preferred option has been derived. Two detention basins are proposed within this CDA, one in the west of the CDA adjacent to Clementine Churchill Hospital. A second, larger, detention basin is proposed to the north of Nathans Road to reduce the amount of surface water ponding in this location. To further prevent property flooding in the east of the CDA, raised kerbs are proposed along Norval and Nathans Roads to keep any surface water flow within the carriageway. In addition, sections of roadside rain garden are proposed on Littleton, Pebworth and Amery Roads. A small section of swale to connect the open drains in Northwick Park is also proposed. Figure E3-1 below outlines the proposed locations of the combined measures.

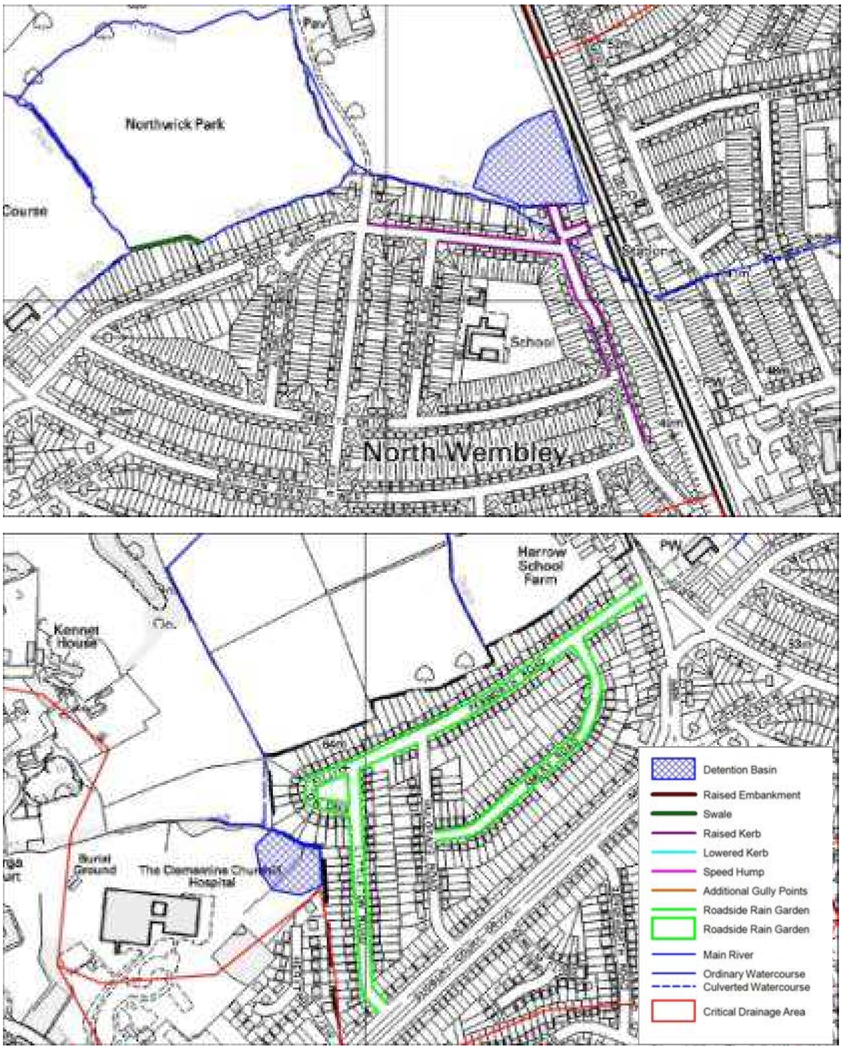

Figure E3-1 Northwick Park Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Detention Basin, Roadside Rain Gardens, Swales, Raised Kerb	£1m – 10m

Table E3-1 Northwick Park Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce localised surface water ponding within the CDA. The detention basin in Northwick Park, to the north of Nathans Road, will help to reduce the severity of surface water ponding along Nathans Road. The addition of a detention basin in this location will aid the drainage network in large scale rainfall events. This option is predominantly focussed on reducing the deep area of ponding on Nathans Road.

There are two hospital sites that fall within areas of modelled flooding, however the patchy and discontinuous nature of the mapping suggest that this is caused by inconsistencies in the LiDAR. Further investigation would be beneficial to gain a more accurate understanding of surface water risk in these two areas. Liaison with the NHS or Primary Care Trust to discuss the different resistance/resilience measures which could be put in place to protect each site would be advantageous.

1.1.29 Belvedere Way – Group2_034

The Drain London mapping identified several areas of significant risk within this CDA. These areas of risk have been discussed in Section E1. The main flood risk issues in this area relate to deep surface water ponding and overland flow. This is an area of known historical flood risk, however the flood risk is from multiple sources, and therefore the most effective scheme for this area must incorporate mitigation measures for flooding from more than one source.

There are approximately 242 non-deprived residential properties at risk of surface water flooding. Of those, 28 fall within the deep (>0.5m) surface water mapping which indicates significant risk to health and safety.

To mitigate the flood risk in this area, the following preferred option has been derived. The main area of historical flood risk is around Belvedere Way. The preferred options predominantly focus on mitigating the risk posed in this area. There are two suitable locations for detention basins to the north of Belvedere Way, in Claremont High School's grounds and at the Lindsay Drive roundabout. The school grounds are ideally located at the confluence of Wealdstone and Kenton Brooks to attenuate flows and to reduce water levels downstream. However this area is known to flood so the effectiveness of a detention basin in this area would require a more detailed assessment. Wealdstone Brook flows through the Lindsay Drive roundabout and is currently surrounded by vegetation. If this vegetation was cleared and a small detention basin was created on either side of the river channel, it may provide another source of flow attenuation upstream of Belvedere Way.

Although these are predominantly fluvial mitigation measures they would benefit the surface water and sewer system drainage networks as there would be more capacity available in the Wealdstone Brook downstream to allow free flowing discharge. In addition to these measures, a series of roadside rain gardens and raised kerbs along Belvedere Way will help to reduce surface water runoff and contain it within the road carriageway. The suggested raised kerbing along Belvedere Way would divert any surface water runoff away from property into two areas of open land adjacent to the Wealdstone Brook. Speed bumps on Tylers Gate will prevent surface water flow from affecting property in this area.

To the west of the CDA, several preferred options are proposed to mitigate surface water runoff. A series of roadside rain gardens and raised kerbs along Dovedale Avenue, Woodcock Hill and Donnington Road will help to reduce surface water runoff in this area. In addition, two storage areas adjacent to the Wealdstone Brook are proposed to attenuate fluvial and surface water flows. As with the storage areas suggested near to Belvedere Way, although these will be predominantly fluvial mitigation measures, they will provide a localised benefit to the surface water and sewer drainage system which in turn will reduce the perceived risk from these assets.

Figure E3-2 below outlines the proposed locations of the combined measures.

Figure E3-2 Belvedere Way Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Detention Basin, Roadside Rain Gardens, Raised Kerbs, Speed Humps	£501k – 1m

Table E3-2 Belvedere Way Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The measures forming part of this preferred option will not fully resolve the issues as this area is at risk of flooding from multiple sources. To fully resolve the flood risk, a system wide strategy needs to be implemented to improve the capacity and maintenance of the Wembley Trunk sewer system and the Wealdstone Brook. The preferred options outlined above are localised mitigation measures that are targeted towards reducing surface water flood risk in key risk areas. The roadside rain gardens would be predominantly beneficial for reducing property inundation from surface water runoff but may provide some benefit in sewer surcharge events and out of bank fluvial events.

This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding. This option is predominantly focussed on resolving the flooding issues on Belvedere Way in North Brent. This CDA intersects the London Boroughs of Brent (LBB) and Harrow (LBH) so the issues identified in this area could be resolved jointly.

The LBH has recently discussed the potential diversion of Kenton Brook through the Queensbury Recreation Ground to create a local feature within the open area of land as part of the London wide Green Grid. This scheme is still in its initial stages, so there may be the potential to incorporate surface water mitigation measures to reduce surface water and fluvial flood risk in this area. This would benefit both the LBB and the LBH. Further investigation should be made to see if any surface water benefits could be incorporated into the scheme.

Thames Water has proposed a flood alleviation scheme on Belvedere Way to reinstate a decommissioned storm overflow that runs to an outfall on the Wealdstone Brook. The overflow was sealed in the early 1990s when a section of the Wealdstone Brook was culverted. Following the sealing of this culvert, local residents reported a noticeable increase in the number of property flooding incidents. This scheme involves the reinstatement of the overflow to pass flow forward and remove the system constriction. This, along with a small section of sewer separation works to reduce the volume of water entering the overflow, are the main components of the scheme. A key local resident is currently lobbying the EA to issue a permit for the sealed overflow. Any works completed as part of this scheme could improve the deliverability of the preferred options suggested above. There may also be the opportunity to link schemes together to gain more funding for flood risk mitigation in this area. It should be noted that the reinstatement of overflows should be treated as a last resort measure due to their negative impacts on water quality and their unsustainable nature.

1.1.30 Dudden Hill – Group2_049

The Drain London mapping identified one large area of significant risk within this CDA. This area of risk has been discussed in Section E1. The main flood risk issues in this area relate to overland flow and deep surface water ponding adjacent to Gladstone Park.

There are approximately 548 non-deprived and 94 deprived residential properties at risk of surface water flooding. Of those, 13 non-deprived properties and one deprived property are classified as having basements. Approximately 70 of the non-deprived properties fall within the deep (>0.5m) surface water mapping which indicates significant risk to health and safety.

To mitigate the flood risk in this area, the following preferred option has been derived. To reduce the amount of ponding water along Kendal Road, several mitigation options are proposed. A series of roadside rain gardens along Anson Road should help to reduce the amount of overland flow reaching Kendal Road. There are several suitable locations for small detention basins which would help to attenuate flow through this area and reduce the severity of ponding on Kendal Road. There are numerous suitable locations for the installation of roadside rain gardens within this CDA as there are several open areas which could be used. Sections of raised kerb have been proposed to contain flow in the road carriageway and prevent it from entering property. This preferred option aims to provide a residual reduction to flood risk in this area. Figure E3-3below outlines the proposed locations of the combined measures.

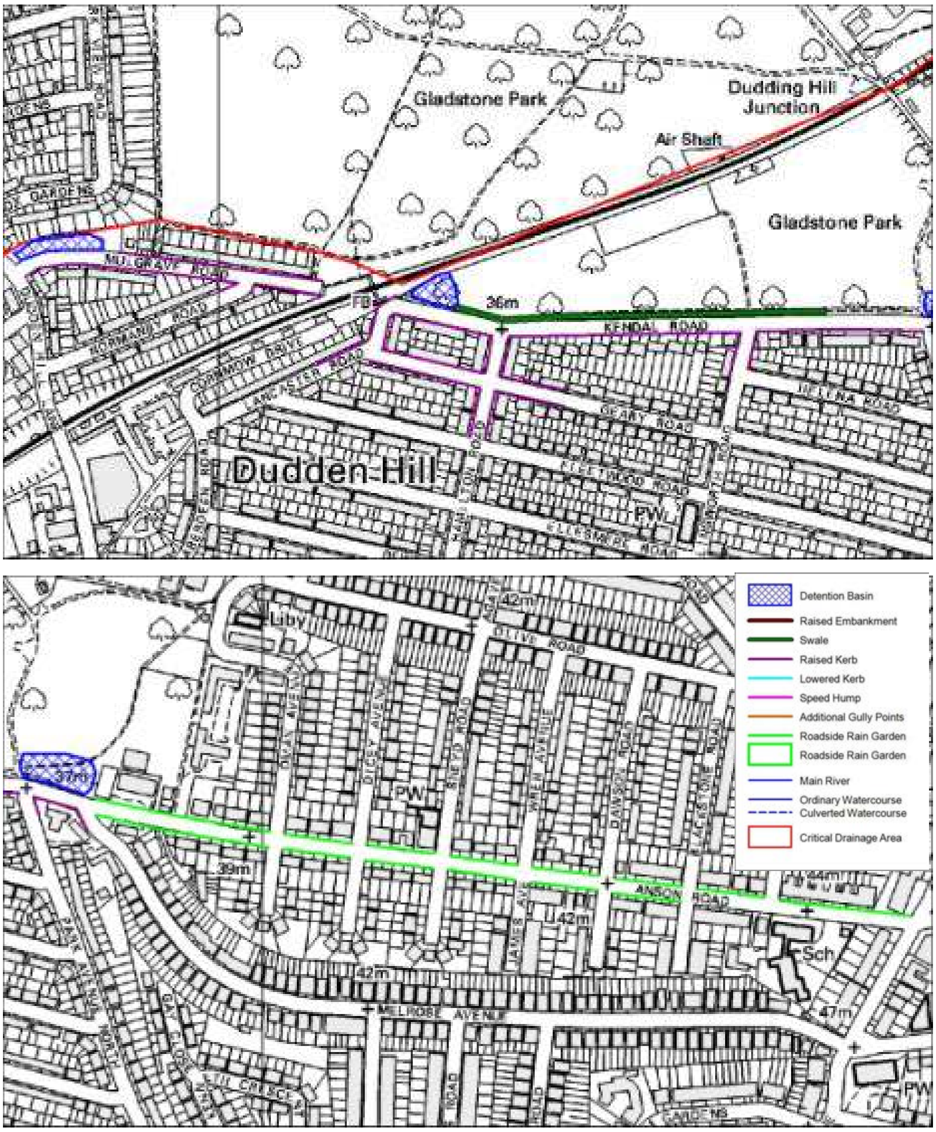

Figure E3-3 Dudden Hill Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Detention Basin, Roadside Rain Gardens, Raised Kerbs, Swales	£251k – 500k

Table E3-3 Dudden Hill Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce localised surface water ponding along Kendal Road with the addition of a small detention basin and a swale. The raised kerbs will help to reduce the likelihood of property inundation in this area, by channelling the flows into the adjacent green open spaces during extreme events. The roadside rain gardens along Anson Road will help to reduce the amount of overland flow reaching Kendal Road. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding.

