Three Rivers District Council Strategic Flood Risk Assessment for Flood Risk Sites

Document: 3 Version: C

Three Rivers District Council

20 November 2012

Halcrow

Three Rivers District Council Strategic Flood Risk Assessment for Flood Risk Sites

Three Rivers District Council

20 November 2012

Halcrow Group Limited
Griffin House, 135 High Street, Crawley
West Sussex RH10 1DQ
tel 01293 434500 fax 01293 434599
halcrow.com

Halcrow

Halcrow Group Limited
Griffin House, 135 High Street, Crawley
West Sussex RH10 1DQ
tel 01293 434500 fax 01293 434599
halcrow.com

Document history

Three Rivers District Council Strategic Flood Risk Assessment for Flood Risk Sites

Three Rivers District Council

This document has been issued and amended as follows:

Version	Date	Description	Created by	Verified by	Approved by
1.A	30/08/11	Draft	Alexandra Seawell	Bruno Venturini	Bruno Venturini
1.B	05/09/11	Draft, with breaches	Alexandra Seawell	Bruno Venturini	Bruno Venturini
2.A	03/01/12	Amendment for EA comments	Alexandra Seawell	Bruno Venturini	Bruno Venturini
2.B	12/01/12	Minor changes to report and figure size	Alexandra Seawell	Bruno Venturini	Bruno Venturini
3.B	15/08/12	Inclusion of River Gade modelling	Alexandra Seawell	Dan Stansfield	Imran Bukhari
3C	20/11/12	Inclusion of comments in response to EA review. Inclusion of client comments.	Alexandra Seawell	Dan Stansfield	Imran Bukhari

This page has been left intentionally blank.

Contents

Maps

Tables

Figures

Appendices

1 Introduction

1.1 Scope of report

This Strategic Flood Risk Assessment (SFRA) has been compiled to provide Three Rivers District Council with a further detailed flood risk evidence base to support its LDF plan-making process in respect to 17 potential development sites which lie within flood risk areas. The sites have been assessed to a Level 2 SFRA standard, with the exception of five sites for which this was not necessary, which corresponds to an 'increased scope' SFRA compared to a typical Level 1 SFRA. Its principal purpose is to facilitate (and if possible avoid by effective allocation of land uses within a site) the application of the Exception Test. The assessment for each site therefore contains detailed analysis of flood risk information and based on this provides recommendations for managing flood risk and potential measures to avoid the need for the Exception Test.

The sites analysed in this SFRA are indicated in **Map 1**.

1.2 The Study Area

1.2.1 The Three Rivers and the Grand Union Canal

The Three Rivers District Council area is located in the county of Hertfordshire to the north-west of London. It derives its name from the three main rivers which run through it; the River Chess in the west of the District, the River Gade in the north-east and the River Colne in the south-east (see **Map 1**). The three rivers meet in the town of Rickmansworth in the south of the District and then continue flowing south, as the River Colne, to join the River Thames. In addition to the three main rivers, the Grand Union Canal runs through the District beside the River Gade and then the lower River Colne.

1.2.2 The District Topography and level of Urbanisation

The topography of the District, based on the available 1m grid resolution Light Detection and Ranging data (LiDAR data, using laser technology from airplanes) indicates that the sites are located within the river valleys and therefore are at low topography relative to their surrounding area.

The District is fairly urbanised with the main settlements being Rickmansworth, Chorleywood, Abbots Langley and South Oxhey (see **Map 1**). However, the north-west of the District remains relatively rural.

1.2.3 The District Geology and Aquifers

The geology of the District is shown in **Map 2**. The majority of the District is underlain by Chalk bedrock, which is normally highly permeable, and is denoted by the Environment Agency as a Principal Aquifer due to its high water-bearing potential for water supply. Areas of the north-east of the District (around Abbots Langley), to the north-east and south-west of Chorleywood, and in the south-east of the District (south of the River Colne) are underlain by Lambeth Group geology, which is generally reasonably permeable, denoted as a Secondary Aquifer; these may have water-bearing potential on a local scale. The far south-east of the District

however is underlain by low permeability London Clay which is not classified as an aquifer and normally acts to prevent the flow of groundwater.

On top of the bedrock, there is a variety of superficial deposits. Most, such as the Alluvium along the river paths, and the Sand and Gravel scattered across most of the District, is reasonably permeable (Secondary Aquifers). However, there are low permeability deposits in various locations; the far north-east and north-west of the District and some of the valleys leading onto the main rivers.

Some of the aquifers are in use for public drinking water supply. Where this occurs, the area surrounding the water supply borehole is designated as a groundwater source protection zone (SPZ) in order to prevent pollution reaching the borehole. The zones are defined as follows:

- the inner protection zone (Zone 1) indicates areas from where pollution can travel to the groundwater source within 50 days or is at least a 50m radius;
- the outer protection zone (Zone 2) indicates areas from where pollution can travel to the groundwater source within 400 days or lies within the nearest 25% of the total catchment area (whichever is largest);
- the total catchment (Zone 3) indicates the total area needed to support removal/discharge of water from the groundwater source;
- a fourth zone is sometimes also defined when local conditions mean that pollution could affect the groundwater source even though it is outside the normal catchment area.

The SPZ are shown in **Map 3**.

2 Data Collection and Methodology

2.1 Data collection

A Level 1 SFRA was carried out for the whole Three Rivers District Council area, in partnership with the neighbouring areas of Dacorum Borough, St Albans District and Watford Borough. The previous SFRA contains a range of data which remains relevant for this SFRA, but as it was carried out in 2007, further data has been requested for this SFRA. This includes the latest versions of data used in the previous SFRA (updated for the proposed sites only), such as flood zones, and additional data which had not been available at the time of the previous SFRA, such as surface water modelling. Further relevant information has been sourced from relevant documents such as site specific Flood Risk Assessments (FRAs) and Catchment Flood Management Plans (CFMPs).

A complete list of the data collected for this SFRA is included in **Appendix A.**

2.2 Modelling data

Various modelling and mapping project outputs have been used to assess fluvial, surface water and groundwater flood risk. Within Three Rivers District, the data available at the start of this project included the Fluvial Flood Zones (see **Section 2.2.1**), Hazard Mapping, Flood Depths and Flow Velocities (see **Section 2.2.2**), the Areas Susceptible to Groundwater Flooding Map (AStGWF, see **Section 2.2.3**), the Areas Susceptible to Surface Water Flooding (AStSWF, see **Section 2.2.4**), and the Flood Map for Surface Water (FMfSW, see **Section 2.2.5**). Two further modelling studies were carried out for the purpose of this Level 2 SFRA; modelling of breaches at selected locations in Rickmansworth (see **Section 2.2.6**) and flood modelling along the River Gade in Kings Langley.

2.2.1 Fluvial Flood Zones

Flood zones are used to define the risk of fluvial and tidal flooding and, in accordance with the National Planning Policy Framework (NPPF) (which superseded Planning Policy Statement 25 (PPS25) in March 2012), are defined as:

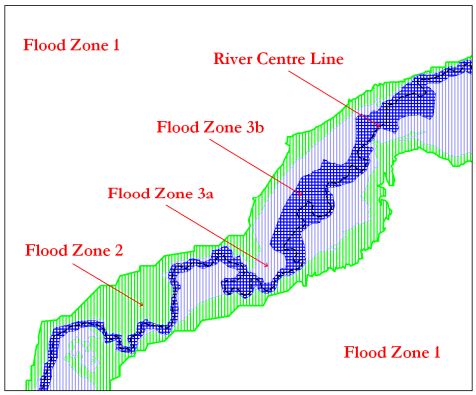


Figure 2-1: Schematic of Flood Zones

- Flood Zone 1 (Low Probability) - this flood zone comprises land assessed as having a less than 1 in 1000 annual probability of river or sea flooding in any year (<0.1%).
- Flood Zone 2 (Medium Probability) - this flood zone comprises land assessed as having between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% - 0.1%) or between a 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5% - 0.1%) in any year.

- Flood Zone 3a (High Probability) - this flood zone comprises land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%), or a 1 in 200 or greater annual probability of flooding from the sea (0.5%) in any year.
- Flood Zone 3b (The Functional Floodplain) - this flood zone comprises land where water has to flow or be stored in times of flood. Local Planning Authorities should identify in their SFRAs areas of functional floodplain and its boundaries accordingly, in agreement with the Environment Agency. The identification of functional floodplain should take account of local circumstances and not be defined solely on rigid probability parameters. But land which would flood with an annual probability of 1 in 20 (5%) or greater in any year, or is designed to flood in an extreme (0.1%) flood, should provide a starting point for consideration and discussions to identify the functional floodplain.

Flood Zone 3 is equal to the combined Flood Zone 3a and 3b area.

Three Rivers District is sufficiently far inland that it does not experience tidal flooding.

Flood Zones 2 and 3 have been created by studying historic floods and by undertaking hydraulic modelling with the creation of undefended (not taking account of defences, see further details below) flood extents for the 1 in 100 and 1 in 1000 year scenarios. The Flood Zones are available from the Environment Agency's national Flood Map. This was originally created following the requirement in PPG25 (the predecessor of PPS25) for the Environment Agency to produce maps showing the predicted extent of tidal and fluvial flood zones for all Main Rivers in England and Wales.

The original mapping was carried out using JFlow software, and was based on a fairly course digital terrain model of 5m resolution resulting in significant inaccuracies. However, since then, detailed modelling on specific river catchments has been used to update the relevant sections of the Flood Map. Within Three Rivers District, detailed modelling has been carried out along the River Colne and the lower reaches of the River Chess and River Gade (up to the upstream face of the M25 Motorway and to Cassiobury Park in Croxley, respectively). This was carried out as part of the Upper Colne SFRM Study (TH013 and TH031) Hydraulic Modelling and Mapping (Halcrow, 2010). The 1 in 100 year and 1 in 1000 year extents from the project have been used to update the Environment Agency Flood Zones 3 and 2, respectively.

Where detailed modelling exists it may also include other scenarios of interest. The River Colne modelling includes the 1 in 20 year for present day, which has been used to estimate Flood Zone 3b, and the 1 in 100 year taking account of climate change, which has been used to estimate Flood Zone 3a in 2070 and 2115. The climate change estimates give an indication of flood risk over the life span of proposed development, with year 2070 representing the anticipated life span of commercial property, and year 2115 representing the anticipated life span of residential property. The effect of climate change on flood extents and peak water levels and peak flows along the river and floodplain has been estimated by increasing catchment flows by 20% - this is applicable to both 2070 and 2115 in accordance with the NPPF climate change table, which is reproduced in **Table 2-1**:

Table 2-1: Recommended national precautionary sensitivity ranges (from the NPPF, table 5)

Parameter	1990 to 2025	2025 to 2055	2055 to 2085	2085 to 2115
Peak rainfall intensity	+5%	+10%	+20%	+30%
Peak river flow	+10%	+20%		
Offshore wind speed	+5%		+10%	
Extreme wave height	+5%		+10%	

Detailed modelling can be undertaken with or without taking account of defences. Modelling without defences is, for example, undertaken by removing from the model any raised river banks - as if these did not exist. This approach is important as it shows what would happen if no maintenance was undertaken so that in the long term the defences would no longer function. The Flood Zones are based on this conservative assumption and are used for spatial planning for the allocation of land uses at district scale and within a site.

As mentioned above, Flood Zone 3b or the functional floodplain has been estimated from detailed modelling by using the 1 in 20 year defended (taking account of defences) model for present day. This is a typical flood event that is used for representing the functional floodplain.

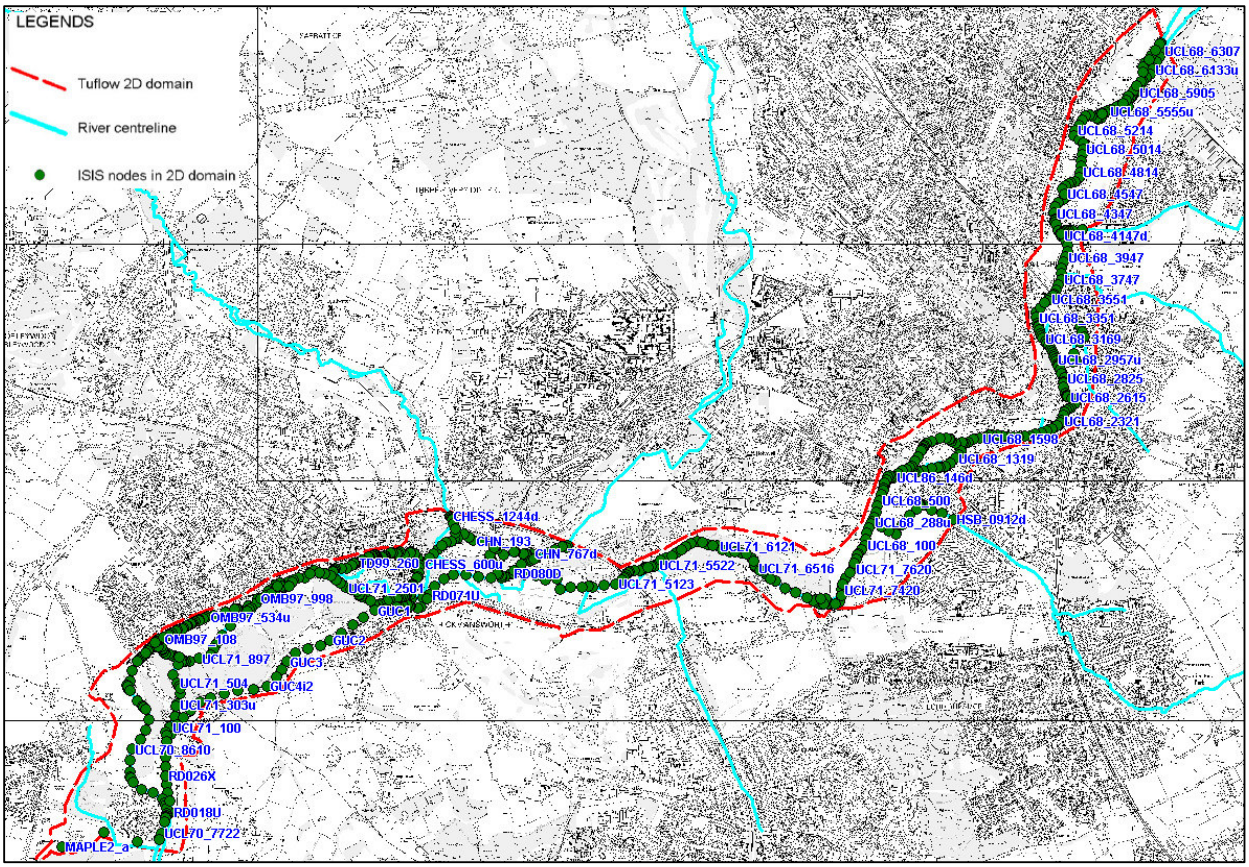
The Areas Benefiting from Defences (ABDs) is the difference in flood extents between the 1 in 100 year flood event with and without defences. The ABD therefore shows those areas which would flood if the defence was not in place under the 1 in 100 year flood event present day (not taking account of climate change).