Thames Water have recently completed system works beneath Gladstone Park so further information should be gathered regarding the size of the storage tanks installed and clarify if any pipe capacity improvements were made. The extent of any network changes should be determined prior to any flood risk mitigation measures being implemented in this area.

1.1.31 Forty Bridge – Group2_054

The Drain London mapping identified one area of significant risk within this CDA. This area of risk has been discussed in Section E1. The main flood risk issue in this area relates to several areas of surface water ponding within the CDA.

There are approximately 108 non-deprived and 19 deprived residential properties at risk of surface water flooding. Of those, two non-deprived properties are at risk of deep (>0.5m) surface water flooding which indicates significant risk to health and safety.

To mitigate the flood risk in this area, the following preferred option has been derived to reduce the amount of surface water ponding at Forty Bridge and Peel Road. As part of this option, a small detention basin in the grounds of Preston Manor School with a connected swale system running parallel to the properties on Holycroft Avenue is proposed. Several areas of raised kerb along St Augustine's Avenue, Preston Road, Peel Road and Ada Road are suggested. In addition, roadside rain gardens along Carlton Avenue East and four additional gully points on Peel Road would be beneficial. Figure E3-4 below outlines the proposed locations of the combined measures.

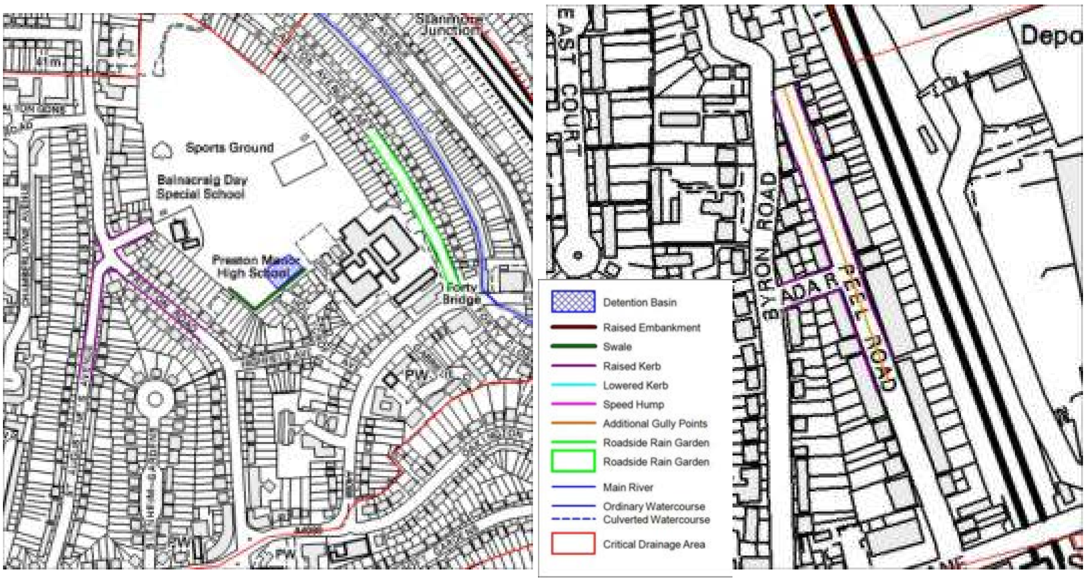

Figure E3-4 Forty Bridge Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Detention Basin, Roadside Rain Gardens, Raised Kerbs, Swales, Additional Gully	£51k – 100k

Table E3-4 Forty Bridge Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy. The proposed measures will help to reduce localised surface water ponding in Forty Bridge and Peel Road. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding.

1.1.32 Church End – Group2_047

The Drain London mapping identified several areas of significant risk within this CDA. These areas of risk have been discussed in Section E1. The main flood risk issues in this area relate to overland flow from the south-east to the north-west. The flow ponds in and around Church End, which is in a low point to the east of the railway line.

There are approximately 63 non-deprived and 576 deprived residential properties at risk of surface water flooding. Approximately 34 of the non-deprived properties at risk of shallow flooding are classified as having basements. Two of the deprived properties fall within the deep (>0.5m) surface water mapping which indicates significant risk to health and safety.

To mitigate the flood risk in this area, the following preferred option has been derived. To reduce the amount of ponding water, a combined series of options are proposed. There are multiple suitable locations for the installation of roadside rain gardens within this CDA as there are existing open areas of green space which could easily be converted. Two small areas of raised kerb have been proposed to contain flow and channel it into the roadside rain garden areas. There is also a small swale system and detention basin proposed to the south-east of the CDA in Roundwood Park. Figure E3-5 outlines the proposed locations of the combined measures.

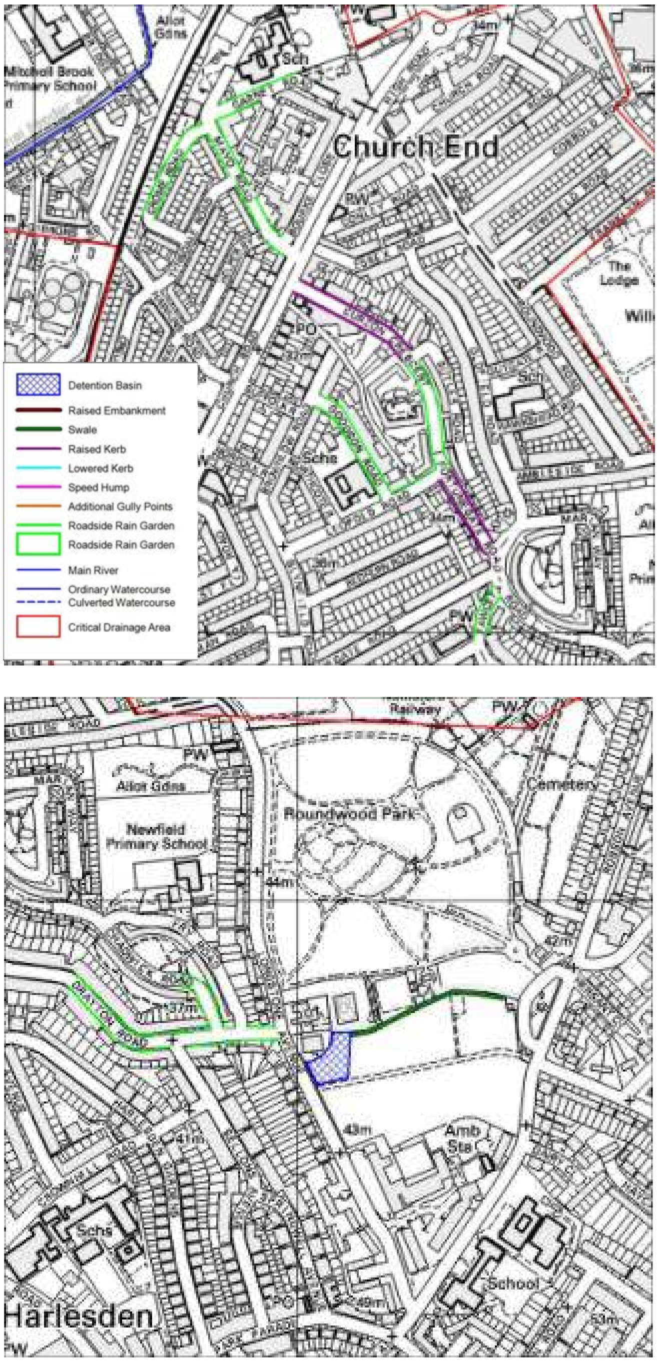

Figure E3-5 Church End Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Detention Basin, Roadside Rain Gardens, Raised Kerbs, Swales, Additional Gully	£101k – 250k

Table E3-5 Church End Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed detention basins and swale system will help to reduce localised surface water ponding at Longstone Avenue and to reduce the amount of surface water runoff from this location. The roadside rain gardens have been positioned in areas where there are clear overland flow paths in the surface water mapping. The combined raised kerbs and rain gardens should help to reduce the severity of surface water ponding on the A407 and the residential roads in Church End. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding.

1.1.33 Barham Park – Group2_038

The Drain London mapping identified several areas of significant risk within this CDA. These areas of risk have been discussed in Section E1. The main flood risk issues in this area relate to overland flow and deep surface water ponding adjacent to the railway line.

There are approximately 352 non-deprived residential properties at risk of surface water flooding. Of those, 75 fall within the deep (>0.5m) surface water mapping which indicates significant risk to health and safety.

To mitigate the flood risk in this area, the following preferred option has been derived. To reduce the amount of overland flow and surface water ponding at Lancelot Road, a series of roadside rain gardens have been proposed in the residential roads to the west. In addition, two sections of raised kerb are proposed on Eton Avenue and Charterhouse Avenue to try to impede overland flow in this area. Figure E3-6 below outlines the proposed locations of the combined measures.

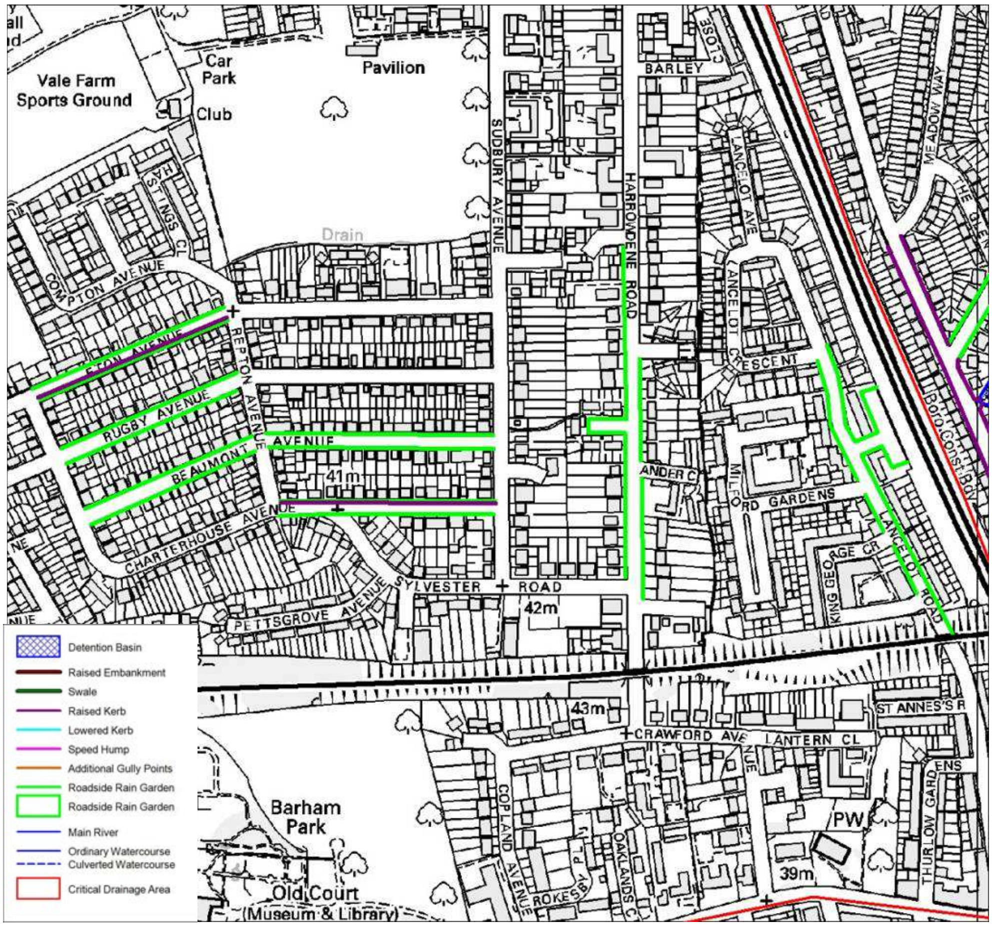

Figure E3-6 Barham Park Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Roadside Rain Gardens, Raised Kerbs	< £25k

Table E3-6 Barham Park Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed roadside rain gardens will help to reduce overland flow and the depth of localised surface water ponding on Lancelot Road. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding.