Within Kings Langley, the Environment Agency Flood Map remains based on the JFlow modelling, which is insufficient for the purpose of this Level 2 SFRA. Therefore new modelling work has been carried out as part of this SFRA to obtain more detailed and accurate results for the River Gade and adjoining watercourses in this area. The modelling work included a 1 in 100 and 1 in 1000 year scenario which have been used instead of the Environment Agency Flood Map for assessing the Kings Langley potential development sites. Likewise, the modelled 1 in 20 year scenario has been used to represent the functional floodplain and the 1 in 100 year with climate change scenario to represent Flood Zone 3a in 2070 and 2115. As there are no raised defences in the modelling domain, the defended and undefended scenario are the same.

2.2.2 Hazard mapping, Flood Depths and Flow Velocities

At locations where 2-dimensional (2d) hydraulic modelling has been undertaken, 2d outputs in the form of hazard mapping, flood depths and flow velocities are available. This is the case for a stretch of the River Colne and short lengths of the River Chess and Gade, based on the latest Environment Agency flood mapping study (see **Figure 2-2**). The software used is iSIS-TuFlow, where iSIS has been used for modelling the in-bank (1d) elements of the river system and TuFlow has been used for the floodplain (2d).

Figure 2-2: River Colne Tuflow modelling domain



For the new River Gade modelling, based on the results from the 1D model for the 1000 year return period event, it was not necessary to develop a 2d Tuflow model of the floodplain as none of the development areas were shown to be at risk of fluvial flooding. The lack of flooding means there are no hazard, depth or velocity maps for the Kings Langley sites.

Flood hazard is used to give an indication of the risk to life posed by flood water. The severity of flood hazard depends on the water depth and velocity, along with an additional degree of hazard from debris in the water. This reflects the danger to a person from a combination of deep and fast flowing water. The combination is important since if, for example, the water is fairly deep but not flowing a person may normally still be able to walk safely through it. However, in very deep water a person would find walking difficult or may even be unable to keep their head above water, at which point the level of risk greatly increases. Conversely, shallow but fast flowing water may be able to unbalance a person and thus also pose a danger. Depending on the flood hazard value calculated, the severity of the hazard is indicated by the class into which the value falls (see **Table 2-2**):

Table 2-2: Flood hazard classification

Flood hazard rating	Hazard to People Classification
Less than 0.75	Very low hazard – Caution
0.75 to 1.25	'Danger for some' – includes children, the elderly and the infirm
1.25 to 2.0	'Danger for most' – includes the general public
More than 2.0	'Danger for all' – includes the emergency services

2.2.3 Areas Susceptible to Groundwater Flooding Map

The Areas Susceptible to Groundwater Flooding Map (AStGWF) was produced by the Environment Agency to assist Lead Local Flood Authorities (LLFAs) in predicting groundwater flood risk for their Preliminary Flood Risk Assessments under the Flood Risk Regulations 2009. The maps are provided as 1km grid squares, each of which is attributed with an estimate of the proportion of its area which is susceptible to groundwater flooding. The susceptibility is based on a consideration of where geological and groundwater conditions suggest that groundwater might emerge. The grid squares also indicate the aquifer source of flooding as either consolidated, such as chalk, sandstone etc. which is termed 'clearwater', or from superficial deposits, such as alluvium or river terrace gravels. It is important to note that while the AStGWF map indicates areas where groundwater flooding may occur, it does not give an indication of the likelihood of that flooding occurring. The Environment Agency recommend that unless the area identified as susceptible to groundwater flooding is also identified as at risk from surface water flooding, it is unlikely that the location would experience groundwater flooding of any appreciable depth. The AStGWF is shown in **Map 4**.

2.2.4 Areas Susceptible to Surface Water Flooding

A national modelling project was carried out by the Environment Agency to assess the risk from surface water flooding. The results were released in July 2009 as the 'Areas Susceptible to Surface Water Flooding' (AStSWF) maps. The mapping covers the entire country and gives an indication of flooding during a 6.5 hour duration 1 in 200 annual probability event. The output flooded areas are graded into areas which are 'less', 'intermediate' and 'more' likely to be susceptible to surface water flooding – for example the 'more' grade indicates areas which are likely to flood first, flood deepest, and/or flood for relatively frequent, less extreme events. The modelling did not take either buildings or drainage systems into account and therefore tends to be less accurate for relatively flat areas where buildings and drainage have a more significant effect. The modelling is fairly course and therefore it should not be considered against any more detailed background mapping than 1:50,000 or used to identify individual property flooding. As the results are indicative they should not be relied upon solely to represent surface water flood risk, but should be compared against local information and knowledge. The AStSWF is shown in **Map 5**.

2.2.5 Flood Map for Surface Water

The Environment Agency's second generation of surface water modelling was released in November 2010 as the 'Flood Map for Surface Water' (FMfSW). In most areas it offers an improvement over the AStSWF map since it takes buildings into account and makes some allowance for infiltration and sewer capacity. Two scenarios are considered; a 1 in 30 and 1 in 200 annual probability event. For each scenario there are two flooding outlines; a 'shallow' flooding outline showing the areas that experience greater than 0.1m depth and a 'deep' flooding outline showing the areas that experience greater than 0.3m depth. The 0.3m depth was chosen as being important since it is about the depth at which it becomes more difficult to walk or drive through the water and is also, for many buildings, the point at which water reaches over the threshold and begins internal flooding. The 0.1m depth was chosen simply as a threshold to define 'real' flooding; below this depth apparent flooding may just be model instability. The FMfSW was also carried out at a greater level of detail and may be viewed against 1:10,000 background mapping, however, it remains indicative and should be compared against local information and knowledge. The FMfSW is shown in **Map 6**.

2.2.6 Improved Flood Map for Surface Water

The Environment Agency are planning to finalise the third generation of surface water modelling and flood maps by December 2013. The new Improved national surface water floodmaps will be derived from more local and robust model parameters, providing enhanced certainty about the areas at risk from deep or fast flowing surface water flooding. The new flood modelling will also result in model outputs that meet the requirements of Flood Risk Regulations 2009, which will include grids of velocity, depth and hazard for all England and Wales. However, it should be noted that once released the national flood maps will remain indicative and should be compared against local information and knowledge.

2.2.7 Breach Modelling

Breach modelling has been undertaken for the Depot (Harefield Road, Rickmansworth), Froghall Farm (Maple Cross) and Maple Lodge (Maple Cross).

Breaches have been selected for these sites to better understand the distribution of residual flood risk within flood zones. It is defined as residual flood risk as this type of flooding would occur only if maintenance was not adequate and resulted in failure of the flood infrastructure during or prior to a flood event occurring.

The breach model runs and outputs produced are summarised in **Table 2-3a to 2-3c** below:

Table 2-3a: Breach modelling scenarios for the Depot, Harefield Road

Breach type for the Depot, Harefield Road	Mapped output used	Comment
Breach during the 1 in 100 year event	Breach not required (see comment)	Water remains in-bank for this event such that little pressure is applied to the raised embankment hence it is unlikely to cause a breach
Breach during the 1 in 100 year event plus climate change for year 2070	Figure 16.2 Figure 16.3	As the embankment is small in height the results are almost identical to overtopping outputs without breaching
Breach during the 1 in 100 year event plus climate change event for year 2115	Figure 16.2 Figure 16.3	Climate change results for year 2115 are the same as for year 2070
Breach during the 1 in 1000 year event	Figure 16.1 (outer layer of Flood Zone 2)	Flood Zone 2 represents a region of flooding between the 1 in 100 year and the 1 in 1000 year events. As the embankment is small in height the results are almost identical to overtopping outputs without breaching

Table 2-3b: Breach modelling scenarios for Froghall Farm

Breach type for Froghall Farm	**Mapped output used**	**Comment**
Breach during the 1 in 100 year event	Figure 18.1 (outer layer of Flood Zone 3)	The extents of Flood Zone 3b and 3a are similar due to the topography of the site and therefore also the extents as a result of a breach for this event
Breach during the 1 in 100 year event plus climate change for year 2070	Figure 18.3 Figure 18.5	Based on breach modelling undertaken as part of this study.
Breach during the 1 in 100 year event plus climate change event for year 2115	Figure 18.3 Figure 18.5	Climate change results for year 2115 are the same as for year 2070
Breach during the 1 in 1000 year event	Figure 18.1 (outer layer of Flood Zone 2)	Flood Zone 2 represents a region of flooding between the 1 in 100 year and the 1 in 1000 year events. The extents of Flood Zone 3 and 2 are similar due to the topography of the site and therefore also the extents as a result of a breach for this event.

Table 2-3c: Breach modelling scenarios for Maple Lodge

Breach type for Maple Lodge	Mapped output used	Comment
Breach during the 1 in 100 year event	None	No flooding as a result of a breach as Flood Zone 3 does not reach the site.
Breach during the 1 in 100 year event plus climate change for year 2070	Figure 19.2 Figure 19.3	Based on breach modelling undertaken as part of this study.
Breach during the 1 in 100 year event plus climate change event for year 2115	Figure 19.2 Figure 19.3	Climate change results for year 2115 are the same as for year 2070
Breach during the 1 in 1000 year event	Figure 19.1 (outer layer of Flood Zone 2)	Flood Zone 2 represents a region of flooding between the 1 in 100 year and the 1 in 1000 year events.

2.3 The NPPF vulnerability classification

In allocating development to proposed sites, it is vital to take into account the acceptable land uses in accordance with the NPPF. The NPPF provides an overview of the types of land use which are acceptable within each flood risk zone, depending on the vulnerability of the associated activities and people. This SFRA focuses specifically on sites where the proposed land use is only acceptable in the flood risk zone(s) present on site if the Exception Test is passed. The Exception Test provides a means whereby land uses of higher vulnerability may be placed in higher risk flood zones provided the following criteria are passed:

a) *It must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk, informed by a Strategic Flood Risk Assessment where one has been prepared; and;*

b) *A site-specific flood risk assessment must demonstrate that the development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall*

The Exception Test may be applied for the combinations of flood zone and land use vulnerability shown in **Table 2-4**.

Table 2-4: Flood Risk Vulnerability and Flood Zone Compatibility (from the NPPF Technical Guidance, Table 3)

	Essential Infrastructure	Water Compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Zone 1	✓	✓	✓	✓	✓
Zone 2	✓	✓	Exception Test required	✓	✓
Zone 3a	Exception Test required	✓	X	Exception Test required	✓
Zone 3b (functional floodplain)	Exception Test required	✓	X	X	X

The types of land use which correspond to each vulnerability classification are shown in **Table 2-5**.

Table 2-5: Flood Risk Vulnerability Classification (from the NPPF Technical Guidance, Table 2)

Classification	Land uses *Note: Buildings that combine a mixture of uses should be placed into the higher of the relevant classes of flood risk sensitivity.*
Essential Infrastructure	• Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk. • Essential utility infrastructure which has to be located in a flood risk area for operational reasons, including electricity generating power stations and grid and primary substations; and water treatment works that need to remain operational in times of flood. • Wind turbines
Highly Vulnerable	• Police stations, Ambulance stations and Fire stations and Command Centres and telecommunications installations required to be operational during flooding. • Emergency dispersal points. • Basement dwellings. • Caravans, mobile homes and park homes intended for permanent residential use. • Installations requiring hazardous substances consent. (Where there is a demonstrable need to locate such installations for bulk storage of materials with port or other similar facilities, or such installations with energy infrastructure or carbon capture and storage installations, that require coastal or water-side locations, or need to be located in other high flood risk areas, in these instances the facilities should be classified as 'Essential Infrastructure'.
More Vulnerable	• Hospitals. • Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels. • Buildings used for: dwelling houses; student halls of residence; drinking establishments; nightclubs; and hotels. • Non-residential uses for health services, nurseries and educational establishments. • Landfill and sites used for waste management facilities for hazardous waste. • Sites used for holiday or short-let caravans and camping, **subject to a specific warning and evacuation plan**.

Less Vulnerable	• Police, ambulance and fire stations which are **not** required to be operational during flooding. • Buildings use for: shops; financial; professional and other services; restaurants and cafes; hot food takeaways; offices; general industry; storage and distribution; non-residential institutions not included in 'more vulnerable'; and assembly and leisure. • Land and buildings used for agriculture and forestry. • Waste treatment (except landfill and hazardous waste facilities). • Minerals working and processing (except for sand and gravel working). • Water treatment works which do **not** need to remain operational during times of flood. • Sewage treatment works (if adequate measures to control pollution and manage sewage during flooding events are in place).
Water Compatible	• Flood control infrastructure. • Water transmission infrastructure and pumping stations. • Sewage transmission infrastructure and pumping stations. • Sand and gravel workings. • Docks, marinas and wharves. • Navigation facilities. • MOD defence installations. • Ship building, repairing and dismantling, dockside fish processing and refrigeration and compatible activities requiring a waterside location. • Water-based recreation (excluding sleeping accommodation). • Lifeguard and coastguard stations. • Amenity open space, nature conservation and biodiversity, outdoor sports and recreation and essential facilities such as changing rooms. • Essential ancillary sleeping or residential accommodation for staff required by uses in this category, **subject to a specific warning and evacuation plan**.

2.4 Catchment Flood Management Plans

Catchment Flood Management Plans (CFMPs) are strategic planning tools through which the Environment Agency seeks to work with other key decision-makers within a river catchment, such as the Local Planning Authority, to identify and agree policies for sustainable flood risk management. The main aims of CFMPs are to:

- understand the factors that contribute to flood risk within a catchment, such as how the land is used, and
- recommend the best ways to manage the risk of flooding within the catchment over the next 50 to 100 years.

Three Rivers District lies within the Thames CFMP region, for which the latest version was completed in July 2008. The Environment Agency website contains a Summary Report (released December 2009) which is available on the Environment Agency website (http://www.environment-agency.gov.uk/research/planning/114391.aspx). The full report was obtained from the Environment Agency for this SFRA to obtain the details on the policies affecting the SFRA sites. Development of these sites will need to take the CFMP policies into account since they will influence the level of flood protection available. For example whether it is planned to maintain the defences in their current form, whether alternative flood risk management methods, such as through land use planning or by altering the river morphology, will be introduced, or in some cases, whether a particular area may be allowed to become subject to an increased level of flood risk in

order to reduce flood risk to the catchment as a whole. Furthermore, the sites in their turn could adversely affect flood management elsewhere if not consistent with the policies (e.g. if they cause loss of floodplain storage upon which other areas rely).

According to the CFMP Summary Report, the Three Rivers District sites are located in either the "Towns and villages in open floodplain (central)" or "Chalk and downland catchments" areas, for which the policies are shown in **Table 2-6**.

Table 2-6: CFMP policies

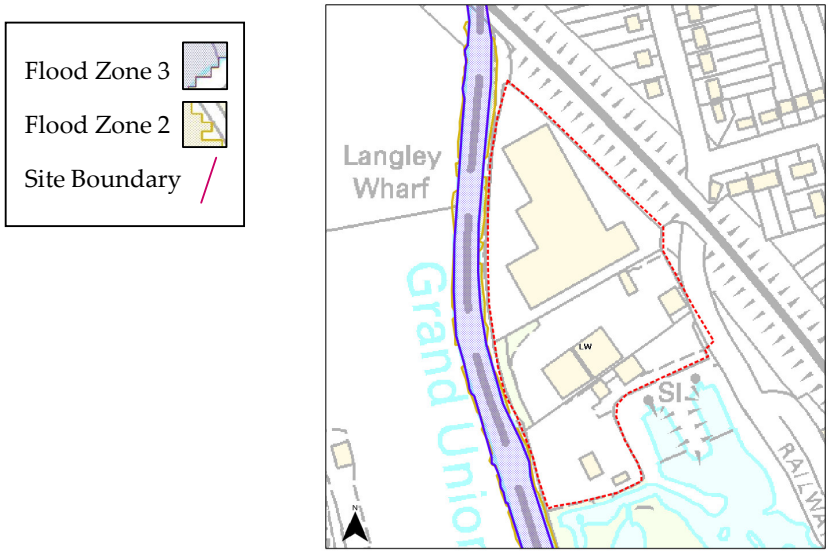
Area	Description	Policy	Messages
Towns and villages in open floodplain (central)	Towns and villages along the River Colne – includes Rickmansworth	Policy 4: Areas of low, moderate or high flood risk where we are already managing the flood risk effectively but where we may need to take further actions to keep pace with climate change.	The Lower Colne defences will be maintained. Defences will be constructed in some locations (e.g. Marlow, Watford and London Colney). Whilst, in some locations there are options to build flood defences, but as they often prove to be more expensive than comparable locations elsewhere in the country this cannot be relied upon for most communities. Maintenance procedures will be reviewed to ensure the channel capacity is maintained in the most efficient way. In the long term, the urban landscape needs to be adapted through land use planning to make space for water where possible and make it more resilient to flooding where it is not possible. NPPF/PPS25 will be promoted to create safe and sustainable development that positively reduces flood risk. It is crucial that the existing undeveloped floodplain is safeguarded from development. Work on flood warning, awareness raising and emergency planning will continue to help people at risk prepare for and respond to flooding.

Area	Description	Policy	Messages
Chalk and downland catchments	The western tributaries of the River Colne, including towns and villages along the Rivers Chess and Gade.	Policy 3: Areas of low to moderate flood risk where we are generally managing existing flood risk effectively, is indicative of the approach across most of these areas. This policy recognises the moderate level of flood risk in these areas.	Communities in this area tend to be spread out so in general will not be a priority for funding large scale flood defences. It will therefore be key to maintain the existing capacity of the rivers, including opening up river corridors through town centres and removing significant restrictions to flow from undersized culverts or bridges. Resilience to flooding will also be increased through redevelopment, although it is recognised that redevelopment rates in this area are quite low so this will take a long time. The remaining floodplain should be retained for uses that are compatible with flood risk management. Flood warning and awareness raising will continue to help people at risk prepare for and respond to flooding.

2.5 Site maps and summary tables compilation

The available data on flood risk and other relevant information has been summarised for each of the 17 potential development sites in the tables included in the following chapters of this report. Guidance and recommendations have also been included for each site on managing flood risk to assist in passing, or avoiding the need for, the Exception Test. Figures have been created within the text to accompany each assessment illustrating the compiled GIS data for each site.

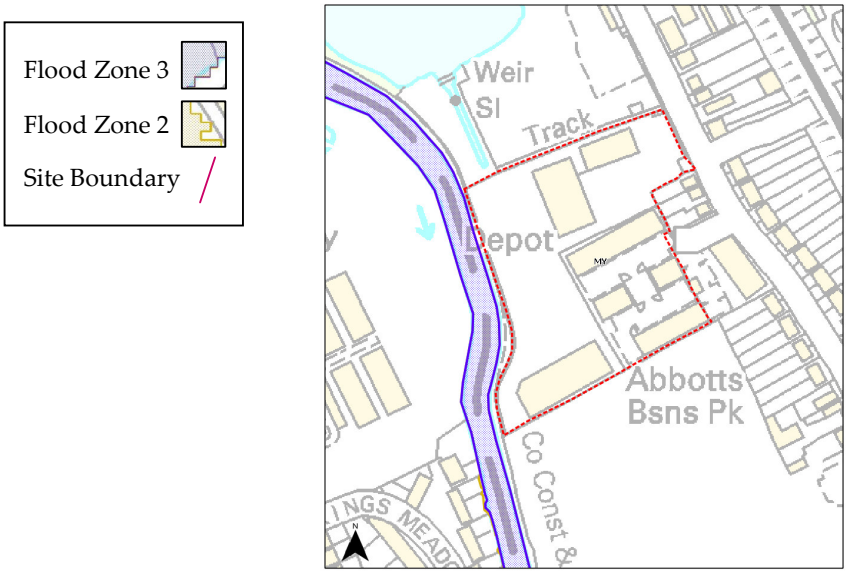
3 Langley Wharf, Kings Langley

Site	Langley Wharf, Kings Langley
ID	LW
Area	2.3 ha
Current land use	Employment use
Proposed land use	Proposed allocation for mixed use development. The four sites in Kings Langley are anticipated to deliver up to 100 dwellings alongside employment uses.
NPPF vulnerability	The NPPF classification for buildings used for financial, professional and other services, offices and general industry is 'less vulnerable'. These would therefore be acceptable in Flood Zones 1, 2 and 3a but would not be permitted in Flood Zone 3b. The NPPF classification for housing is 'more vulnerable'. It would therefore be acceptable in Flood Zones 1 and 2, require the Exception Test for Flood Zone 3a, and would not be permitted in Flood Zone 3b.
Watercourses	The River Gade and Grand Union Canal, which are combined along this stretch, flow past the site's western border. There is a lake just beyond the site's southern border.
Historical fluvial flooding	None
Flood Zones	According to the flood extents from the River Gade modelling study (used to derive new Flood Zone Maps), this site is in Flood Zone 1 (see Figure 3-1 below). 
2d parameters	Not required as model indicates no flooding out of bank.
Defences	The latest update of the National Flood and Coastal Defence Database (NFCDD) from the Environment Agency does not show any defence running along the western boundary of the site.
Access	Access to Railway Terrace, Lower Road and Hyde Lane remains clear in all flood events.

Site	Langley Wharf, Kings Langley
Flood Warning	A small part in the centre of the site (from the river to the outer edge of flood zone 2) is within the "The River Gade at Kings Langley and Croxley, including Abbots Langley" flood warning area.
Historical surface water flooding	None
Surface water modelling	According to the Areas Susceptible to Surface Water Flooding (AStSWF) the site lies along the path of runoff flowing down the River Gade valley and most of the site becomes flooded. Most of the flooded area is of 'intermediate' susceptibility and some is at 'less' susceptibility. The Flood Map for Surface Water (FMfSW) shows much less flooding. Only in the area in the centre (for the 1 in 200 year event) there is shallow flooding with a few patches around the site border. As the AStSWF and FMfSW outlines are determined from national-scale mapping, it is important to compare them to local data as a reality check. No historical surface water flooding is recorded for the site, which may mean the site is not susceptible, but surface water incidents traditionally have rarely been recorded and thus it may be that the site has flooded but no record exists.
Historical groundwater flooding	None.
Geology and Groundwater mapping	The site is underlain by Chalk bedrock and superficial deposits of Alluvium. Both of these geologies are permeable and therefore pose a risk of groundwater flooding, particularly given the site's location in the river valley where the low topography and nearby watercourse mean that groundwater levels are likely to be close to the surface. The AStGWF suggests that the site lies within an area where the geology and groundwater levels may make the site susceptible to groundwater emerging - this applies to 25-50% of the area of the 1km square the site lies in. Given the site's permeable geology in combination with the site's location in the river valley where the low topography and nearby watercourse mean that groundwater levels are likely to be close to the surface, it is likely the site is within the relevant 25-50% of the area. Groundwater flooding is considered most likely in the parts of the site where surface water flooding is indicated (low points).
Source Protection Zone	The site is in source protection zone 2, defined by a 400 day travel time from a point below the water table. This zone has a minimum radius of 250 or 500 metres around the source, depending on the size of the abstraction.
Summary of flood risk	According to the latest flood zones this site is entirely in Flood Zone 1 which is the lowest level of flood risk and suitable for all land use vulnerability classes. Shallow flooding up to (0.1 to 0.3m) is anticipated in relation to surface water flood risk. The site is potentially at high risk of groundwater flooding.
Development recommendations	According to the latest flood zones, this is a preferred site for development from a flood risk perspective, being entirely in Flood Zone 1. A sequential approach is recommended in planning the layout of buildings within the site to avoid, where possible, potential locations of high groundwater or surface water flooding.

Site	Langley Wharf, Kings Langley
Development recommendations (continued)	The roads to the site, Railway Terrace, Lower Road and Hyde Lane, remain clear for all flood events so can be used for dry safe access from/to the site. It is recommended that future Flood Risk Assessments allow for designing the development for potential high groundwater levels. This could be achieved for example by making the lower 0.3m height of the ground floors flood resilient. Due to the high risk of groundwater flooding, habitable basements are not recommended for this site. Any surface strategies for the proposed development need to be robust to ensure adequate protection against surface water flood risk. As the surface water modelling outlines are more extensive than the fluvial outlines (which are in-bank), and there is too little historical data to check the surface water modelling, it is recommended that floor levels of all properties be set at least 0.3m above proposed surrounding ground levels. Site layouts should be designed to ensure that the flow of surface water runoff, to infiltration or discharge locations as appropriate, is not impeded, and so that the safe access routes are maintained. It is recommended that SUDS be employed to manage surface runoff, in accordance with the surface water management train and the guidance in "Preliminary rainfall runoff management for developments". Drainage proposals must ensure no increase in the peak rate of stormwater runoff leaving the site, the volume of runoff leaving the site, or the pollution load to receiving waters from stormwater runoff for the lifetime of the development, including an allowance for the effects of climate change. Analysis of the site suggests that groundwater levels may be too high for infiltration SUDS and therefore it is recommended that runoff be discharged into the neighbouring watercourse using natural attenuation features (such as wetlands) to control the rate and volume of runoff to greenfield characteristics. Green roofs are also recommended for use as attenuation storage; the volumes provided are typically small and thus significant only for smaller storms, however they provide other useful benefits such as encouraging biodiversity and improving air quality. Further information on calculating storage can be found in the Environment Agency Green Roof Toolkit at: http://www.environment-agency.gov.uk/business/sectors/91967.aspx. Rainwater harvesting is also recommended, with the additional benefit of reducing reliance on mains water supply – as a result it cannot normally be counted as part of the storage volumes as tanks are not completely emptied between events, but it does provide some informal storage potential. As the site is in source protection zone 2, it is important to ensure a high water quality of surface runoff discharging from the site, including treatment where necessary (via a wetland for example), to avoid indirect contamination of the groundwater source. Even if discharged to the river, contamination may affect the aquifer as the river is in hydraulic connectivity. Naturally, a high water quality will also benefit the river itself. The impact of blockages of nearby drains on flood risk to the site needs to be assessed as part of a Flood Risk Assessment.
Allocation Recommendation	It is recommended to allocate this site with the provision that the above recommendations are followed.