1.1.34 Capitol Way Commercial Area – Group2_059

The Drain London mapping identified several areas of significant risk within this CDA. These areas of risk have been discussed in Section E1. The main flood risk in this area relates to surface water ponding on Stag Lane and Roe Green. There are approximately 211 non-deprived residential properties at risk of surface water flooding.

To mitigate the flood risk in this area, the following preferred option has been derived. To reduce the amount of surface water ponding along Stag Lane and Roe Green, a series of combined options have been developed. A raised kerb is proposed along the western side of Stag Lane to keep surface water flow in the road carriageway. A swale along the eastern edge of Stag Lane would provide a temporary store for surface water flow in this location. To the south of the CDA, a small detention basin is proposed to the west of Roe Green to aid the alleviation of surface water ponding in this location. In addition, further raised kerbing along Roe Green and Fairfields Close will help to contain surface water flow in the road carriageway. Figure E3-7 below outlines the proposed locations of the combined measures.

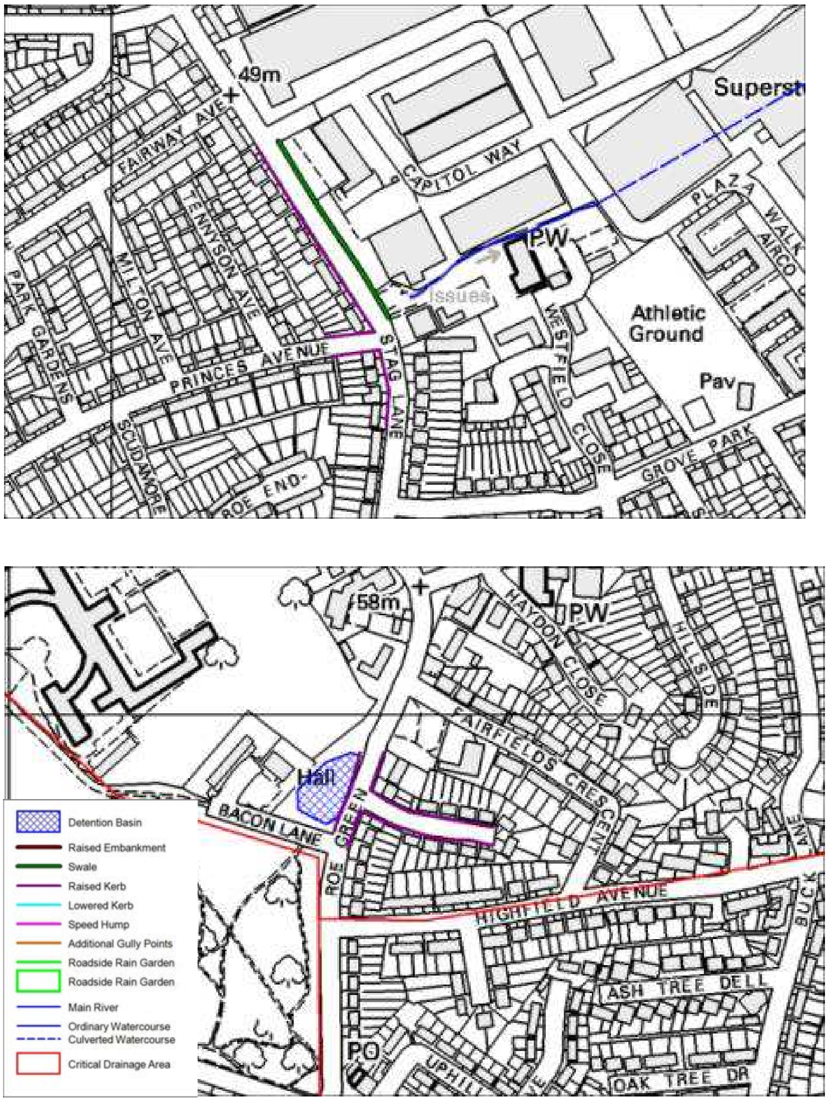

Figure E3-7 Capitol Way Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Detention Basin, Raised Kerbs, Swales	£51k – 100k

Table E3-7 Capitol Way Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce localised surface water ponding within the CDA. This combined option will eliminate approximately 80% of the risk posed to property and will mitigate approximately 5%.

Further investigation should be made into the possibility of lowering the entrance road into the Sikh Centre car park on Stag Lane. This would help to create a more direct flow path for surface water runoff to enter the Tranway ditch adjacent to Capitol Way Industrial Estate.

1.1.35 Wembley Stadium – Group2_055

The Drain London mapping identified several areas of significant risk within this CDA. The areas of risk have been discussed in Section E1. The main flood risk issues in this area relate to surface water ponding. This area has been identified as a future regeneration area in the London Plan. As a result, it is vital that stringent planning policy is in place to ensure that any future development in this area takes into account source control measures and does not contribute to flood risk in this area.

This area is dominated by the Wembley Stadium development where there are small pockets of flood risk; however these may be caused by inconsistencies in the LiDAR rather than identifying real risk. The most significant area of risk is to the south of the CDA at Wembley Stadium station and along the railway line. The railway line is a direct transport link into London which makes it a regionally important infrastructure asset.

To mitigate the flood risk in this area, the following preferred option has been derived. To reduce the amount of surface water flow on the railway line, a series of small detention basins and swale systems are proposed, however further investigation is required to ensure these elements are feasible for further investigation due to the proximity and space constraints of the main railway line. Figure E3-8 below outlines the proposed locations of the combined measures.

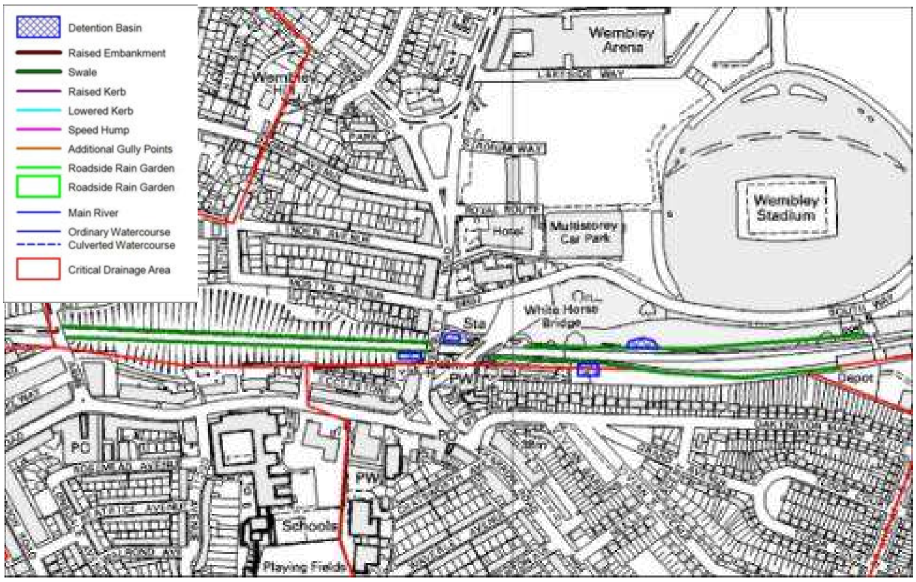

Table E3-8 Wembley Stadium Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Detention Basin, Swales	£101k – 250k

Table E3-8 Wembley Stadium Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce localised surface water ponding along the railway line and at Wembley Stadium railway station. The swales and detention basins should be sufficient to intercept any surface water runoff onto the railway line. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding. Further investigation should be made to ensure that the most appropriate policies to minimise run-off are taken forward for the regeneration area.

1.1.36 Winchester Avenue – Group2_035

The Drain London mapping identified one large area and several smaller areas of significant risk. These areas of risk have been discussed in Section E1. The main flood risk issues in this area relate to overland flow and deep surface water ponding adjacent to the railway line on Winchester Avenue.

There are approximately 126 non-deprived residential properties at risk of surface water flooding. Of these, 23 non-deprived properties fall within the deep (>0.5m) surface water mapping which indicates significant risk to health and safety. To mitigate the flood risk in this area, the following preferred option has been derived. A detention basin is proposed in the open area at Sherborne Gardens. In addition, a series of raised kerbs along Wimborne Drive, Waltham Drive and Calder Gardens to contain flows in the road carriageway are proposed. Figure E3-9 below outlines the proposed locations of the combined measures.

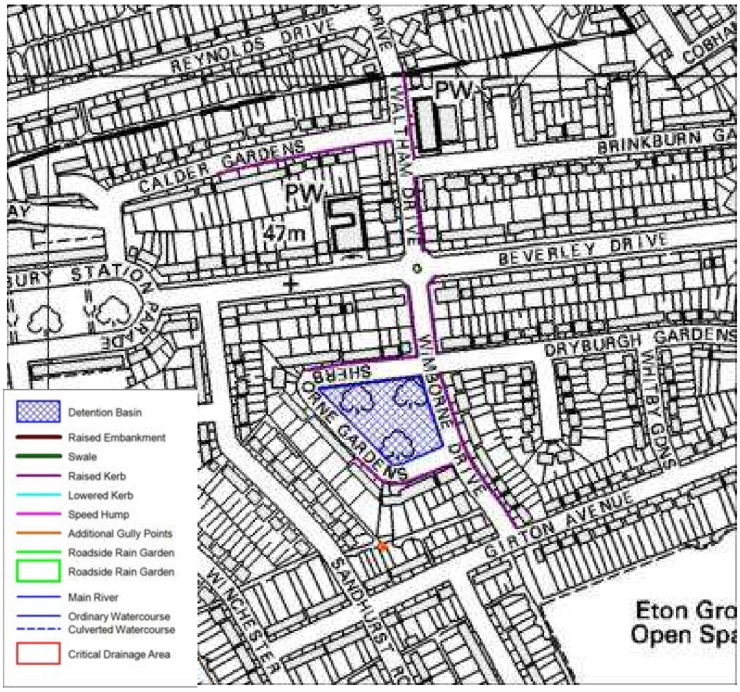

Figure E3-9 Winchester Avenue Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Detention Basin, Raised Kerb	£101k – 250k

Table E3-9 Winchester Avenue Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce localised surface water ponding at Winchester Avenue. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding. Further investigation into the condition and maintenance regime for all assets crossing under the railway line in this area would be beneficial.

1.1.37 Harrow Road – Group2_056

The Drain London mapping identified one large area of significant risk within this CDA. This area of risk has been discussed in Section E1. The main flood risk issues in this area relate to overland flow and surface water ponding on the Harrow Road.

There are approximately 69 non-deprived residential properties at risk of surface water flooding. Harrow Road is at risk of ponding on both carriageways and this is a regionally important infrastructure link. The mitigation measures have focussed on resolving flood risk to this asset. To mitigate the flood risk in this area, the following option is potential. A small detention basin on the area of open land behind the properties on Harrow Road will help to alleviate some of the ponding in this location. A small connecting ditch along the wide alley between the properties on Harrow Road will help to direct overland flow into the detention basin. In addition, a series of roadside rain gardens along Harrow Road to reduce the amount of overland flow are proposed. Figure E3-10 below outlines the proposed locations of the combined measures.

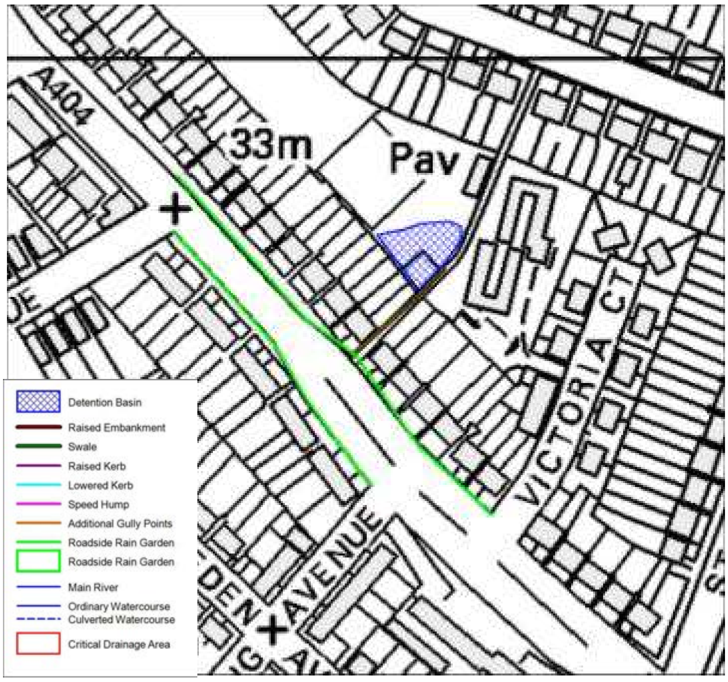

Figure E3-10 Harrow Road Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Detention Basin, Roadside Rain Garden, Ditch	£26k – 50k

Table E3-10 Harrow Road Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce localised surface water ponding along Harrow Road. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding.