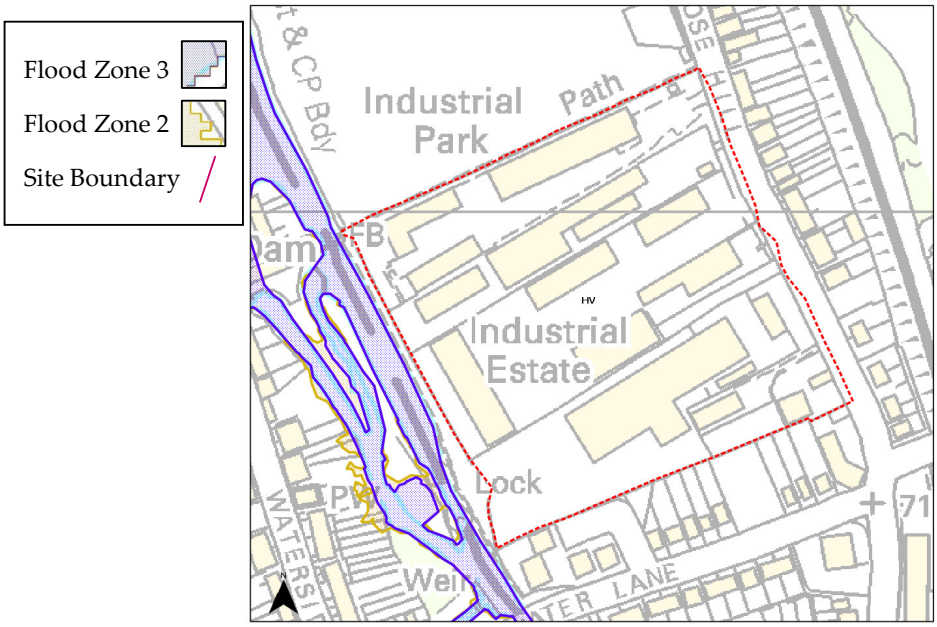
4 Masters Yard, Kings Langley

Site	Masters Yard, Kings Langley
ID	MY
Area	1.8 ha
Current land use	Employment use
Proposed land use	Proposed allocation for mixed use development. The four sites in Kings Langley are anticipated to deliver up to 100 dwellings alongside employment uses.
NPPF vulnerability	The NPPF classification for buildings used for financial, professional and other services, offices and general industry in 'less vulnerable'. These would therefore be acceptable in Flood Zones 1, 2 and 3a but would not be permitted in Flood Zone 3b. The NPPF classification for housing is 'more vulnerable'. It would therefore be acceptable in Flood Zones 1 and 2, require the Exception Test for Flood Zone 3a, and would not be permitted in Flood Zone 3b.
Watercourses	The River Gade and Grand Union Canal, which are combined along this stretch, flow past the site's western border. There is a lake just beyond the site's northern border.
Historical fluvial flooding	None
Flood Zones	According to the flood extents from the River Gade modelling study (used to derive new Flood Zone Maps), this site is in Flood Zone 1 (see Figure 4-1 below). 
2d parameters	Not required as model indicates no flooding out of bank.
Defences	The latest update of the National Flood and Coastal Defence Database (NFCDD) from the Environment Agency does not indicate the presence of a defence running alongside the western boundary of the site.

Site	Masters Yard, Kings Langley
Access	Access to Primrose Hill, Railway Terrace and Harthall Lane remains clear in all flood events.
Flood Warning	Most of the site (from the river to the outer edge of flood zone 2) is within the "The River Gade at Kings Langley and Croxley, including Abbots Langley" flood warning area.
Historical surface water flooding	None
Surface water modelling	According to the Areas Susceptible to Surface Water Flooding (AStSWF) the site lies along the path of runoff flowing down the River Gade valley and from Harthall Lane, and most of the site becomes flooded. Most of the flooded area is of 'intermediate' susceptibility, some is at 'less' susceptibility. The Flood Map for Surface Water (FMfSW) shows similar but less flooding for the 1 in 200 year event and less still for the other scenarios. As the AStSWF and FMfSW outlines are determined from national-scale mapping, it is important to compare them to local data as a reality check. No historical surface water flooding is recorded for the site, which may mean the site is not susceptible, but surface water incidents traditionally have rarely been recorded and thus it may be that the site has flooded but no record exists.
Historical groundwater flooding	None
Geology and Groundwater mapping	The site is underlain by Chalk bedrock and superficial deposits of Alluvium. Both of these geologies are permeable and therefore pose a risk of groundwater flooding. The AStGWF suggests that the site lies within an area where the geology and groundwater levels may make the site susceptible to groundwater emerging - this applies to 25-50% of the area of the 1km square the site lies in. Given the site's permeable geology in combination with the site's location in the river valley where the low topography and nearby watercourse mean that groundwater levels are likely to be close to the surface, it is likely the site is within the relevant 25-50% of the area. Groundwater flooding is considered most likely in the parts of the site where surface water flooding is indicated (low points).
Source Protection Zone	The site is in source protection zone 2, defined by a 400 day travel time from a point below the water table. This zone has a minimum radius of 250 or 500 metres around the source, depending on the size of the abstraction.
Summary of flood risk	According to the latest flood zones this site is entirely in Flood Zone 1 which is the lowest level of flood risk and suitable for all land use vulnerability classes. Much of the site is potentially at risk of surface water flooding, with the south-east part in particular being susceptible to deep flooding. The site is potentially at high risk of groundwater flooding.
Development recommendations	According to the updated flood zones, this is a preferred site for development from a flood risk perspective, being entirely in Flood Zone 1. A sequential approach is recommended in planning the layout of buildings within the site to avoid, where possible, potential locations of high groundwater or deep surface water flooding. The roads to the site, Primrose Hill, Railway Terrace and Harthall Lane, remain clear for all flood events so can be used for dry safe access from/to the site.

Site	Masters Yard, Kings Langley
Development recommendations (continued)	It is recommended that future Flood Risk Assessments allow for designing the development for potential high groundwater levels. This could be achieved for example by making the lower 0.3m height of the ground floors flood resilient. Due to the high risk of groundwater flooding, habitable basements are not recommended for this site. Any surface strategies for the proposed development need to be robust to ensure adequate protection against surface water flood risk. As the surface water modelling outlines are more extensive than the fluvial outlines (which are in-bank), and there is too little historical data to check the surface water modelling, it is recommended that floor levels of all properties be set at least 0.3m above proposed surrounding ground levels. Site layouts should be designed to ensure that the flow of surface water runoff, to infiltration or discharge locations as appropriate, is not impeded, and so that the safe access routes are maintained. It is recommended that SUDS be employed to manage surface runoff, in accordance with the surface water management train and the guidance in "Preliminary rainfall runoff management for developments". Drainage proposals must ensure no increase in the peak rate of stormwater runoff leaving the site, the volume of runoff leaving the site, or the pollution load to receiving waters from stormwater runoff for the lifetime of the development, including an allowance for the effects of climate change. Analysis of the site suggests that groundwater levels may be too high for infiltration SUDS and therefore it is recommended that runoff be discharged into the neighbouring watercourse using natural attenuation features (such as wetlands) to control the rate and volume of runoff to greenfield characteristics. Green roofs are also recommended for use as attenuation storage; the volumes provided are typically small and thus significant only for smaller storms, however they provide other useful benefits such as encouraging biodiversity and improving air quality. Further information on calculating storage can be found in the Environment Agency Green Roof Toolkit at: http://www.environment-agency.gov.uk/business/sectors/91967.aspx. Rainwater harvesting is also recommended as it brings the additional benefit of reducing reliance on mains water supply – as a result it cannot normally be counted as part of the storage volumes as tanks are not completely emptied between events, but it does provide some informal storage potential. As the site is in source protection zone 2, it is important to ensure a high water quality of surface runoff discharging from the site, including treatment where necessary (via a wetland for example), to avoid contamination of the groundwater source. Even if discharged to the river, contamination may affect the aquifer as the river is in hydraulic connectivity. Naturally, a high water quality will also benefit the river itself. The impact of blockages of nearby drains on flood risk to the site should be assessed as part of any future Flood Risk Assessment.
Allocation Recommendation	It is recommended to allocate this site with the provision that the above recommendations are followed.

5 Happy Valley and Kings Park, Kings Langley

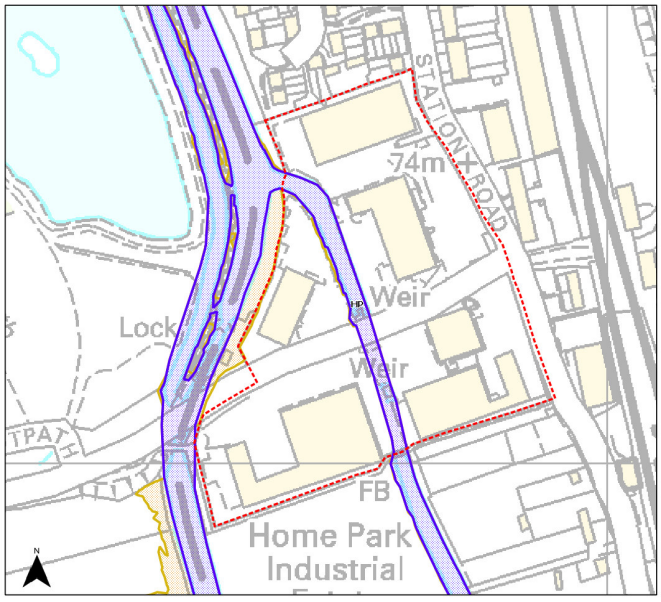
Site	Happy Valley and Kings Park, Kings Langley
ID	HV
Area	4.0 ha
Current land use	Employment use
Proposed land use	Proposed allocation for mixed use development. The four sites in Kings Langley are anticipated to deliver up to 100 dwellings alongside employment uses.
NPPF vulnerability	The NPPF classification for buildings used for financial, professional and other services, offices and general industry in 'less vulnerable'. These would therefore be acceptable in Flood Zones 1, 2 and 3a but would not be permitted in Flood Zone 3b. The NPPF classification for housing is 'more vulnerable'. It would therefore be acceptable in Flood Zones 1 and 2, require the Exception Test for Flood Zone 3a, and would not be permitted in Flood Zone 3b.
Watercourses	The River Gade and Grand Union Canal, as three branches, flow past the site's western border.
Historical fluvial flooding	None
Flood Zones	According to the flood extents from the River Gade modelling study, this site is in Flood Zone 1 (see Figure 5-1 below). 
2d parameters	Not required as model indicates no flooding out of bank.

Site	Happy Valley and Kings Park, Kings Langley
Defences	The latest update of the National Flood and Coastal Defence Database (NFCDD) from the Environment Agency indicates the presence of a defence in the form of a lined channel, giving a standard of protection of 5 years to the site. NFCDD indicates that no concerns are currently expressed over this defence, however it is reliant upon maintenance continuing in the future to ensure capacity is maintained.
Access	Access to Primrose Hill, Station Road and Tom's Lane remains clear in all flood events.
Flood Warning	Most of the site (from the river to the outer edge of flood zone 2) is within the "The River Gade at Kings Langley and Croxley, including Abbots Langley" flood warning area.
Historical surface water flooding	None within the site, however there is a surface water area on the western side of the River Gade (data source: 2007 SFRA).
Surface water modelling	According to the AStSWF the site lies along the path of runoff flowing down the River Gade valley, and most of the site becomes flooded. Most of the flooded area is of 'intermediate' susceptibility, with smaller areas at 'less' and 'more' susceptibility. The FMfSW suggests that the southern and northern thirds of the site are more susceptible to flooding, but the centre third remains clear. The area of flooding is largest for the 1 in 200 year shallow and smaller for the 1 in 200 year deep and 30 year shallow. There is no deep flooding for the 1 in 30 year. As the AStSWF and FMfSW outlines are determined from national-scale mapping, it is important to compare them to local data as a reality check. No historical surface water flooding is recorded for the site, which may mean the site is not susceptible, but surface water incidents traditionally have rarely been recorded and thus it may be that the site has flooded but no record exists. The historical flooding on the other side of the river is along the modelling flow paths, although not in the highest susceptibility areas.
Historical groundwater flooding	None
Geology and Groundwater mapping	The site is underlain by Chalk bedrock, with superficial deposits of Alluvium over most of the site. Both of these geologies are permeable and therefore pose a risk of groundwater flooding. The AStGWF suggests that the site lies within an area where the geology and groundwater levels may make the site susceptible to groundwater emerging - this applies to 50-75% of the area of the 1km square the site lies in. Given the site's permeable geology in combination with the site's location in the river valley where the low topography and nearby watercourse mean that groundwater levels are likely to be close to the surface, it is likely the site is within the relevant 50-75% of the area. Groundwater flooding is considered most likely in the parts of the site where surface water flooding is indicated (low points).
Source Protection Zone	The south of the site is in source protection zone 1, defined as the 50 day travel time from any point below the water table to the source. This zone has a minimum radius of 50 metres. The north of the site is in source protection zone 2, defined by a 400 day travel time from a point below the water table. This zone has a minimum radius of 250 or 500 metres around the source, depending on the size of the abstraction.
Summary of flood risk	According to the updated flood zones this site is entirely in Flood Zone 1 which is the lowest level of flood risk and suitable for all land use vulnerability classes. Much of the site is potentially at risk of surface water flooding, with some deep flooding particularly in the north. The site is potentially at high risk of groundwater flooding.

Site	Happy Valley and Kings Park, Kings Langley
Development recommendations	According to the latest flood zones, this is a preferred site for development from a fluvial flood risk perspective, being entirely in Flood Zone 1. A sequential approach is recommended in planning the layout of buildings within the site to avoid, where possible, potential locations of high groundwater or surface water flooding. Whilst no concerns are currently expressed over the condition of the site's defence (a lined channel), it is reliant upon maintenance continuing in the future to ensure capacity is maintained. Future planning applications need to consider how adequate maintenance of the defence will take place over the life of the development. Primrose Hill, Station Road and Tom's Lane, remain clear for all flood events so can be used for dry safe access from/to the site. It is recommended that future Flood Risk Assessments allow for designing the development for potential high groundwater levels. This could be achieved for example by making the lower 0.3m height of the ground floors flood resilient. Due to the high risk of groundwater flooding, habitable basements are not recommended for this site. Any surface strategies for the proposed development need to be robust to ensure adequate protection against surface water flood risk. As the surface water modelling outlines are more extensive than the fluvial outlines (which are in-bank), and there is too little historical data to check the surface water modelling, it is recommended that floor levels of all properties be set at least 0.3m above proposed surrounding ground levels. Site layouts should be designed to ensure that the flow of surface water runoff, to infiltration or discharge locations as appropriate, is not impeded, and so that the safe access routes are maintained. It is recommended that SUDS be employed to manage surface runoff, in accordance with the surface water management train and the guidance in "Preliminary rainfall runoff management for developments". Drainage proposals must ensure no increase in the peak rate of stormwater runoff leaving the site, the volume of runoff leaving the site, or the pollution load to receiving waters from stormwater runoff for the lifetime of the development, including an allowance for the effects of climate change. Analysis of the site suggests that groundwater levels may be too high for infiltration SUDS and therefore it is recommended that runoff be discharged into the neighbouring watercourse using attenuation devices to control the rate and volume of runoff to greenfield characteristics. Green roofs are also recommended for use as attenuation storage; the volumes provided are typically small and thus significant only for smaller storms, however they provide other useful benefits such as encouraging biodiversity and improving air quality. Further information on calculating storage can be found in the Environment Agency Green Roof Toolkit at: http://www.environment-agency.gov.uk/business/sectors/91967.aspx. Rainwater harvesting is also recommended, with the additional benefit of reducing reliance on mains water supply – as a result it cannot normally be counted as part of the storage volumes as tanks are not completely emptied between events, but it does provide some informal storage potential.

Site	Happy Valley and Kings Park, Kings Langley
Development recommendations (continued)	As the site is in source protection zones 1 and 2, it is important to ensure a high water quality of surface runoff discharging from the site, including treatment where necessary, to avoid contamination of the groundwater source. Even if discharged to the river, contamination may affect the aquifer as the river is in hydraulic connectivity. Naturally, a high water quality will also benefit the river itself. The impact of blockages of nearby drains on flood risk to the site needs to be assessed as part of a Flood Risk Assessment.
Allocation Recommendation	It is recommended to allocate this site with the provision that the above recommendations are followed.

6 Home Park, Kings Langley

Site	Home Park, Kings Langley
ID	HP
Area	3.6 ha
Current land use	Employment use
Proposed land use	Proposed allocation for mixed use development. The four sites in Kings Langley are anticipated to deliver up to 100 dwellings alongside employment uses.
NPPF vulnerability	The NPPF classification for buildings used for financial, professional and other services, offices and general industry in 'less vulnerable'. These would therefore be acceptable in Flood Zones 1, 2 and 3a but would not be permitted in Flood Zone 3b. The NPPF classification for housing is 'more vulnerable'. It would therefore be acceptable in Flood Zones 1 and 2, require the Exception Test for Flood Zone 3a, and would not be permitted in Flood Zone 3b.
Watercourses	The River Gade/Grand Union Canal flow past the site's western border, and there is a lake to the west of this. A tributary of the river/canal, Mill Stream, runs through the site and is partially culverted.
Historical fluvial flooding	None
Flood Zones	According to the flood extents from the River Gade modelling study, this site is in Flood Zone 1 (see Figure 6-1 below). The watercourse which runs through the site remains in bank for all modelled events. Flood Zone 3 Flood Zone 2 Site Boundary 
2d parameters	Not required as model indicates no flooding out of bank.

Site	Home Park, Kings Langley
Defences	The latest update of the National Flood and Coastal Defence Database (NFCDD) from the Environment Agency indicates the presence of a defence in the form of a culverted channel (the Mill Stream that crosses through the site). The asset gives a standard of protection of 25 years. No concerns are currently expressed over this defence however it is reliant upon maintenance continuing in the future to ensure capacity is maintained and that there are no blockages (in particular due to the lack of maintenance of the trash screen) or collapse.
Access	Access to Station Road remains clear in all flood events.
Flood Warning	Most of the site (from the river to the outer edge of flood zone 2) is within the "The River Gade at Kings Langley and Croxley, including Abbots Langley" flood warning area.
Historical surface water flooding	None
Surface water modelling	The AStSWF predicts only a moderate amount of flooding across the site, mainly from a flow path to the east. Most of the flooded area is of 'less' susceptibility, with smaller areas at 'intermediate' susceptibility. The FMfSW also shows only minor flooding, mainly in the south-west and along the course of Mill Stream. This is mainly shallow flooding for both the 1 in 30 and 1 in 200 year scenarios, apart from some of the flooding in the south-west which is deep for both scenarios. As the AStSWF and FMfSW outlines are determined from national-scale mapping, it is important to compare them to local data as a reality check. No historical surface water flooding is recorded for the site, which may mean the site is not susceptible, but surface water incidents traditionally have rarely been recorded and thus it may be that the site has flooded but no record exists.
Historical groundwater flooding	None
Geology and Groundwater mapping	The site is underlain by Chalk bedrock, with superficial deposits of Alluvium over the west of the site and Head (Clay, Silt, Sand and Gravel) over a small area in the north. All of these geologies are classified as permeable and therefore pose a risk of groundwater flooding. The AStGWF suggests that the site lies within an area where the geology and groundwater levels may make the site susceptible to groundwater emerging - this applies to 50-75% of the area of the 1km square the site lies in. Given the site's permeable geology in combination with the site's location in the river valley where the low topography and nearby watercourse mean that groundwater levels are likely to be close to the surface, it is likely the site is within the relevant 50-75% of the area. Groundwater flooding is considered most likely in the parts of the site where surface water flooding is indicated (low points).
Source Protection Zone	The site is in source protection zone 2, defined by a 400 day travel time from a point below the water table. This zone has a minimum radius of 250 or 500 metres around the source, depending on the size of the abstraction.
Summary of flood risk	According to the updated flood zones this site is entirely in Flood Zone 1 which is the lowest level of flood risk and suitable for all land use vulnerability classes. Much of the site is potentially at risk of surface water flooding; this is for the most part shallow although some deep flooding is expected in the south-west. The site is potentially at high risk of groundwater flooding.

Site	Home Park, Kings Langley
Development recommendations	According to the latest flood zones, this is a preferred site for development from a fluvial flood risk perspective, being entirely in Flood Zone 1. A sequential approach is recommended in planning the layout of buildings within the site to avoid, where possible, potential locations of high groundwater or surface water flooding. Whilst no concerns are currently expressed over the condition of the site's defence (a culverted channel), it is reliant upon maintenance continuing in the future to ensure capacity is maintained and that there are no blockages or collapse. Future planning applications need to consider how adequate maintenance of the defence will take place over the life of the development. Access to Station Road, which is just to the east of the site, remains clear in all flood events. This route should be used for safe access to/egress from the site. It is recommended that future Flood Risk Assessments allow for designing the development for potential high groundwater levels. This could be achieved for example by making the lower 0.3m height of the ground floors flood resilient. Due to the high risk of groundwater flooding, habitable basements are not recommended for this site. Any surface strategies for the proposed development need to be robust to ensure adequate protection against surface water flood risk. As the surface water modelling outlines are more extensive than the fluvial outlines (which are in-bank), and there is too little historical data to check the surface water modelling, it is recommended that floor levels of all properties be set at least 0.3m above proposed surrounding ground levels. Site layouts should be designed to ensure that the flow of surface water runoff, to infiltration or discharge locations as appropriate, is not impeded, and so that the safe access routes are maintained. It is recommended that SUDS be employed to manage surface runoff, in accordance with the surface water management train and the guidance in "Preliminary rainfall runoff management for developments". Drainage proposals must ensure no increase in the peak rate of stormwater runoff leaving the site, the volume of runoff leaving the site, or the pollution load to receiving waters from stormwater runoff for the lifetime of the development, including an allowance for the effects of climate change. Analysis of the site suggests that groundwater levels may be too high for infiltration SUDS and therefore it is recommended that runoff be discharged into the neighbouring watercourse using natural attenuation features (wetlands for example) to control the rate and volume of runoff to greenfield characteristics. Green roofs are also recommended for use as attenuation storage; the volumes provided are typically small and thus significant only for smaller storms, however they provide other useful benefits such as encouraging biodiversity and improving air quality. Further information on calculating storage can be found in the Environment Agency Green Roof Toolkit at: http://www.environment-agency.gov.uk/business/sectors/91967.aspx. Rainwater harvesting is also recommended, with the additional benefit of reducing reliance on mains water supply – as a result it cannot normally be counted as part of the storage volumes as tanks are not completely emptied between events, but it does provide some informal storage potential.

Site	Home Park, Kings Langley
Development recommendations (continued)	As the site is in source protection zone 2, it is important to ensure a high water quality of surface runoff discharging from the site, including treatment where necessary (via wetlands for example), to avoid contamination of the groundwater source. Even if discharged to the river, contamination may affect the aquifer as the river is in hydraulic connectivity. Naturally, a high water quality will also benefit the river itself. The impact of blockages of nearby drains on flood risk to the site needs to be assessed as part of a Flood Risk Assessment. It is recommended that during redevelopment the opportunity be taken to deculvert Mill Stream. This would reduce the risk of flooding from water backing up due to lack of capacity during larger rainfall events, and blockages. Opening up the watercourse also provides biodiversity and amenity/aesthetic benefits. Development should be sufficiently set back from the stream floodplain to allow space for water.
Allocation Recommendation	It is recommended to allocate this site with the provision that the above recommendations are followed.

7 North East Baldwins Lane, Croxley Green

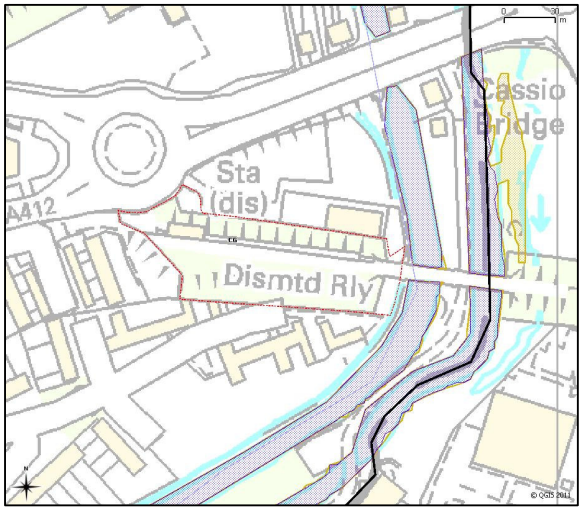
Site	North East Baldwins Lane, Croxley Green
ID	BL
Area	12.3 ha
Current land use	Greenfield
Proposed land use	Potential allocation for secondary school.
NPPF vulnerability	The NPPF classification for educational establishments is 'more vulnerable'. It would therefore be acceptable in Flood Zones 1 and 2, require the Exception Test for Flood Zone 3a, and would not be permitted in Flood Zone 3b.
Watercourses	The Grand Union Canal runs along the easternmost border of the site and the River Gade about 200m further east. There is also a short channel which joins the canal just where it touches the site's border. There is a small lake situated between the Canal and River Gade.
Historical fluvial flooding	None within the site, however there was fluvial flooding on the other side of the river in the summer of 1999.
Flood Zones	According to the latest flood zones, this site is in Flood Zone 1 (see Figure 7-1 below).
2d parameters	Not required as model indicates no flooding out of bank.
Defences	The latest update of the National Flood and Coastal Defence Database (NFCDD) from the Environment Agency indicates the presence of a defence in the form a 0.8m diameter culverted channel crossing beneath the railway embankment on the south eastern corner of the site. The asset is likely to drain local surface runoff and it gives an indicative standard of protection of 25 years. No concerns are currently expressed over this defence, however it is reliant upon maintenance continuing in the future to ensure capacity is maintained and that there are no blockages or collapse.
Access	Access to Lodge End and then west, or onto Baldwins Lane remains clear for all events.

Site	North East Baldwins Lane, Croxley Green
Flood Warning	The site is not in a flood warning area (although the "The River Gade at Kings Langley and Croxley, including Abbots Langley" lies just to the east along the canal).
Historical surface water flooding	None
Surface water modelling	According to the AStSWF surface runoff flows down Lodge End, the road along the site's western border, Ludlow Way, and along the path of the Canal and River. Both of these flow routes join along the southern border of the site. This causes flooding along the western, southern and south-eastern parts of the site, with most of the flooding area being of the 'more' susceptibility category. The FMfSW indicates a similar pattern of flooding and suggests most of the flooded area will be deep for both the 1 in 200 and 1 in 30 year events. As the AStSWF and FMfSW outlines are determined from national-scale mapping, it is important to compare them to local data as a reality check. No historical surface water flooding is recorded for the site, which may mean the site is not susceptible, but surface water incidents traditionally have rarely been recorded and thus it may be that the site has flooded but no record exists.
Historical groundwater flooding	None
Geology and Groundwater mapping	Most of the site directly overlies the Chalk bedrock, although there is a small area with superficial deposits of Alluvium along the south-east border. Both of these geologies are permeable and therefore pose a risk of groundwater flooding. The AStGWF suggests that the site lies within an area where the geology and groundwater levels may make the site susceptible to groundwater emerging - this applies to 25-50% of the area of the 1km square the site lies in. The north-east part of the site is quite high so is probably at relatively low risk, whereas the west and south of the site (where surface water flooding is indicated) are likely to be at risk of groundwater flooding (low points). The OS map indicates the presence of watercress beds on the south eastern corner of the site which suggests the presence of permanently wet ground.
Source Protection Zone	A tiny portion of the site in the southern corner is in source protection zone 1, defined as the 50 day travel time from any point below the water table to the source. This zone has a minimum radius of 50 metres. About a third of the site is in source protection zone 2, defined by a 400 day travel time from a point below the water table. This zone has a minimum radius of 250 or 500 metres around the source, depending on the size of the abstraction. The northern two-thirds of the site is in source protection zone 3, defined as the area around a source within which all groundwater recharge is presumed to be discharged at the source.
Summary of flood risk	According to the latest flood zones this site is entirely in Flood Zone 1 which is the lowest level of flood risk and suitable for all land use vulnerability classes. Most of the site may not be at risk of surface water flooding but some of the areas around the border are more likely, with deep flooding across much of the flooded area. The site is potentially at risk of groundwater flooding, although the raised position of the south-east of the site may help reduce risk in this area.