1.1.38 Tokyngton – Group2_044

The Drain London mapping identified one area of significant risk within this CDA. This area of risk has been discussed in Section E1. The main flood risk issues in this area relate to overland flow and deep surface water ponding on the A406 North Circular underpass at Tokyngton.

There are approximately 69 non-deprived residential properties at risk of surface water flooding. The A406 North Circular is at risk of severe ponding in the underpass adjacent to Tokyngton.

To mitigate the flood risk in this area, the following preferred option has been derived. To reduce the amount of surface water ponding water on the A406, six additional gully entry points are proposed to improve the drainage through the underpass. In addition, several roadside rain gardens are proposed on Monks Park where there is another small area of surface water ponding. Figure E3-11 below outlines the proposed locations of the combined measures.

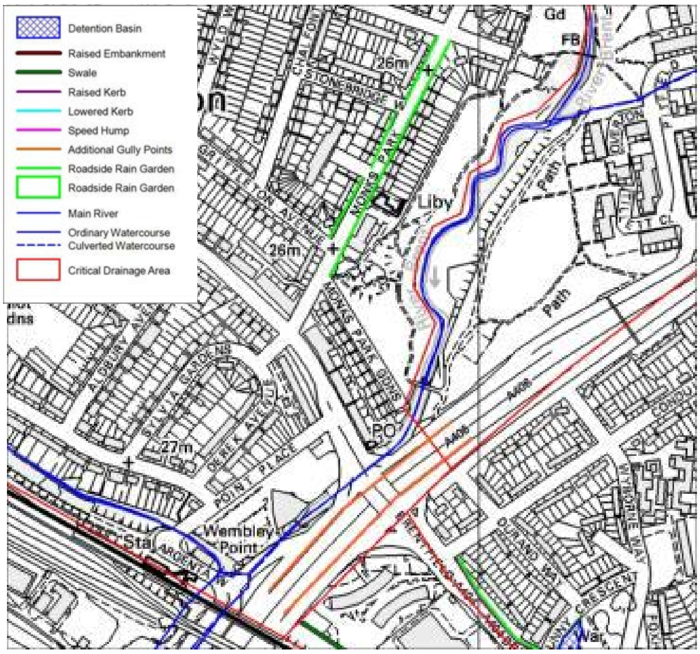

Figure E3-11 Tokyngton Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Roadside Rain Garden, Additional Gully Point	< £25k

Table E3-11 Tokyngton Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. There may be significant cost increases as a result of working on such a strategically important road. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding.

1.1.39 Neasden – Group2_048

The Drain London mapping identified several areas of significant risk within this CDA. These areas of risk have been discussed in Section E1. The main flood risk issues in this area relate to deep surface water ponding to the north-east of the CDA adjacent to the railway line.

There are approximately 52 non-deprived and 189 deprived residential properties at risk of surface water flooding. Of these, 41 deprived properties fall within the deep (>0.5m) surface water mapping, which indicates significant risk to health and safety. The Jubilee line, a regionally important infrastructure asset, is also at risk from surface water ponding.

To mitigate the flood risk in this area, the following preferred option has been derived. To reduce the amount of overland flow and surface water ponding under Neasden Lane and along the Jubilee railway line, a combined option has been developed. Two small detention basins have been suggested to help to reduce the severity of the ponding on Neasden Lane. To prevent property flooding, a series of raised kerbs have been incorporated into the option to try to keep flow within the road carriageways. A 155m long embankment is proposed along the edge of the railway line within the industrial area, currently used as an open car park to the east of Neasden Lane to prevent inundation of the Jubilee railway line. Figure E3-12 below outlines the proposed locations of the combined measures.

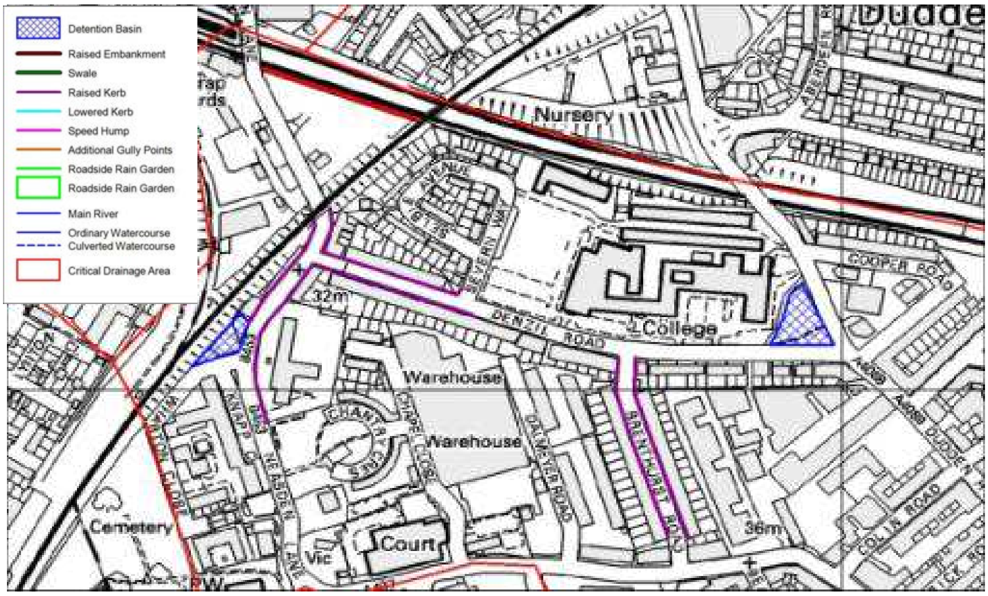

Figure E3-12 Neasden Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Detention Basin, Raised Kerb, Raised Embankment	£101k – 250k

Table E3-12 Neasden Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce localised surface water ponding within the CDA. The detention basin on Neasden Lane, in conjunction with the raised kerbs, will help to reduce the severity of ponding in this area. The raised embankment will protect the railway line but will result in deeper flooding within the car park of the industrial estate to the east of Neasden Lane. Further, smaller, berms could be put in place to prevent surface water in this area from inundating the industrial units. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding.

Further investigation should be made into the possibility of lowering the industrial area of land to the east of Neasden Lane adjacent to the railway line to provide a more significant detention area for surface water in a large event, but would require further negotiations.

1.1.40 Review Road – Group2_052

The Drain London mapping identified one area of significant risk within this CDA. The area of risk has been discussed in Section E1. The main flood risk issues in this area relate to overland flow and deep surface water ponding on Review Road and the A406 North Circular, a regionally important infrastructure asset.

There are approximately 181 non-deprived residential properties at risk of surface water flooding. Of these, 19 properties fall within the deep (>0.5m) surface water mapping which indicates significant risk to health and safety. This surface water flooding indicates that both carriageways of the A406 North Circular would also be at risk of inundation.

To mitigate the flood risk in this area, the following preferred option has been derived. To reduce the amount of overland flow and surface water ponding within this CDA, a series of raised kerb and roadside rain gardens are proposed. Eight additional gully entry points are proposed along Brook Road to improve drainage. Figure E3-13 below outlines the proposed locations of the combined measures.

Figure E3-13 Review Road Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Roadside Rain Garden, Raised Kerb, Additional Gully Point	< £25k

Table E3-13 Review Road Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce localised surface water ponding within the CDA. The roadside rain gardens on Review road should help to reduce/slow down surface water runoff and ponding in this area. The raised kerb along Brook Road should contain shallow surface water runoff within the residential road carriageway. A higher kerb may be required at the end of Brook Road at the footbridge over the A406 to prevent surface water from reaching the main road. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding.

1.1.41 Willesden Junction Station – Group2_058

The Drain London mapping identified one main area of significant risk to the south of this CDA. This area of risk has been discussed in Section E1. The main flood risk issues in this area relate to deep surface water ponding along the railway line to the south of the CDA. This area falls within the Kensal Green regeneration area as defined by the London Plan. As a result, it is vital that stringent planning policy is in place to ensure that any future development in this area takes into account source control measures and does not contribute to flood risk in this area.

There are two regionally important infrastructure assets at risk within this CDA: the railway line (Overground Rail and Bakerloo) and Willesden Junction Station. These assets fall between the boundary of the London Boroughs of Brent and Hammersmith and Fulham. This presents the possibility of a cross-borough solution to this area's issue.

To assist in reducing the amount of surface water ponding at the station and on the railway line, a series of swales and small detention basins have been proposed, that should link in with and assist the current track drainage to help reduce the flows across the asset. Figure E3-14 below outlines the proposed locations of the combined measures.

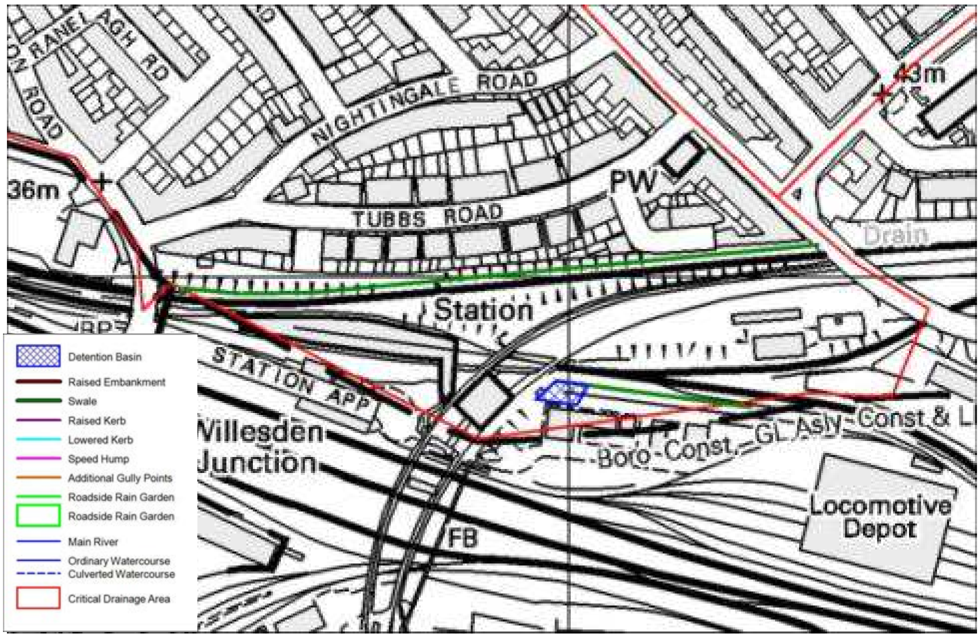

Figure E3-14 Willesden Junction Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Detention Basin, Swales	£26k – 50k

Table E3-14 Willesden Junction Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce localised surface water ponding within the CDA. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding. Further investigation is required, including liaison with both Network Rail and LUL to identify the current drainage facilities and feasibility for utilising the space in the area to help direct surface water into these preferential areas.

1.1.42 Brentfield A404 – Group2_045

The Drain London mapping identified one area of significant risk. This area of risk has been discussed in Section E1. The main flood risk issue in this area relates to surface water ponding within the CDA. The Brentfield A404, a regionally important infrastructure asset, is at risk of surface water ponding on both carriageways.

There are approximately 141 deprived residential properties at risk of surface water flooding. Of these, three properties fall within the deep (>0.5m) surface water mapping which indicates significant risk to health and safety. This surface water flooding indicates that both carriageways of the Brentfield A404 would also be at risk of inundation.

To mitigate the flood risk in this area, the following preferred option has been derived. To reduce the amount of surface water ponding on the A404, a combined option has been developed. As part of this option, a small detention basin in Sunny Crescent War Memorial Park, with a connected swale system running parallel to Sunny Crescent, is proposed. In addition, a section of raised kerb and roadside rain gardens along the A404 between Sunny Crescent and Conduit Way would be beneficial. Figure E3-15 below outlines the proposed locations of the combined measures.

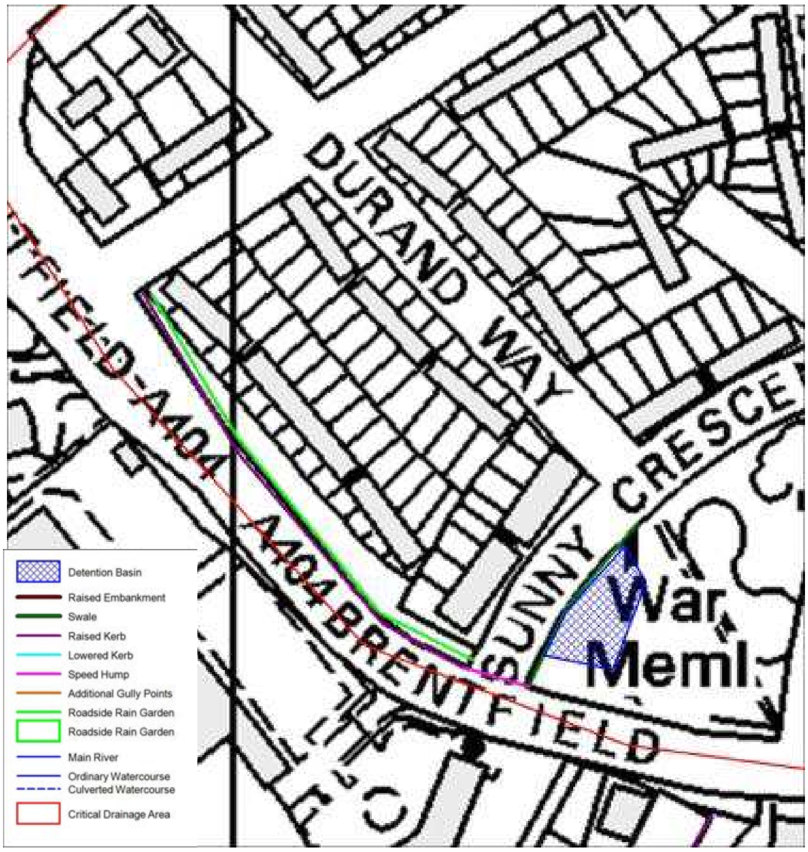

Figure E3-15 Brentfield Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Detention Basin, Swales, Roadside Rain Gardens, Raised Kerb, Speed Hump	£26k – 50k

Table E3-15 Brentfield Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce localised surface water ponding on the Brentfield A404. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding. Further investigation into the effectiveness of small speed humps placed at the junctions with the Brentfield A404 to prevent overland flow along the road carriageways from reaching the main road is required.

1.1.43 Stonebridge – Group2_046

The Drain London mapping identified several areas at risk within this CDA. These areas of risk have been discussed in Section E1. The main flood risk issue in this area relates to overland flow and surface water ponding within the CDA. The Brentfield A404, a regionally important infrastructure asset, is at risk of surface water ponding.

There are approximately 136 non-deprived residential properties at risk of surface water flooding. The surface water flooding within this CDA partially encroaches onto the A404.

To mitigate the flood risk in this area, the following preferred option has been derived. A small detention basin adjacent to the railway embankment, with a swale system connected to the north west and south east along the embankment, will provide additional storage for surface water flow. A small section of raised kerb along First Drive will keep any overland flow within the road carriageway. Figure E3-16 below outlines the proposed locations of the combined measures.

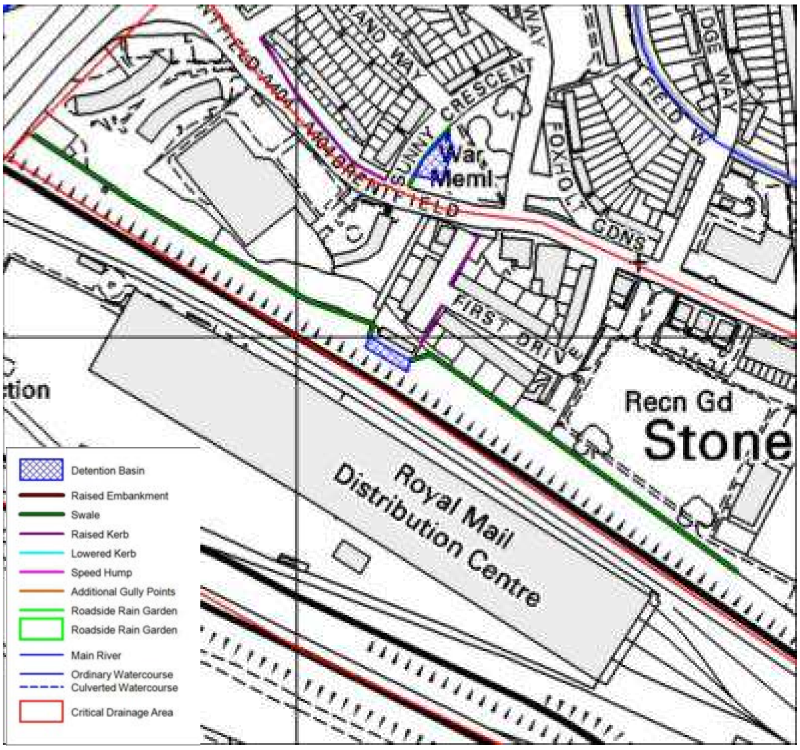

Figure E3-16 Stonebridge Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Detention Basin, Swales, Raised Kerb	£26k – 50k

Table E3-16 Stonebridge Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce localised surface water ponding adjacent to the railway embankment and will help to reduce any overland flow that may affect the Brentfield A404. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding.

1.1.44 King Edward VII Park – Group2_039

The Drain London mapping identified one large area of significant risk within this CDA. This area of risk has been discussed in Section E1. The main flood risk issues in this area relate to deep surface water ponding on St Johns Road and adjacent to the railway line.

There are approximately 123 non-deprived residential properties at risk of surface water flooding. None of the properties or infrastructure within this CDA are at risk of deep surface water flooding.

To mitigate the flood risk in this area, the following preferred option has been derived. A large detention basin in King Edward VII Park, with a connecting swale system, will reduce the amount of surface water runoff entering the drainage system. A series of roadside rain gardens along Castleton Avenue and Kingsway would also help to reduce the amount of surface water runoff in this area. In addition, a section of raised kerb along St Johns Road would help to protect properties in this area. Figure E3-17 below outlines the proposed locations of the combined measures.

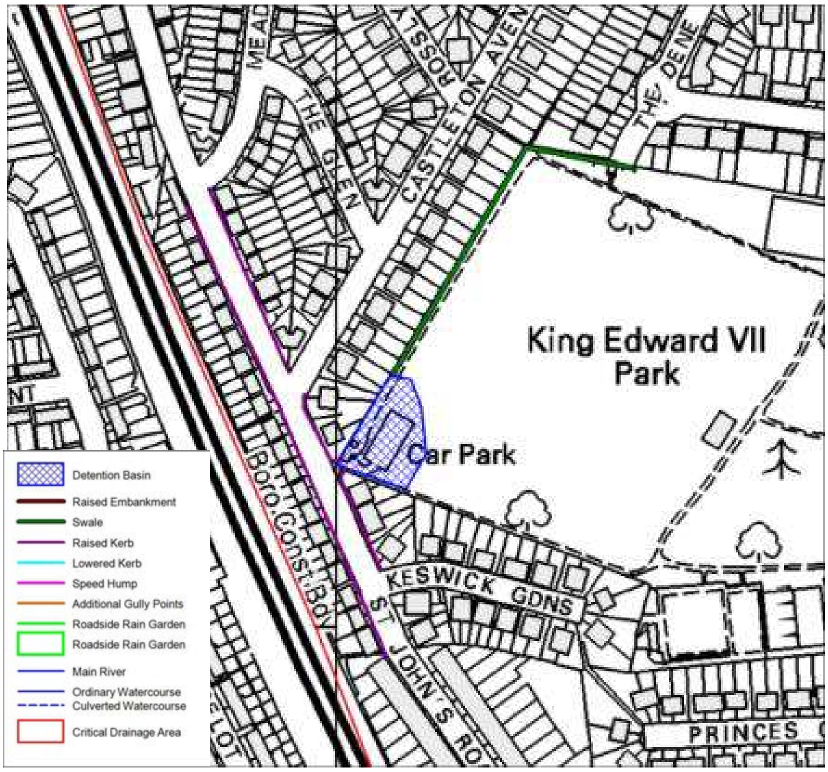

Figure E3-17 King Edward VII Park Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Detention Basin, Swales, Roadside Rain Garden, Raised Kerb	£101k – 250k

Table E3-17 King Edward VII Park Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce localised surface water ponding. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding.

1.1.45 Alperton – Group2_041

The Drain London mapping identified several areas of significant risk within this CDA. These areas of risk have been discussed in Section E1. The main flood risk issues in this area relate to surface water ponding in several areas.

There are approximately 49 non-deprived residential properties at risk of surface water flooding. Of these, three properties fall within the deep (>0.5m) surface water mapping which indicates significant risk to health and safety.

To mitigate the flood risk in this area, the following preferred option has been derived. A detention basin is proposed in the grounds of Alperton Community School with a connecting swale system adjacent to the railway line and car park on Atlip Road. In addition, raised kerbs along Clifford and Sunleigh Roads will help to keep surface water runoff in the road carriageway. Figure E3-18 below outlines the proposed locations of the combined measures.

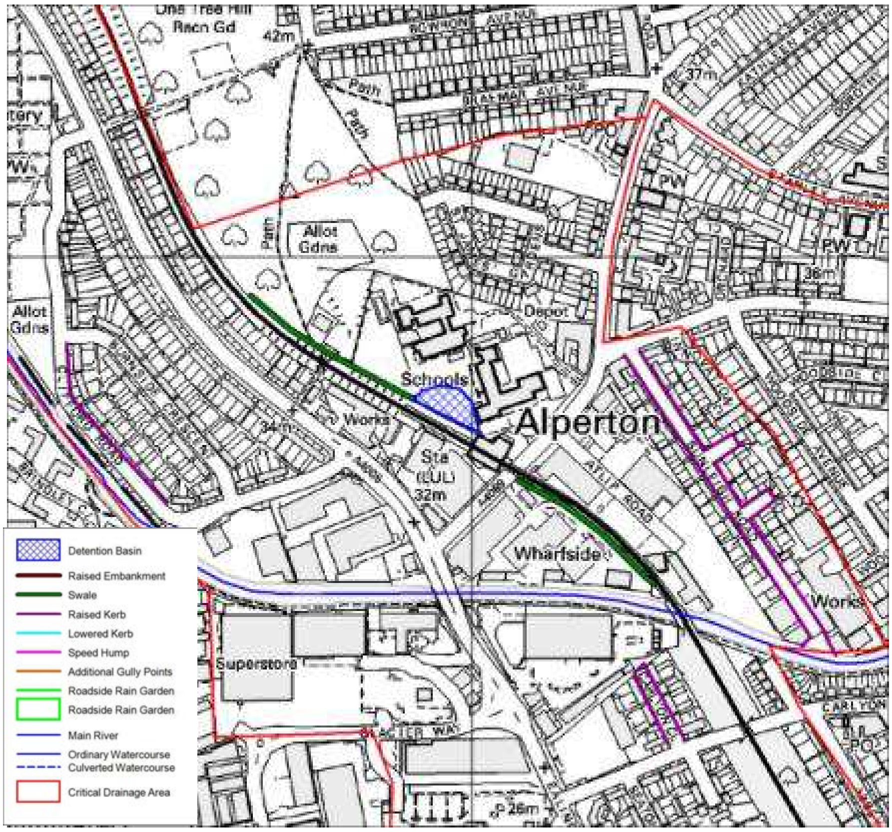

Figure E3-18 Alperton Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Detention Basin, Swales, Raised Kerb	£101k – 250k

Table E3-18 Alperton Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce localised surface water ponding. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding.

1.1.46 A4089 – Group2_040

The Drain London mapping identified one large area of significant risk within this CDA. This area of risk has been discussed in Section E1. The main flood risk issues in this area relate to overland flow and deep surface water ponding on the A4089.

There are approximately 93 non-deprived and 64 deprived residential properties at risk of surface water flooding. Of these, ten of the deprived properties fall within the deep (>0.5m) surface water mapping which indicates significant risk to health and safety. The A4089 is at risk of deep flooding and is a regionally important infrastructure asset.

To mitigate the flood risk in this area, the following preferred option has been derived. A series of raised kerbs along the A4089, Harrow Road and Chaplin Road are proposed. In addition, the installation of raised speed humps on Chaplin and Union Roads to compartmentalise surface water runoff in this area. Figure 2-20 below outlines the proposed locations of the combined measures.