Site	North East Baldwins Lane, Croxley Green
Development recommendations	According to the latest flood zones, this is a preferred site for development from a flood risk perspective, being entirely in Flood Zone 1. A sequential approach is recommended in planning the layout of buildings within the site to avoid, where possible, potential locations of high groundwater or deep surface water flooding. Access to Lodge End and then west, or onto Baldwins Lane remains clear for all events. This route should be used for safe access to/egress from the site. It is recommended that future Flood Risk Assessments allow for designing the development for potential high groundwater levels. This could be achieved for example by making the lower 0.3m height of the ground floors flood resilient. Due to the high risk of groundwater flooding, habitable basements are not recommended for this site. Any surface strategies for the proposed development need to be robust to ensure adequate protection against surface water flood risk. As surface water flooding is concentrated along the west and south border it is recommended that area is allocated for infiltration/attenuation SUDS with buildings located away from the flood risk area. If buildings do need to encroach on the flood risk area then floor levels should be 0.3m above ground. Elsewhere, floor levels may be set 0.15m above proposed surrounding ground levels. Site layouts should be designed to ensure that the flow of surface water runoff, to infiltration or discharge locations as appropriate, is not impeded and that there are safe access routes around the surface runoff paths. It is recommended that SUDS be employed to manage surface runoff, in accordance with the surface water management train and the guidance in "Preliminary rainfall runoff management for developments". Drainage proposals must ensure no increase in the peak rate of stormwater runoff leaving the site, the volume of runoff leaving the site, or the pollution load to receiving waters from stormwater runoff for the lifetime of the development, including an allowance for the effects of climate change. It is possible that groundwater levels may be far enough below the surface in at least the north-east part of the site to allow sufficient space for infiltration devices. A site investigation would be needed to determine this. If not, it is recommended that runoff be discharged into the neighbouring watercourse using attenuation devices to control the rate and volume of runoff to greenfield characteristics. Given the size of the site, it presents a particularly good opportunity to use features such as wetlands and ponds. These typically require more land-take than other SUDS but bring additional benefits of enhancing biodiversity and providing amenity/aesthetic features for residents. Green roofs are also recommended for use as attenuation storage; the volumes provided are typically small and thus significant only for smaller storms, however they provide other useful benefits such as encouraging biodiversity and improving air quality. Further information on calculating storage can be found in the Environment Agency Green Roof Toolkit at: http://www.environment-agency.gov.uk/business/sectors/91967.aspx. Rainwater harvesting is also recommended, with the additional benefit of reducing reliance on mains water supply – as a result it cannot normally be counted as part of the storage volumes as tanks are not completely emptied between events, but it does provide some informal storage potential.

Site	North East Baldwins Lane, Croxley Green
Development recommendations (continued)	As the site is in source protection zone 1, 2 and 3, it is important to ensure a high water quality of surface runoff discharging from the site, including treatment where necessary, to avoid contamination of the groundwater source. Even if discharged to the river, contamination may affect the aquifer as the river is in hydraulic connectivity. Naturally, a high water quality will also benefit the river itself. The impact of blockages of nearby drains on flood risk to the site needs to be assessed as part of a Flood Risk Assessment. The culvert beneath the railway embankment will be dependent upon maintenance continuing in the future to ensure its capacity is maintained and that there are no blockages or collapse. Future planning applications need to consider how adequate maintenance of the defence will take place over the life of the development.
Allocation Recommendation	It is recommended to allocate this site with the provision that the above recommendations are followed.

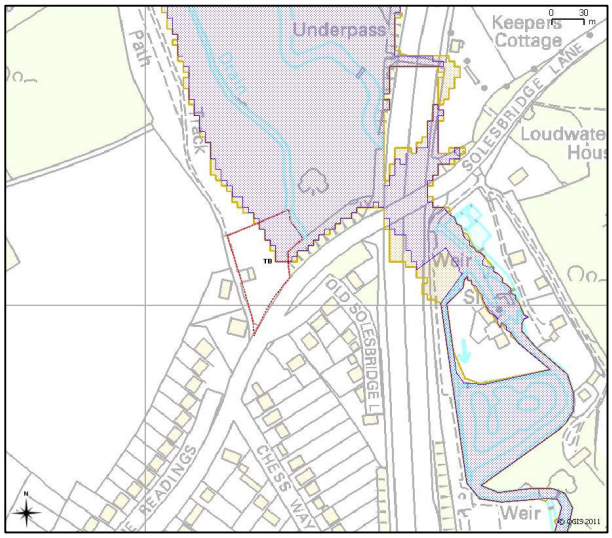
8 Croxley Green Station

Site	Croxley Green Station
ID	CG
Area	0.7 ha
Current land use	Dismantled railway/woodland
Proposed land use	Not currently intending to allocate, but has been considered as a housing site with an indicative capacity of 35 dwellings'
NPPF vulnerability	The NPPF classification for housing is 'more vulnerable'. It would therefore be acceptable in Flood Zones 1 and 2, require the Exception Test for Flood Zone 3a, and would not be permitted in Flood Zone 3b.
Watercourses	The Grand Union Canal runs along the eastern border of the site and the River Gade 30m to the east, parallel to the Canal.
Historical fluvial flooding	None
Flood Zones	According to the latest flood zones, this site is in Flood Zone 1 (see Figure 8-1 below). Flood Zone 3 Flood Zone 2 Site Boundary 
2d parameters	Not required as model indicates no flooding out of bank.
Defences	The latest update of the National Flood and Coastal Defence Database (NFCDD) from the Environment Agency indicates the presence of a defence in the form of a 0.5m diameter culverted channel crossing beneath the dismantled railway on the eastern side of the site. The asset is likely to drain local surface runoff and it gives an indicative standard of protection of 25 years. NFCDD indicates no concerns currently expressed over this defence, although it is known to be prone to build up of vegetation. The asset is reliant upon maintenance continuing in the future to ensure capacity is maintained (which will be reduced when vegetation is thick) and that there are no blockages or collapse.
Access	Access to Sycamore Road and the A412 remains clear for all events.

Site	Croxley Green Station
Flood Warning	The site is not in a flood warning area (although the "The River Gade at Kings Langley and Croxley, including Abbots Langley" lies just to the east along the canal).
Historical surface water flooding	None
Surface water modelling	The AStSWF suggests that surface water flooding mainly goes around the site, leaving it an 'island' (due to raised embankment left by the railway), apart from a little flooding along the border particularly at the eastern end where flooding of 'more' susceptibility is indicated. The FMfSW also indicates little flooding on site, although in this case it is not cut off as there is no flooding to the west. The flooded area is mainly to the east, including parts of the south-eastern and north-eastern borders and mainly deep flooding during the 1 in 200 year but only shallow flooding for the 1 in 30 year. As the AStSWF and FMfSW outlines are determined from national-scale mapping, it is important to compare them to local data as a reality check. No historical surface water flooding is recorded for the site, which may mean the site is not susceptible, but surface water incidents traditionally have rarely been recorded and thus it may be that the site has flooded but no record exists.
Historical groundwater flooding	None
Geology and Groundwater mapping	The site is underlain by Chalk bedrock with superficial deposits of Alluvium in the east of the site. These geologies are permeable and therefore pose a risk of groundwater flooding. The AStGWF suggests that the site lies within an area where the geology and groundwater levels may make the site susceptible to groundwater emerging - this applies to 25-50% of the area of the 1km square the site lies in. At present, the railway embankment keeps most of the site above groundwater levels but it is possible that, due to its narrowness, this will be removed during development, bringing the site down to the level of the river valley where a combination of low topography and nearby watercourses means that groundwater levels could be close to the surface and the site may be at risk of flooding.
Source Protection Zone	The site is in source protection zone 1, defined as the 50 day travel time from any point below the water table to the source. This zone has a minimum radius of 50 metres.
Summary of flood risk	According to the latest flood zones this site is entirely in Flood Zone 1 which is the lowest level of flood risk and suitable for all land use vulnerability classes. Most of the site is not at risk of surface water flooding but some of the areas around the border are, with deep flooding expected for more extreme events. If the disused railway embankment is removed, the redeveloped site could be potentially at high risk of groundwater and surface water flood risk.

Site	Croxley Green Station
Development recommendations	According to the latest flood zones, this is a preferred site for development, being entirely in Flood Zone 1. Should there be a proposal to remove the disused railway embankment, it is recommended that this is not completely removed and to keep at least a 0.5m height above surrounding ground levels. This approach will ensure that the groundwater and surface water flood risk do not increase within the site. Any surface strategies for the proposed development need to be robust to ensure adequate protection against surface water flood risk. Finished floor levels of properties to be set 0.15m above proposed surrounding ground levels. Site layouts should be designed to ensure that the flow of surface water runoff, to infiltration or discharge locations as appropriate, is not impeded and that there are safe access routes around the surface runoff paths. It is recommended that SUDS be employed to manage surface runoff, in accordance with the surface water management train and the guidance in "Preliminary rainfall runoff management for developments". Drainage proposals must ensure no increase in the peak rate of stormwater runoff leaving the site, the volume of runoff leaving the site, or the pollution load to receiving waters from stormwater runoff for the lifetime of the development, including an allowance for the effects of climate change. Analysis of the site suggests that groundwater levels may be too high for infiltration SUDS and therefore it is recommended that runoff be discharged into the neighbouring watercourse using attenuation devices to control the rate and volume of runoff to greenfield characteristics. Green roofs are also recommended for use as attenuation storage; the volumes provided are typically small and thus significant only for smaller storms, however they provide other useful benefits such as encouraging biodiversity and improving air quality. Further information on calculating storage can be found in the Environment Agency Green Roof Toolkit at: http://www.environment-agency.gov.uk/business/sectors/91967.aspx. Rainwater harvesting is also recommended, with the additional benefit of reducing reliance on mains water supply – as a result it cannot normally be counted as part of the storage volumes as tanks are not completely emptied between events, but it does provide some informal storage potential. As the site is in source protection zone 1, it is particularly important to ensure a high water quality of surface runoff discharging from the site, including treatment where necessary, to avoid contamination of the groundwater source since there is very little time for natural degradation and dilution of pollutants in the soil. Even if discharged to the river, contamination may affect the aquifer as the river is in hydraulic connectivity. Naturally, a high water quality will also benefit the river itself. The impact of blockages of nearby drains on flood risk to the site needs to be assessed as part of a Flood Risk Assessment. The culvert beneath the railway embankment will be dependent upon maintenance continuing in the future to ensure capacity is maintained and that there are no blockages or collapse. Future planning applications need to consider how adequate maintenance of the defence will take place over the life of the development.
Allocation Recommendation	It is recommended to allocate this site with the provision that the above recommendations are followed.

9 The Barn, Solesbridge Lane, Chorleywood

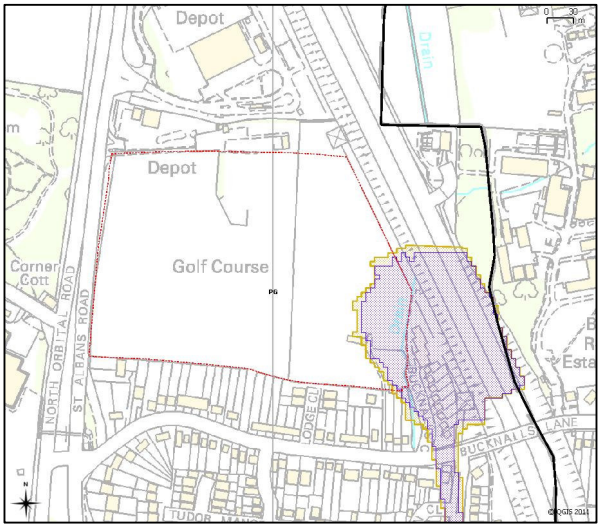
Site	The Barn, Solesbridge Lane, Chorleywood
ID	TB
Area	0.4 ha
Current land use	Greenfield apart from one building
Proposed land use	Not currently intending to allocate, but has been considered as a housing site with an indicative capacity of 10 dwellings.
NPPF vulnerability	The NPPF classification for housing is 'more vulnerable'. It would therefore be acceptable in Flood Zones 1 and 2, require the Exception Test for Flood Zone 3a, and would not be permitted in Flood Zone 3b.
Watercourses	The River Chess lies about 110m away from the site to the east. There is also a drainage channel which runs along the site's north-east border, apparently in a northerly direction to meet the River Chess (which flows south).
Historical fluvial flooding	None
Flood Zones	The site currently has 1% of its area within Flood Zone 2 and 26% in Flood Zone 3. The remainder of the site is Flood Zone 1 (see Figure 9-1 below). Flood Zone 3 Flood Zone 2 Site Boundary  The current flood mapping in the site is produced from JFLOW modelling which may represent a conservative estimate of flood extents. An Environment Agency flood mapping model has recently been completed for the River Chess just downstream of the site (the river model starts downstream of the M25 up to its confluence with the River Colne). This model could therefore be extended upstream to improve the extents of Flood Zones 2 and 3 at the site and to estimate the extents of Flood Zone 3b. However, in the absence of detailed 1D/2D modelling a precautionary approach should be taken. Given the well defined floodplain area, it may be reasonable to assume that Flood Zone 3b is the same extent as Flood Zone 3a. The precautionary approach is further advised given the location of this area upstream of a potential structure constriction (for example if the culvert becomes blocked). In the absence of modelling for the site location, it is assumed conservatively that, under the effects of climate change, Flood Zone 3 will expand to cover the entire current Flood Zone 2.

Site	The Barn, Solesbridge Lane, Chorleywood
2d parameters	In the absence of detailed 2d modelling, no data is available in relation to flood depths, velocities, rate of onset of flooding and hazard.
Defences	According to the latest update of the National Flood and Coastal Defence Database (NFCDD) from the Environment Agency, there is a 1.5m high and 6m wide rectangular culvert of the River Chess crossing beneath the M25 – this has an indicative standard of 1000 year, but can only indirectly affect the site, which floods at lower return periods. However, without this large capacity culvert, backing up of flood water could worsen flooding at the site. No concerns are currently expressed over this defence in regard to its condition.
Access	Access to Solesbridge Lane remains clear in all flood events, although it may only be possible to go west – the road to the east is flooded by Flood Zones 3 and 2.
Flood Warning	A small part of the site, in the north-east corner, is within the "River Chess at Chenies, including Latimer and Sarratt" flood warning area.
Historical surface water flooding	None
Surface water modelling	The AStSWF shows barely any flooding on the site; just a few small patches of 'less' and 'intermediate' susceptibility in the far north-east corner. The FMfSW actually shows a little more flooding, although only marginally so. Again it is the far north-east corner that is shown as at risk of surface water flooding; shallow and deep flooding in the 1 in 200 year event, but only shallow flooding in the 1 in 30 year event. As the AStSWF and FMfSW outlines are determined from national-scale mapping, it is important to compare them to local data as a reality check. No historical surface water flooding is recorded for the site, which may mean the site is not susceptible, but surface water incidents traditionally have rarely been recorded and thus it may be that the site has flooded but no record exists.
Historical groundwater flooding	None
Geology and Groundwater mapping	The site is underlain by Chalk bedrock but appears to be just beyond the nearby superficial deposit of Alluvium. The Chalk is highly permeable (classified as a principal aquifer) and therefore poses a risk of flooding if groundwater levels reach the surface. The AStGWF indicates that less than 25% of the 1km square in which the site lies has geology and groundwater levels that may make the site susceptible to groundwater emerging. Whilst the site is located in the river valley it is just at the beginning of where the valley sides begin to slope upwards (to the west) so groundwater levels may be a bit further below the surface resulting in a slight reduction in the risk of groundwater emergence. As very little of the site is susceptible to surface water flooding, this supports there being a relatively low risk of groundwater flooding above the surface. However, basements may still be at risk.
Source Protection Zone	The site is in source protection zone 2, defined by a 400 day travel time from a point below the water table. This zone has a minimum radius of 250 or 500 metres around the source, depending on the size of the abstraction.
Summary of flood risk	Most of the site is in Flood Zone 1 but about a third is in Flood Zone 3. Only a small proportion of the site may be at risk of surface water flooding, although this includes some deep flooding. The site is at potential risk of groundwater flooding, although its slightly raised position may help reduce the risk.

Site	The Barn, Solesbridge Lane, Chorleywood
Development recommendations	The need for the Exception Text can be avoided by only locating housing in the Flood Zone 1 and 2 parts of the site. Housing is not permitted in Flood Zone 3b, and even if detailed modelling does find that this is much smaller than the current assumption of it equalling Flood Zone 3a, if the Flood Zone 3a area is allocated it is likely that expensive measures such as defences or land raising with flood storage compensation will be required in order to pass the Exception Test. As a further precaution, given that Flood Zone 2 is barely larger than Flood Zone 3, it is recommended that development is restricted to the Flood Zone 1 area so there is less loss of space for floodwater along the river corridor and so all housing has the lowest level of flood risk. If housing is proposed within Flood Zone 3 then modelling will be required to assess the extent of Flood Zone 3b (as only water compatible and essential infrastructure are allowed within this zone) and to obtain a better assessment of Flood Zones 2 and 3. It is also recommended that any detailed modelling as part of a Flood Risk Assessment allows for the assessment of flood depths, flood velocities, flood hazard and rate of onset of flooding within and in the vicinity of the site. Although the nearby culvert on the River Chess does not provide the indicated 1 in 1000 year standard of protection at the site, without this large capacity culvert, backing up of flood water could worsen flooding at the site. No concerns are currently expressed over this defence, however it is reliant upon maintenance continuing in the future to ensure capacity is maintained and that there are no blockages or collapse. Future planning applications need to consider how adequate maintenance of the defence will take place over the life of the development. Ground floor finished floor levels should be set 0.6m above the 1 in 100 year flood level or 0.3m above the 1 in 100 year with climate change flood level. Detailed modelling would be required to determine this level. For any buildings within Flood Zones 2 and 3, flood resilient design to be adopted for at least the lower 0.3m height of the ground floor. Access to Solesbridge Lane remains clear in all flood events, although it may only be possible to go west; this route should be used for safe access and egress. It is recommended that future Flood Risk Assessments allow for designing the development for potential groundwater risk. This could be achieved for example by making the lower 0.3m height of the ground floors flood resilient. Due to the risk of groundwater flooding, habitable basements are not recommended for this site. Any surface strategies for the proposed development need to be robust to ensure adequate protection against surface water flood risk. As the surface water outlines fall only within the Flood Zone 2 and 3 area, these floor levels will already be sufficiently raised based on fluvial flood heights. For the rest of the site, floor levels should be raised 0.15m above proposed surrounding ground levels. Site layouts should be designed to ensure that the flow of surface water runoff, to infiltration or discharge locations as appropriate, is not impeded, and so that the safe access routes are maintained.

Site	The Barn, Solesbridge Lane, Chorleywood
Development recommendations (continued)	It is recommended that SUDS be employed to manage surface runoff, in accordance with the surface water management train and the guidance in "Preliminary rainfall runoff management for developments". Drainage proposals must ensure no increase in the peak rate of stormwater runoff leaving the site, the volume of runoff leaving the site, or the pollution load to receiving waters from stormwater runoff for the lifetime of the development, including an allowance for the effects of climate change. It is possible that groundwater levels may be far enough below the surface in at least the west part of the site to allow sufficient space for infiltration devices. A site investigation would be needed to determine this. If not, it is recommended that runoff be discharged into the neighbouring watercourse using attenuation devices to control the rate and volume of runoff to greenfield characteristics. Green roofs are also recommended for use as attenuation storage; the volumes provided are typically small and thus significant only for smaller storms, however they provide other useful benefits such as encouraging biodiversity and improving air quality. Further information on calculating storage can be found in the Environment Agency Green Roof Toolkit at: http://www.environment-agency.gov.uk/business/sectors/91967.aspx. Rainwater harvesting is also recommended, with the additional benefit of reducing reliance on mains water supply – as a result it cannot normally be counted as part of the storage volumes as tanks are not completely emptied between events, but it does provide some informal storage potential. As the site is in source protection zone 2, it is important to ensure a high water quality of surface runoff discharging from the site, including treatment where necessary, to avoid contamination of the groundwater source. Even if discharged to the river, contamination may affect the aquifer as the river is in hydraulic connectivity. Naturally, a high water quality will also benefit the river itself. Flood Risk Assessments need to assess the effect of potential drain blockages on flood risk to the site. This will be the case for the drain that runs along the eastern boundary of the site, in particular if it crosses in a culvert beneath Solesbridge Lane.
Allocation Recommendation	It is recommended to only provisionally allocate this site until detailed modelling demonstrates that the Exception Test can be passed. Alternatively, it is recommended that the allocated site boundary is amended to exclude the conservative Flood Zone 2 outline.

10 Fairways Farm and Penfold Golf Course, Garston

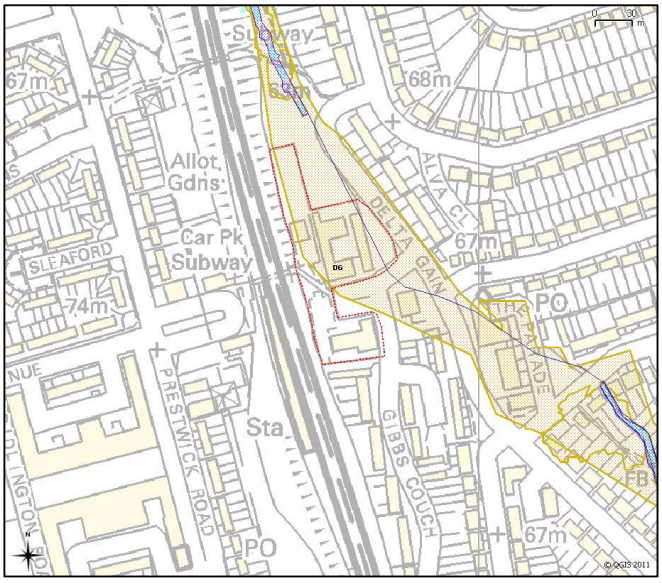
Site	Fairways Farm and Penfold Golf Course, Garston
ID	PG
Area	8.35ha
Current land use	Greenfield
Proposed land use	Not currently intending to allocate, but has been considered as a housing site with an indicative capacity of 350 dwellings.
NPPF vulnerability	The NPPF classification for housing is 'more vulnerable'. It would therefore be acceptable in Flood Zones 1 and 2, require the Exception Test for Flood Zone 3a, and would not be permitted in Flood Zone 3b.
Watercourses	A tributary of the River Colne (Bucknalls Brook) flows along the south-east border of the site. This section of the tributary is not classified as a main river, although, after disappearing into a culvert just south of the site, it becomes main river when it emerges in Garston Park.
Historical fluvial flooding	None
Flood Zones	The site currently has 1% of its area within Flood Zone 2 and 7% in Flood Zone 3. The remainder of the site is Flood Zone 1 (see Figure 10-1 below). Flood Zone 3 Flood Zone 2 Site Boundary  The existing flood extents are derived from JFlow. As there is no detailed modelling readily available for the site to provide the extents of Flood Zone 3b, it is recommended that this is provisionally assumed to cover the entire Flood Zone 3 within the site (i.e. no Flood Zone 3a). It is likely that Flood Zone 3b will not be this large and its actual extent can be determined using detailed modelling of the area, as part of a Flood Risk Assessment for a planning application. In the absence of detailed modelling for the site location, it is assumed conservatively that, under the effects of climate change, Flood Zone 3 will expand to cover the entire current Flood Zone 2.

Site	Fairways Farm and Penfold Golf Course, Garston
2d parameters	In the absence of detailed 2d modelling, no data is available in relation to flood depths, velocities, rate of onset of flooding and hazard. These however are not required if housing and access are not allocated within Flood Zone 3.
Defences	The site has no defences or upstream storage areas.
Access	Access to St Albans Road/North Orbital Road remains clear in all flood events however, access to Bucknalls Close is cut off and it is flooded by Flood Zones 2 and 3.
Flood Warning	The site is not in a flood warning area.
Historical surface water flooding	None
Surface water modelling	According to the AStSWF the south-east corner of the site is at risk of surface water flooding, mainly as 'more' and 'intermediate' susceptibility. There is also a small patch of 'less' susceptible flooding in the north of the site. The FMfSW shows a similar pattern of flooding, although generally of less extensive area. The patch in the north has only shallow flooding for both the 1 in 30 and 1 in 200 year scenarios. In the south-east corner there is also deep flooding for the 1 in 200 year scenario. The site does not have any deep flooding for the 1 in 30 year scenario. As the AStSWF and FMfSW outlines are determined from national-scale mapping, it is important to compare them to local data as a reality check. No historical surface water flooding is recorded for the site, which may mean the site is not susceptible, but surface water incidents traditionally have rarely been recorded and thus it may be that the site has flooded but no record exists.
Historical groundwater flooding	None
Geology and Groundwater mapping	The site is underlain by Chalk bedrock and superficial deposits of Alluvium. Both of these geologies are permeable and therefore pose a risk of groundwater flooding. The AStGWF indicates that less than 25% of the 1km square in which the site lies has geology and groundwater levels that may make the site susceptible to groundwater emerging. The eastern part of the site lies in the river valley so is probably in the emergence area, with groundwater flooding most likely to reach appreciable depths where surface water flooding is indicated. The west of the site is situated at the beginning of where the valley sides begin to slope upwards so groundwater levels may be a bit further below the surface resulting in a slight reduction in the risk of groundwater emergence. However, basements may still be at risk.
Source Protection Zone	The site is in source protection zone 2, defined by a 400 day travel time from a point below the water table. This zone has a minimum radius of 250 or 500 metres around the source, depending on the size of the abstraction.
Summary of flood risk	Most of the site is in Flood Zone 1 (92%) which has the lowest level of flood risk. A fairly small proportion of the site may be at risk of surface water flooding, although this includes some deep flooding in the south-east corner. The site is potentially at risk of groundwater flooding, although part of the site's slightly raised position may help reduce the risk in that area.

Site	Fairways Farm and Penfold Golf Course, Garston
Development recommendations	A sequential approach is recommended in planning the layout of buildings within the site. It is recommended in particular that, if housing is allocated to this site, only the Flood Zone 1 area is used. Given the similar extents of Flood Zones 2 and 3, there will be minimal difference in developable area. This would mean that the houses will all be at the lowest level of risk and will avoid the drains and culverts in the south-east of the site. It will also avoid much of the surface water flood risk within the site. There is no need for modelling (to assess Flood Zone 3b, the 1 in 100 year peak water levels with and without climate change and 2d parameters) if housing and access are not allocated within Flood Zones 2 and 3. This is because of the close proximity of Flood Zones 2 and 3 which indicates steep gradients towards Flood Zone 1. This also avoids the need for the Exception Test. It will be important however, that the ground floor finished floor levels are set at least 0.15m above the surrounding ground. Access to St Albans Road/North Orbital Road remains clear in all flood events; these routes should be used for safe dry access and egress. It is recommended that future Flood Risk Assessments allow for designing the development for potential groundwater risk. This could be achieved for example by making the lower 0.3m height of the ground floors flood resilient. Due to the risk of groundwater flooding, habitable basements are not recommended for this site. Any surface strategies for the proposed development need to be robust to ensure adequate protection against surface water flood risk. The surface water outlines correspond approximately to fluvial Flood Zones 2 and 3, therefore these floor levels will already be sufficiently raised based on fluvial flood heights. For the rest of the site, floor levels should be raised 0.15m above proposed surrounding ground levels. Site layouts should be designed to ensure that the flow of surface water runoff, to infiltration or discharge locations as appropriate, is not impeded, and so that the safe access routes are maintained. It is recommended that SUDS be employed to manage surface runoff, in accordance with the surface water management train and the guidance in "Preliminary rainfall runoff management for developments". Drainage proposals must ensure no increase in the peak rate of stormwater runoff leaving the site, the volume of runoff leaving the site, or the pollution load to receiving waters from stormwater runoff for the lifetime of the development, including an allowance for the effects of climate change. It is possible that groundwater levels may be far enough below the surface in at least the west part of the site to allow sufficient space for infiltration devices. A site investigation would be needed to determine this. If not, it is recommended that runoff be discharged into the neighbouring watercourse using attenuation devices to control the rate and volume of runoff to greenfield characteristics. Green roofs are also recommended for use as attenuation storage; the volumes provided are typically small and thus significant only for smaller storms, however they provide other useful benefits such as encouraging biodiversity and improving air quality. Further information on calculating storage can be found in the Environment Agency Green Roof Toolkit at: http://www.environment-agency.gov.uk/business/sectors/91967.aspx. Rainwater harvesting is also recommended, with the additional benefit of reducing reliance on mains water supply – as a result it cannot normally be counted as part of the storage volumes as tanks are not completely emptied between events, but it does provide some informal storage potential.