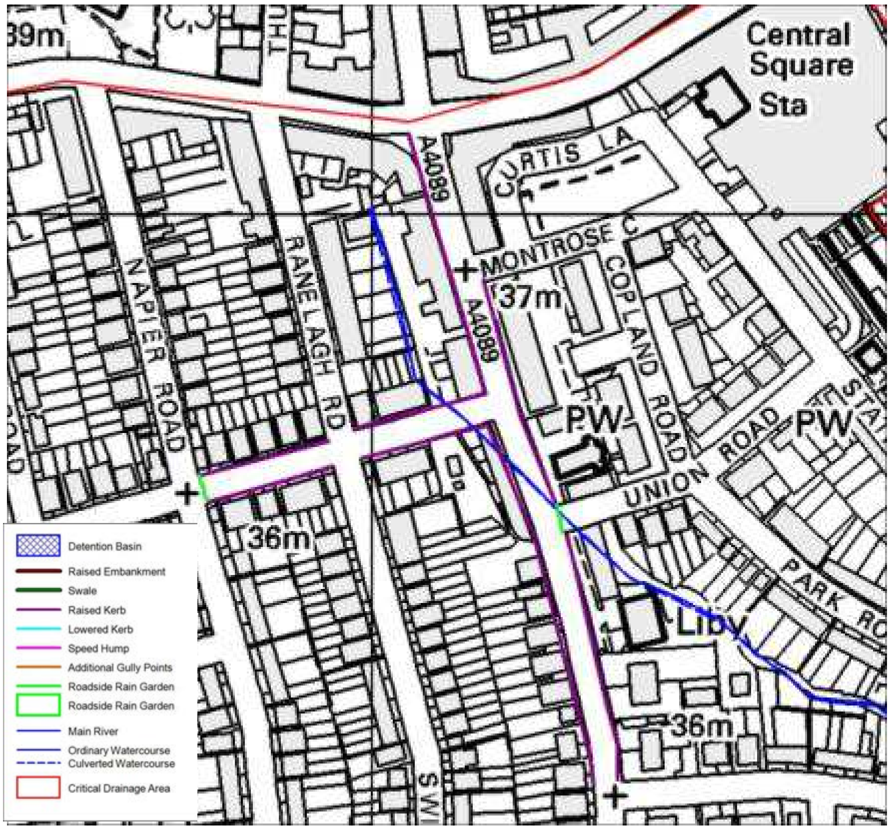

Figure E3-19 A4089 Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Raised Kerb, Speed Hump	< £25k

Table E3-19 A4089 Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to prevent any surface water flow from affecting property and will retain any excess surface water flow within the road carriageway. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding.

This option is focussed on preventing inundation of properties in this CDA, a further investigation into the current maintenance regime and drainage setup on the A4089 would be beneficial to establish if more gully entry points would be required.

1.1.47 North Circular – Group2_042

The Drain London mapping identified one area of significant risk within this CDA. This area of risk has been discussed in Section E1. The main flood risk issues in this area relate to deep surface water ponding on the A406 North Circular, a regionally important infrastructure asset.

There are approximately 53 non-deprived residential properties at risk of surface water flooding. The A406 North Circular is at risk of deep surface water flooding.

To mitigate the flood risk in this area, the following preferred option has been derived. Install six additional gully points in the A406 underpass to improve drainage through the underpass. Figure E3-20 below outlines the proposed locations of the combined measures.

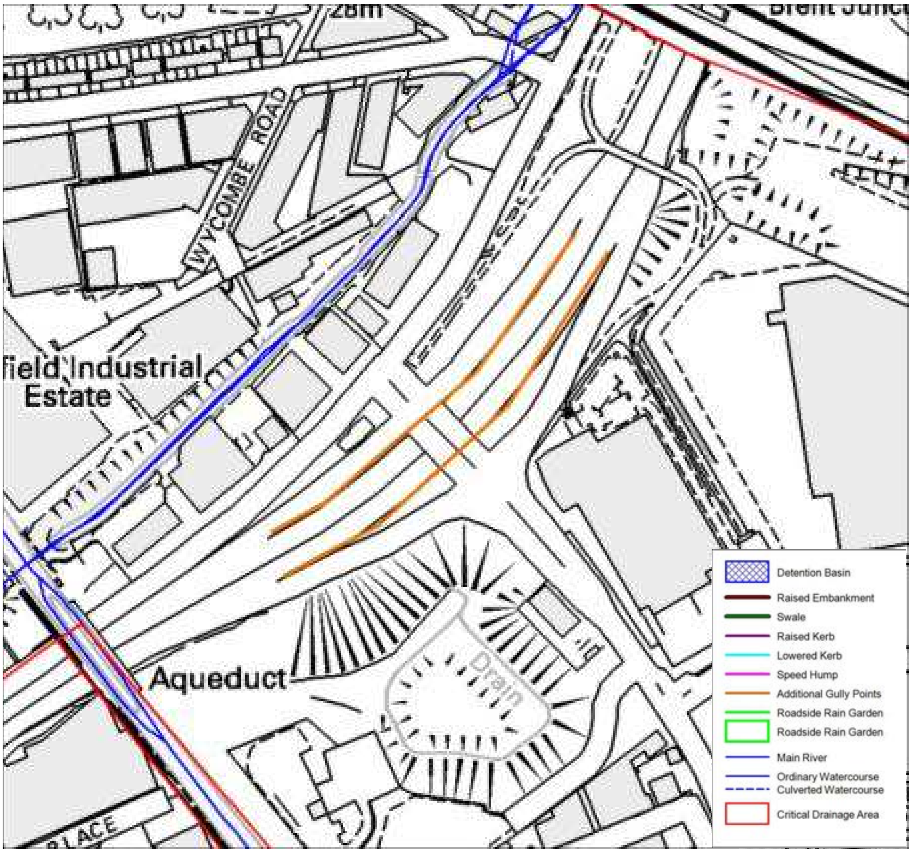

Figure E3-20 North Circular Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Additional Gully Point	< £25k

Table E3-20 North Circular Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce localised surface water ponding on the A406 North Circular. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding. A full assessment of the current drainage and pumping capacity of the system through the underpass by TfL would be beneficial as this is such a key transport route within the borough.

1.1.48 Park Royal – Group2_043

The Drain London mapping identified several areas of risk within this CDA and they have been discussed in Section E1. The main flood risk issues in this area relate to overland flow and surface water ponding in this predominantly commercial area.

There are approximately 12 non-deprived residential properties at risk of surface water flooding. This is a predominantly industrial area with 52 commercial properties at risk of shallow surface water flooding and three at risk of deep (>0.5m) surface water flooding.

To mitigate the flood risk in this area, the following preferred option has been derived. A series of roadside rain gardens along Cumberland Avenue, Willenfield Road, Abbey Road and Central Way will help to intercept and reduce surface water runoff in this CDA. Figure E3-21 below outlines the proposed locations of the combined measures.

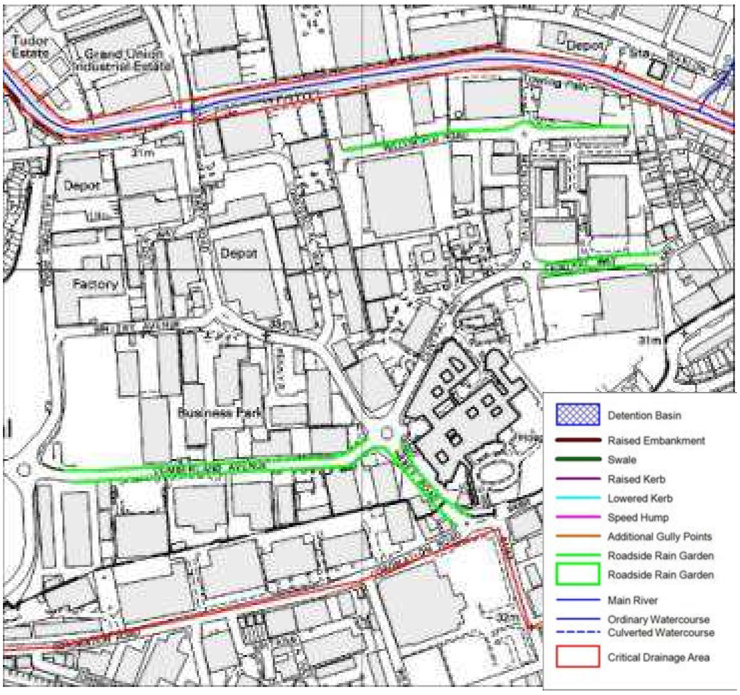

Figure E3-21 Park Royal Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Roadside Rain Garden	< £25k

Table E3-21 Park Royal Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce surface water runoff through the commercial areas. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding.

1.1.49 Tudor Gardens – Group2_053

The Drain London mapping identified several areas of significant risk within this CDA. This area of risk has been discussed in Section E1. The main flood risk issues in this area relate to overland flow and deep surface water ponding on Tudor Gardens.

There are approximately 98 non-deprived residential properties at risk of surface water flooding. Of these, four non-deprived properties fall within the deep (>0.5m) surface water mapping which indicates significant risk to health and safety.

To mitigate the flood risk in this area, the following preferred option has been derived. A small detention basin in front of St Andrews Church is proposed, in conjunction with a series of roadside rain gardens along Tudor Gardens. In addition, raised kerbs are proposed along sections of Tudor Gardens, Queens Walk and Old Church Lane. Figure E3-22 below outlines the proposed locations of the combined measures.

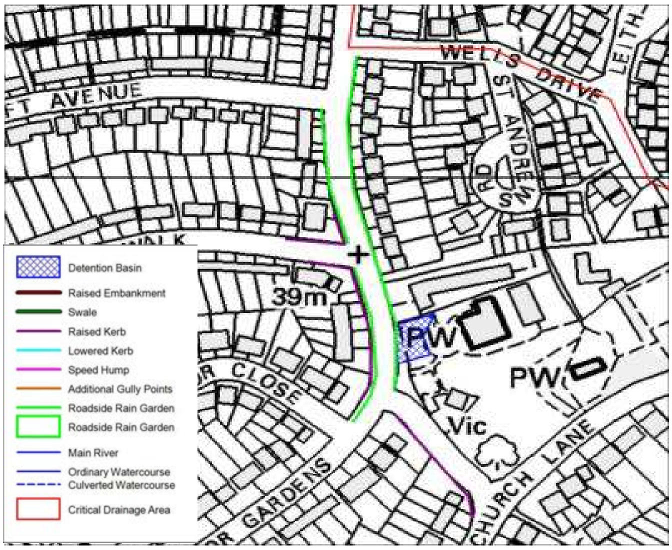

Figure E3-22 Tudor Gardens Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Detention Basin, Roadside Rain Garden, Raised Kerb	£26k – 50k

Table E3-22 Tudor Gardens Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce localised surface water ponding and runoff. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding.

1.1.50 The Circle – Group2_051

The Drain London mapping identified one area of significant risk within this CDA. This area of risk has been discussed in Section E1. The main flood risk issues in this area relate to deep surface water ponding on The Circle.

There are approximately 71 non-deprived residential properties at risk of surface water flooding. Of these, 16 non-deprived properties fall within the deep (>0.5m) surface water mapping which indicates significant risk to health and safety.

To mitigate the flood risk in this area, the following preferred option has been derived. The installation of a series of roadside rain gardens along The Circle will provide additional storage for surface water flow and slow down the rate at which it enters the drainage system. Figure E3-23 below outlines the proposed locations of the combined measures.

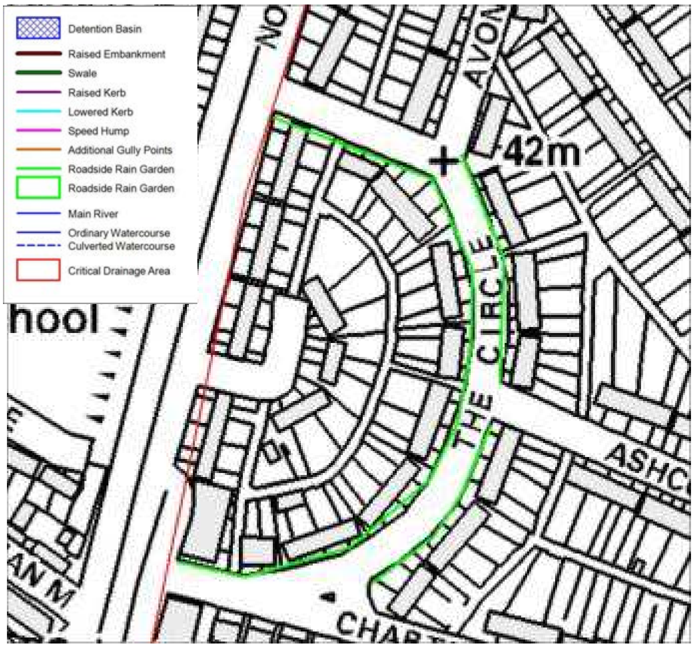

Figure E3-23 The Circle Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Roadside Rain Garden	< £25k

Table E3-23 The Circle Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce localised surface water ponding and overland flow on The Circle. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding.

1.1.51 Roe Green Park/Fryent Country Park – Group2_060

The Drain London mapping identified several areas of significant risk within this CDA. This area of risk has been discussed in Section E1. The main flood risk issues in this area relate to overland flow and deep surface water ponding on the Jubilee railway line.

There are approximately 68 non-deprived residential properties at risk of surface water flooding. A section of the Jubilee Line runs through this CDA and the mapping suggests that it is at risk of deep surface water flooding in places. This tube line is a regionally important infrastructure asset.

To mitigate the flood risk in this area, the following preferred option has been derived. Two detention basins are proposed, one behind Shakespeare Drive and one in Fryent Park. A swale running parallel to the railway line is also proposed to help channel any surface water flow away from the infrastructure asset, in parallel with the existing track drainage. In addition, a small section of raised kerb is proposed along Shakespeare Drive to channel flows into the detention basin. Figure E3-24 below outlines the proposed locations of the combined measures.

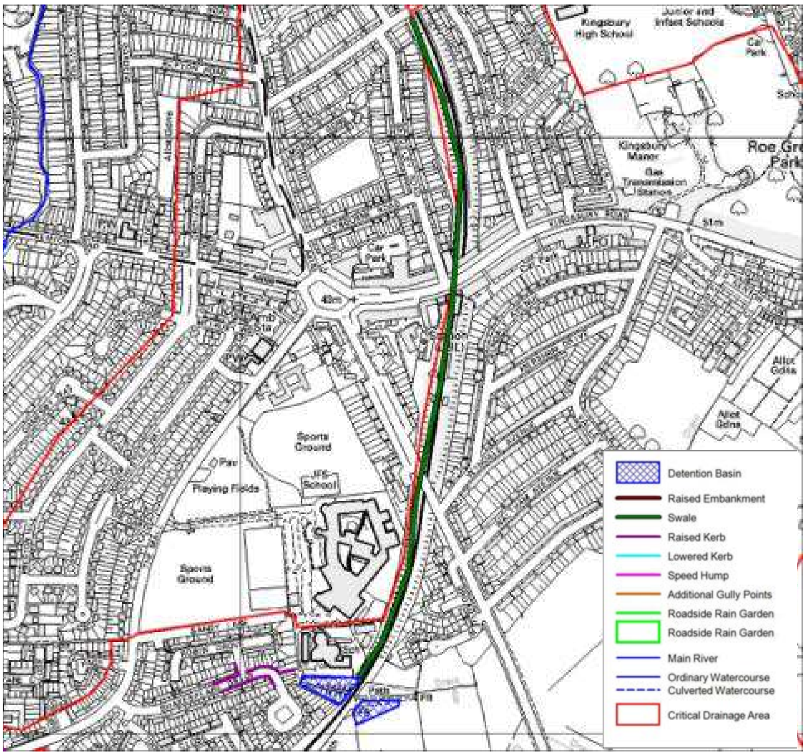

Figure E3-24 Roe Green Park/Fryent Country Park Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Detention Basin, Raised Kerb, Swales	£101k - 250k

Table E3-24 Roe Green Park/Fryent Country Park Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce localised surface water ponding and runoff on the Jubilee Line and the surrounding residential roads. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding.

Further investigation to ground truth the likelihood of the railway line flooding in this location will allow for the development of the most appropriate flood mitigation scheme in this area.

1.1.52 A4088 – Group2_050

The Drain London mapping identified one area of significant risk within this CDA. This area of risk has been discussed in Section E1. The main flood risk issues in this area relate to deep surface water ponding on the A4088 underpass.

There are approximately 35 non-deprived residential properties at risk of surface water flooding. The A4088 underpass is at risk of deep surface water flooding, and this is a regionally important infrastructure asset.

To mitigate the flood risk in this area, the following preferred option has been derived. The installation of six additional gully entry points is proposed to improve drainage through the underpass. Figure E3-25 below outlines the proposed locations of the combined measures.

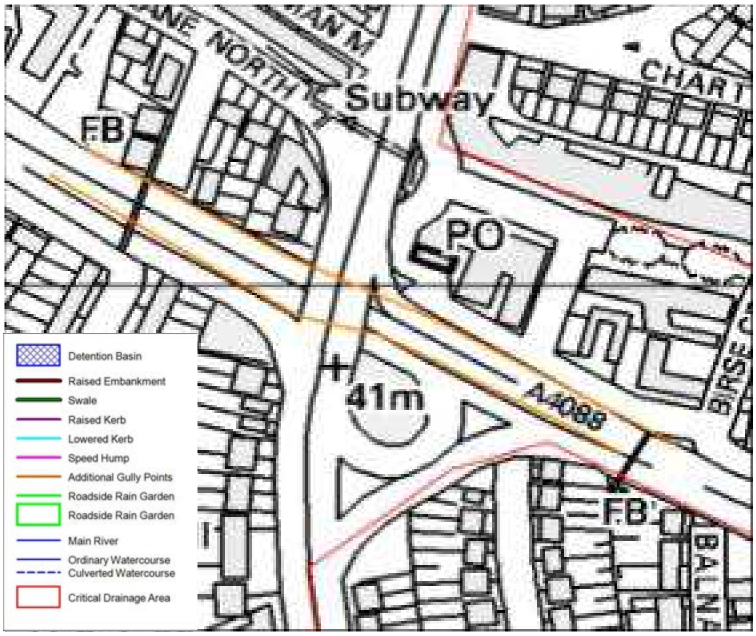

Figure E3-25 A4088 Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Additional Gully Points	< £25k

Table E3-25 A4088 Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce localised surface water ponding along the A4088. This option will not eliminate the risk posed to property and infrastructure but help mitigate the risks to the A4088 by helping to reduce the deeper areas of ponding.

A full assessment of the current drainage and pumping capacity of the system through the underpass by TfL would be beneficial as this is such a key transport route within the borough.

1.1.53 Preston Sports Ground – Group2_036

The Drain London mapping identified several areas of significant risk within this CDA. This area of risk has been discussed in Section E1. The main flood risk issues in this area relate to deep surface water ponding on Preston Waye.

There are approximately 31 non-deprived residential properties at risk of surface water flooding. Of these, four properties fall within the deep (>0.5m) surface water mapping which indicates significant risk to health and safety.

To mitigate the flood risk in this area, the following preferred option has been derived. A detention basin and swale system on Preston Sports Ground is proposed to reduce surface water ponding and overland flow. Figure E3-26 below outlines the proposed locations of the combined measures.

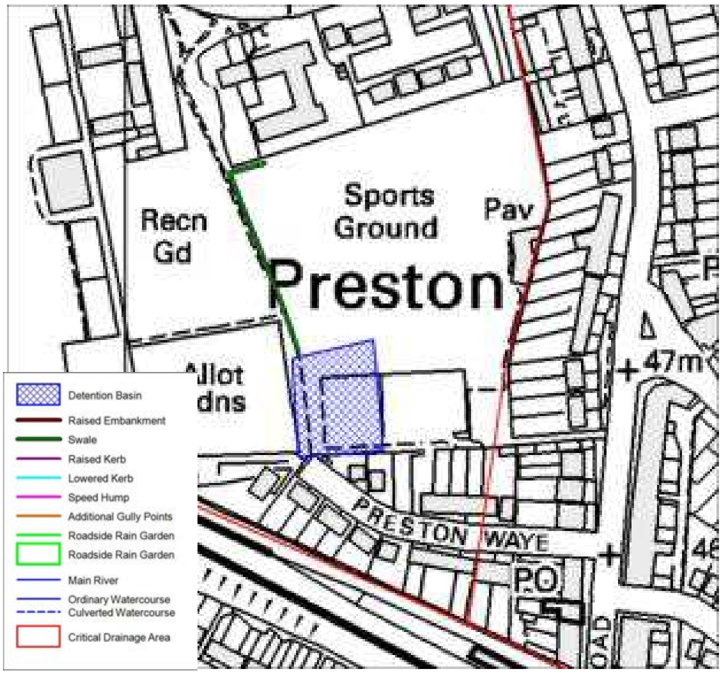

Figure E3-26 Preston Sports Ground Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Detention Basin, Swales	£251k – 500k

Table E3-26 Preston Sports Ground Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy. The proposed measures will help to reduce localised surface water ponding on Preston Waye. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding.

1.1.54 Monks Park North – Group2_057

The Drain London mapping identified two areas of risk within this CDA. These areas of risk have been discussed in Section E1. The main flood risk issues in this area relate to surface water ponding on both sides of Monks Park North.

There are approximately 12 non-deprived residential properties at risk of surface water flooding and no properties or infrastructure at risk of deep surface water flooding.

To mitigate the flood risk in this area, the following preferred option has been derived. Two small detention basins are proposed, one in Oakington Manor Primary School grounds and one in the open area of ground adjacent to the River Brent. Figure E3-27 below outlines the proposed locations of the combined measures.

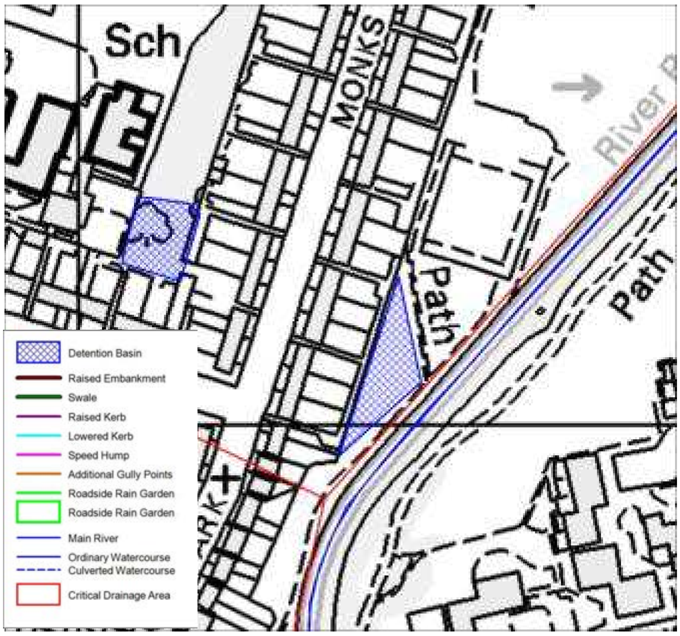

Figure E3-27 Monks Park North Preferred Option Locations

The estimated capital expenditure of this option is summarised below:

Proposed Measures	Estimated Cost
Detention Basin	£101k – 250k

Table E3-27 Monks Park North Preferred Option Costs

The costs outlined above are an approximate estimation for illustration purposes. A more detailed study of this particular area would be required to determine the most effective flood mitigation strategy.

The proposed measures will help to reduce localised surface water ponding. This option will not completely eliminate the risk posed to property but it should mitigate the risks and help reduce the deeper areas of ponding. The storage area located adjacent to the River Brent is likely to act as more of a fluvial mitigation measure than a surface water measure. Further modelling to assess the effectiveness of this location for reducing surface water flood risk during a fluvial flood event would be necessary.

Appendix F – Peer Review

Appendix G – Spatial Planner Information Pack

Background

PPS 25 sets out national planning guidance for development in relation to flood risk. It takes a risk based approach and categorises land uses into different vulnerabilities, which are appropriate to different flood zones.

PPS 25 applies to all forms of flood risk, however, surface water, groundwater and ordinary watercourse flood risks are generally less well understood than fluvial or coastal flood risk. In part this is due to the much faster response times of surface water flooding, a perception that the impacts are relatively minor and the highly variable nature of influences, e.g. storm patterns, local drainage blockages, interactions with the sewer system.

However climate change models are predicting more frequent heavy storms and there is emerging evidence that this is already happening. It is also clear from the flooding that occurred in several parts of England in summer 2007 that surface water flooding can have major impacts. In the heavily urbanised area of London, the risks are significant and it is important that appropriate consideration is given to these risks when new development is proposed.

The planning system is a key tool in reducing flood risk, and with this additional information, this can apply to the surface water risk as well as fluvial and tidal risk.

Since April 2011, London Boroughs have been given the roles of Lead Local Flood Authorities (LLFAs) by the Flood and Water Management Act 2010. This means that each borough has new duties. The Planning Department has an important role to play in delivering these new duties and must ensure that it forms part of authority wide co-ordination of the LLFA role.

Whilst this document is titled a SWMP, it also identifies flood risk at ordinary watercourses and has been adapted to include consideration of groundwater flood risk through the identification of a map showing “Increased Potential for Elevated Groundwater (IPEG).

The Greater London Authority will examine the 33 SWMPs across London to update the Regional Flood Risk Appraisal during 2012.

Using the SWMP to update the borough SFRA

Most borough SFRAs have little or no historic analysis of surface water, groundwater and ordinary watercourse flood risk. The North London SFRA analysed flood risk from all sources however the report does not identify any specific events associated with non-Main River sources as there were very few historic records available. The report did use existing datasets to identify areas at risk of flooding from non-Main River sources.

The mapping within this SWMP (Figures D-9 – D18 in Appendix D) shows some areas that are vulnerable to extensive deep accumulations of water (>0.5m), these area have a high certainty of flooding during extreme storms and the damage occurring is likely to be significant. The mapping also shows some small areas of potentially deep (>0.5m), these area may have particular risks associated with them, but may also occur due to irregularities in mapping and modelling. The mapping also shows areas shallower flooding (<0.5m), some isolated and some more extensive flooding. Maps show general flow directions and approximate velocities (in the form of ‘hazard’ maps) as even relatively shallow water flowing a high velocities can be a threat to life and can cause damage.

For most boroughs the production of this SWMP will be a significant addition of new/updated data. Therefore, in due course, this should trigger a review of the SFRA. The SFRA should consider these risks in the following ways:

- Large areas of deep (>0.5m) flooding should be shown as Local Flood Risk Zones, unless there is evidence to suggest that these risk have been mitigated, for example by high capacity drainage or pumping infrastructure.
- Small, isolated areas of deep (>0.5m) flooding should be investigated to determine how likely they are to be at flood risk but do not need to be shown if there is no significant risk.
- Large areas of shallower flooding should be identified as Local Flood Risk Zones if they pose a significant risk, but do not need to be shown if the risks are relatively minor.
- Smaller isolated areas of shallower flooding should generally not be identified as Local Flood Risk Zones, unless there is a particular significant risk associated with that area, as it must be expected that most areas will be affected to some extent by rainwater.
- Routes of fast flowing water may be considered as Local Flood Risk Zones if they pose a significant risk.
- Areas of Increased Potential for Elevated Groundwater, should be shown where they are likely to pose a significant risk of flooding or where they are likely to affect the nature of future development, especially for the design and use of sub-surface spaces.

Identifying an area as a Local Flood Risk Zone, should mean that it is then be treated in a similar way to Environment Agency Flood Zone 3, namely that a Flood Risk Assessment is required and measures should be taken to reduce the likelihood and impact of any flooding.

Where a Critical Drainage Area contributes significant amounts of surface water to a Local Flood Risk Zone, the SFRA should identify this and suggest strict application of sustainable drainage measures in line with the London Plan Sustainable Drainage Hierarchy.

Using the SWMP to update policies in Development Plan Documents

Ideally the review of the borough SFRA should be a pre-cursor to any significant change to the Core Strategy and development control policies. Therefore reference to the SFRA should automatically update the approach to local flood risks. Where the SFRA has not been updated, the review of Development Plan Documents should consider the same steps outlined above for the SFRA review.

Using the SWMP to influence major areas of redevelopment

Where major development areas are proposed, either in the London Plan or within the Core Strategy DPD, these should be examined for:

- Local Flood Risk Zones that affects the area
- Increased Potential for Elevated Groundwater
- Contribution of run-off to Local Flood Risk Zones beyond the actual redevelopment area.

Given the large scale of major developments, it is unlikely that the Local Flood Risk would prevent redevelopment taking place, but it may affect the location, uses, design and resilience of the proposals. Therefore, a Flood Risk Assessment needs to be undertaken and it should consider:

- the location of different types of land use within the site(s)
- the layout and design of buildings and spaces to take account of flood risk, for example by dedicating particular flow routes or flood storage areas
- measures to reduce the impact of any flood, through flood resistance/resilience measures/materials
- incorporating sustainable drainage and rainwater storage to reduce run-off to adjacent areas
- linkages or joint approaches for groups of sites, possibly including those in surrounding areas

Using the SWMP to influence specific development proposals

Where development is proposed in an area covered wholly or partially by a Local Flood Risk Zone, this should trigger a Flood Risk Assessment, as already required under PPS25.

Whilst some small scale developments may not be appropriate in high risk areas, in most cases it will be a matter of ensuring that the Flood Risk Assessment consider those items listed under major developments above and also considers some or all of the following site specific issues:

- Are the flow paths and areas of ponding correct, and will these be altered by the proposed development?
- Has the site been planned sequentially to keep major surface water flow paths clear?
- Has exceedance of the site's drainage capacity been adequately dealt with? Where will exceedance flows run off the site?
- Could there be benefits to existing properties at risk downstream of the site if additional storage could be provided on the site?
- In the event of surface water flooding to the site, have safe access to / egress from the site been adequately considered.
- Have the site levels been altered, or will they be altered during development? Consider how this will impact surface water flood risk on the site and to adjacent areas.
- Have inter-dependencies between utilities and the development been considered? (for example, the electricity supply for building lifts or water pumps)

Specific Locational Considerations

Within the London Borough of Brent, the following major redevelopment areas have already been identified.

Opportunity Area	Relevant Boroughs
Cricklewood/Brent Cross	Barnet Brent
Park Royal/Willesden Junction	Brent Ealing Hammersmith & Fulham
Wembley	Brent

Table G-1 Summary of major redevelopment areas in LBB

Mapping Checklist

The table below indicates the SWMP maps which are of potential use to spatial planning, and indicates which maps may be suitable for replacing existing SFRA maps:

Issue	SWMP maps	Consider replacing existing SFRA maps?
Surface water flood risk	D-9 – D-18 (Appendix D)	Yes – more detailed methodology to that used for the SFRA.
Increased potential for elevated groundwater	Figure 3-3 (vol 2)	Yes – more detailed methodology to that used for the SFRA.
Infiltration SUDs suitability map	D.7 (Appendix D)	Yes – provides a consistent initial infiltration SUDs screening process for all London Boroughs, but does not replace on-site assessments.
Recorded incidents of sewer flooding	D.5 (Appendix D)	Yes – similar method (based on postcode sector) but brings the records up-to-date to June 2010.

Table G-2 SWMP maps of potential use to spatial planners

Appendix H – Resilience Forum and Emergency Planner Information Pack

Background

Presently, surface water flooding is less well understood than other sources of flooding, partly because surface water events tend to happen and disperse quickly meaning that there is a lack of accurate and consistent records and partly because they are not tied to readily identifiable features such as rivers or the sea. Therefore this SWMP offers an opportunity to communicate up to date information about locations at risk from surface water flooding to those with an interest. Responses in an emergency will be informed by known surface water flooding locations, especially near public buildings and major transport routes and important infrastructure.

The purpose of this information pack is to assist in communicating surface water flood risk to the London Local Resilience Forum, and Emergency Planners within the London Resilience Partnership to enable them to ensure that incident management plans are updated based on the improved understanding of surface water flooding. SWMP mapping outputs and knowledge will be used to:

- Update Community Risk Registers (CRR);
- Update Multi-Agency Flood Plans (MAFP).

This pack is presented as a Frequently Asked Questions (FAQ) document and contains information that addresses the following points:

1. How can SWMP outputs improve Community Risk Registers?
2. How can SWMP outputs improve Multi-Agency Flood Planning?
3. How do SWMP outputs compliment the Flood Forecasting Centre's Extreme Rainfall Alert (ERA)?
4. Examples of Good Practice

In updating Multi-Agency Flood Plans, as well as the neighbouring boroughs, LBB also have a responsibility to partner with other key stakeholders and risk management authorities, who share the responsibility for decisions and actions. Ideally, the informal relationships established within the context of the Drain London programme should be formalised to ensure clear lines of communication and continued mutual cooperation through the development of a Memorandum of Understanding. This should include appropriate aspects for Surface Water Flood Risk Management.

The Environment Agency has proposed Strategic Flood Risk Management Boards within Greater London to coordinate local Flood Risk Management. LBB will form part of the West London FRMP with the surrounding London Boroughs of Harrow, Barnet, Ealing, Hillingdon and Hounslow. The following list outlines the purpose of setting up this Group:

- To develop a collective understanding of flood risk across North West London,
- to discuss and help Boroughs with the LLFA requirements,
- to share best practice and develop resources within the North West,

- to provide the framework for management of flooding across the area and to identify how to communicate risks and responsibilities to the communities within the area – promoting the concepts of personal responsibility and the Big Society,
- to potentially develop a common approach to IT, GIS Systems and the management of asset registers across the North West,
- to identify opportunities for resource sharing (for example to potentially assist with the emerging requirements (over 2011/12) for the format and scope of the SUDS Approval Body),
- to track and help to reduce the risks and consequences across the catchment, and
- to identify annually, a short list of schemes, agreed by the Partnership to submit to the Regional Flood Defence Committee (RFDC) seeking EA levy monies to assist delivery (individual Boroughs can also pursue funding requests for other projects as part of their LLFA duties).

1. How can SWMP outputs improve Community Risk Registers?

Community Risk Registers (CRR) are prepared by Category 1 responders and are required as part of the Civil Contingencies Act (CCA) 2004. The CCA requires that Category 1 responders undertake risk assessments and maintain these risks in a CCR. In this context risks are defined as events which could result in major consequences, and they include risks from flooding.

Outputs from SWMP can be used to reduce the uncertainties associated with assessing the likelihood and impact of surface water flooding (see Community Risk Register HL18 for more information on current risk assessment). SWMP presents an opportunity for the identification of vulnerable sites and populations which may be at increased risk, and allows for risk-based prevention or mitigation actions to be taken.

2. How can SWMP outputs improve Multi-Agency Flood Plans?

Multi-Agency Flood Plans (MAFP) are specific emergency plans which should be developed by LRFs, to deliver a coordinated plan to respond to flood incidents. MAFPs recognise the need for specific flooding emergency plans, due to the complex nature of flooding and the consequences that arise. Guidance on producing a MAFP is available at http://www.ukresilience.gov.uk/media/ukresilience/assets/flooding_ma_planning_guidance_0208.pdf.

Outputs from SWMPs should inform the development of, or update, the MAFP.

The SWMP surface water mapping should be used as an initial indicator of a possible risk. A Flood Risk Assessment at a site shown as being at risk of surface water flooding should consider:

- Impacts on flood receptor sites
- The degree of receptor vulnerability
- In the event of surface water flooding to the site, has safe access to / egress from the site been adequately considered?

The table below indicates the SWMP maps which are of potential use to emergency planning, and indicates which maps may be suitable for updating existing MAFP maps:

Issue	SWMP maps	Consider updating existing MAFP maps?
Surface water flood risk	D.9– D.18 (Appendix D)	Yes – more detailed methodology to that used for the MAFP.
Increased potential for elevated groundwater	3.3 (vol 2)	Yes – more detailed methodology to that used for the MAFP.

Table H-1 SWMP maps of potential use to emergency planners

3. How do SWMP outputs compliment the Flood Forecasting Centre's Extreme Rainfall Alert (ERA)?

In 2008 the Met Office and the Environment Agency set up the Flood Forecasting Centre to provide services to emergency and professional partners. The Flood Forecasting Centre provides an Extreme Rainfall Alert (ERA) service to Category 1 and Category 2 responders. The ERA is issued at county level and is used to forecast and warn for extreme rainfall that could lead to surface water flooding, particularly in urban areas. It is designed to help local response organisations manage the impact of flooding via two products:

Guidance – issued when there is a 10% or greater chance or extreme rainfall;

Alert – issued when there is a greater than 20% chance of extreme rainfall.

The ERA cannot provide site-specific real-time surface water flood forecast, but does offer a county level alert of impending rainfall. The alert is based on the probability of rainfall occurring, rather than being a definitive forecast.

Surface water flooding has very short lead times and is hard to predict in real time because local topography and drainage infrastructure affect the direction of runoff and location of flooding. However, the assessment carried out as part of this SWMP study has taken an important step towards the likely flow pathways and locations of ponding of surface water. Used in parallel with the ERA, this can be used to improve emergency planning and responses for surface water flooding events.

4. Examples of Good Practice for Emergency Planners

Ensure that a programme of engagement on flood risk awareness is initiated within the Borough. Meet with key corporate communications teams to agree an approach to social change, education and awareness raising in line with the needs of the Borough.

Build trust - Public and stakeholder trust in authorities through **long term, transparent engagement.**

- Ensure there are key messages in the that encourage attitude and behaviour change with the public. This will help to address misconceptions that flooding results from a failure on someone's part.
- Educate the public to help them better understand where responsibilities lie, changes they can make to their own lifestyles, and actions they can take to physically reduce personal flood risk.
- Encourage communities towards creating their own community action/response plans to support wider ownership of risk and responsibilities

- Consider holding face to face interviews with at -risk families and groups to better inform your Community Risk Register. This will help both you and them to better understand risk and plan to manage it.
- Establish a **common baseline for flood data** and information in line with EA requirements. Set up a Borough '**One-Stop Shop'** to enable efficient information consolidation and data sharing. This will support efficient planning and updating of the MAFP.
- **Develop a surface water flooding response plan with vulnerable receptors as external partners**. Vulnerable receptors could include hospitals, schools and care homes. Identify these through Emergency Planning and other relevant forums and build into stakeholder engagement. This will assist with prioritisation decisions. For example 'early warning' processes, appropriate measures, funding and resourcing.
- Link the actions from the SWMP directly to the **Flood Risk Management Strategy** for the Borough such that a programme of work is visible.
- Link with the Planning Department's **Strategic Flood Risk Assessment** (SRFA) to ensure that Emergency Planners are involved in land use decisions for new development.
- Create a key facts and 'what to do' section for surface water flooding in **emergency handbooks**. Provide easy- to- reach contact points, and regularly update your website
- Work with other agencies, such as the **Environment Agency flood alert/warning schemes**, in the interests of cost effectiveness and good communication - but still own the responsibility for your borough. Use others' information to reinforce your own process.

Appendix I – Action Plan

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