Site	Fairways Farm and Penfold Golf Course, Garston
Development recommendations (continued)	As the site is in source protection zone 2, it is important to ensure a high water quality of surface runoff discharging from the site, including treatment where necessary, to avoid contamination of the groundwater source. Even if discharged to the river, contamination may affect the aquifer as the river is in hydraulic connectivity. Naturally, a high water quality will also benefit the river itself. The impact of blockages of nearby drains on flood risk to the site needs to be assessed as part of a Flood Risk Assessment.
Allocation Recommendation	It is recommended that this site could be allocated with the provision that the above recommendations are followed.

11 Delta Gain, Carpenders Park

Site	Delta Gain, Carpenders Park
ID	DG
Area	0.8 ha
Current land use	Employment use
Proposed land use	Proposed employment allocation
NPPF vulnerability	The NPPF classification for buildings used for financial, professional and other services, offices and general industry in 'less vulnerable'. These would therefore be acceptable in Flood Zones 1, 2 and 3a but would not be permitted in Flood Zone 3b.
Watercourses	The site lies along one of the main tributaries of the River Colne (the Hartsbourne stream). According to the Environment Agency's main river map, the tributary passes through the centre-east of the site, although it is not visible in the OS mapping as it is culverted through this section.
Historical fluvial flooding	The Environment Agency historical flooding records indicate the site was flooded in 1988 and 1992, covering many kilometres of the Hartsbourne and about half the site in the north and east.
Flood Zones	The site currently has 60% of its area within Flood Zone 2 (see Figure 11-1 below). The remainder of the site is Flood Zone 1 (no Flood Zone 3). Flood Zone 3 Flood Zone 2 Site Boundary  In the absence of detailed modelling for the site location, it is assumed conservatively that, under the effects of climate change, Flood Zone 3 will expand to cover the entire current Flood Zone 2.
2d parameters	In the absence of detailed 2d modelling, no data is available in relation to flood depths, velocities and hazard.

Site	Delta Gain, Carpenders Park
Defences	The Environment Agency Datashare data indicates a flood storage area (FSA) about 1km upstream of the site which serves to attenuate flows through the Hartsbourne and the downstream River Colne. The design standard of protection of the FSA is 1000 years. The latest update of the National Flood and Coastal Defence Database (NFCDD) from the Environment Agency indicates the presence of three defence structures: a) the Hartsbourne Stream FSA embankment and culvert built in 1996, b) an upstream channel lined with concrete and c) a 339m long culvert (2m wide and 1.2m high) that crosses beneath the site. No concerns are currently expressed over these defences in regard to their condition. The site is at risk from the unlikely breach of the upstream FSA; as this information is confidential it has not been possible to provide details in this report.
Access	Road access to Delta Gain is cut off during a 1 in 1000 year event however not for the 1 in 100 year event. There is a railway underpass for pedestrian access into Prestwick Road from the site, which remains clear of Flood Zone 2.
Flood Warning	The site is not in a flood warning area.
Historical surface water flooding	None
Surface water modelling	The AStSWF predicts that most of the site is at risk of surface water flooding due to runoff flowing down the tributary and also from along the railway line to the west. About half the site, mainly the north-east, is in the 'more' susceptible category, the rest of the flooded area is of 'less' and 'intermediate' susceptibility. The FMfSW shows that the centre-east of the site is at risk of surface water flooding during a 1 in 30 year event, and a 1 in 200 year event also affects the north-east and south-east of the site. Flooding is only predicted from the river and not from the railway according to the FMfSW. As the AStSWF and FMfSW outlines are determined from national-scale mapping, it is important to compare them to local data as a reality check. No historical surface water flooding is recorded for the site, which may mean the site is not susceptible, but surface water incidents traditionally have rarely been recorded and thus it may be that the site has flooded but no record exists.
Historical groundwater flooding	None
Geology and Groundwater mapping	The site is underlain by Lambeth Group bedrock, with superficial deposits of Sand and Gravel over the north-east of the site. Both of these geologies are classified as permeable and therefore pose a risk of groundwater flooding. The AStGWF indicates that less than 25% of the 1km square in which the site lies has geology and groundwater levels that may make the site susceptible to groundwater emerging. However, the site's low-lying position in the river valley makes it more than likely to be in the emergence area. Groundwater flooding is most likely to reach appreciable depths in the parts of the site where surface water flooding is indicated.
Source Protection Zone	The site is not in a source protection zone.

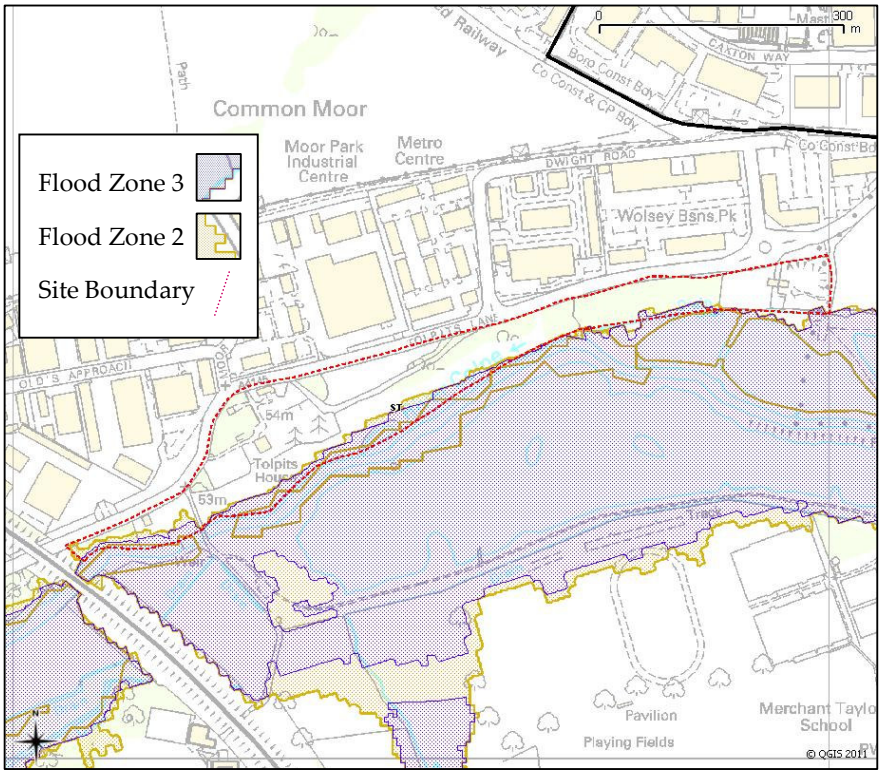
Site	Delta Gain, Carpenders Park
Summary of flood risk	The site is at relatively low fluvial flood risk and, being only flood zones 1 and 2, is suitable for the proposed uses. Although historical flooding has been recorded at the Delta Gain (1988, 1992) the FSA upstream was subsequently constructed reducing the flood risk to the site. The site is at risk from the unlikely breach of the upstream FSA; as this information is confidential it has not been possible to provide details in this report. Much of the site may be at risk of surface water flooding, with deep flooding in the north and centre-east. The site is potentially at high risk of groundwater flooding, although its slightly raised position may help reduce the risk.

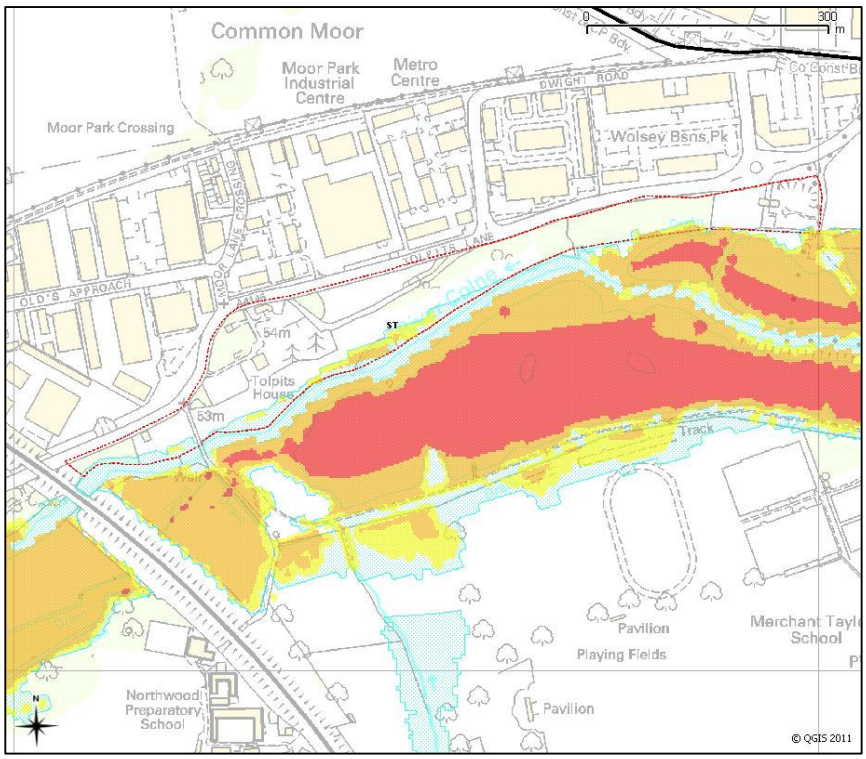
Site	Delta Gain, Carpenders Park
Development recommendations	A sequential approach is recommended in planning the layout of buildings within the site. It is recommended that the most vulnerable buildings be placed in the flood zone 1 areas where possible. Ground floor finished floor levels should be set 0.6m above the 1 in 100 year flood level or 0.3m above the 1 in 100 year with climate change flood level. Detailed modelling would be required to determine this level. If the Exception Test needs to be applied (if the proposed land uses change from being 'less vulnerable'), it is recommended that hydraulic modelling is carried out to test the combined effect of the standard of protection of defences (including a breach of the upstream FSA), taking into account the effects of climate change, and to ensure that they are now able to protect against flooding from an event such as in 1988 and 1992. For any buildings within Flood Zone 2 flood resilient design to be adopted for at least the lower 0.3m height of the ground floor. Road access to Delta Gain is cut off during a 1 in 1000 year event but not for the 1 in 100 year event. There is a railway underpass for pedestrian access into Prestwick Road from the site, which remains clear of Flood Zone 2. Safe access/egress should therefore be through Delta Gain or, in exceptional circumstances, through the railway underpass into Prestwick Road. It is recommended that future Flood Risk Assessments allow for designing the development for potential high groundwater levels. This could be achieved for example by making the lower 0.3m height of the ground floors flood resilient. Due to the high risk of groundwater flooding, habitable basements are not recommended for this site. Any surface strategies for the proposed development need to be robust to ensure adequate protection against surface water flood risk. As the surface water modelling outlines are more extensive than the fluvial outlines, and there is too little historical data to check the surface water modelling, it is recommended that floor levels of all properties be set at least 0.3m above proposed surrounding ground levels. Site layouts should be designed to ensure that the flow of surface water runoff, to infiltration or discharge locations as appropriate, is not impeded, and so that the safe access routes are maintained. It is recommended that SUDS be employed to manage surface runoff, in accordance with the surface water management train and the guidance in "Preliminary rainfall runoff management for developments". Drainage proposals must ensure no increase in the peak rate of stormwater runoff leaving the site, the volume of runoff leaving the site, or the pollution load to receiving waters from stormwater runoff for the lifetime of the development, including an allowance for the effects of climate change.

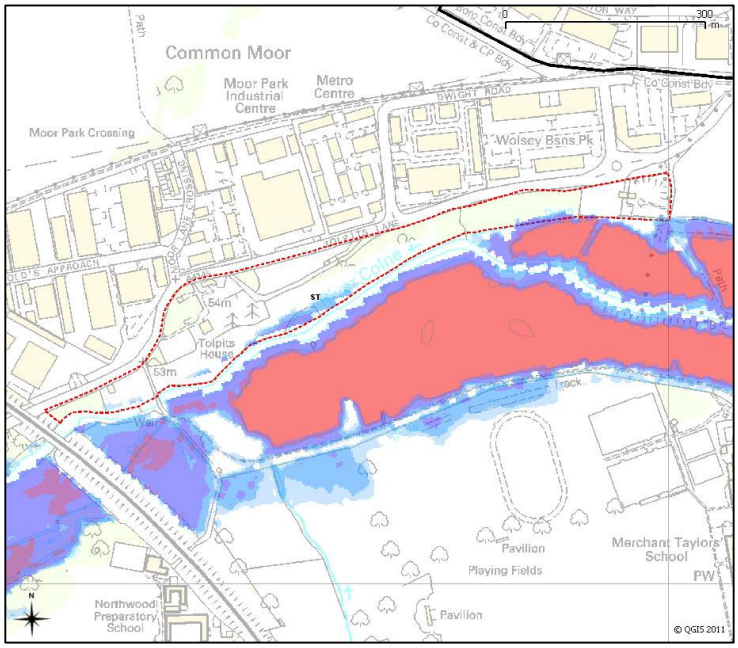
Site	Delta Gain, Carpenders Park
Development recommendations (continued)	It is possible that groundwater levels may be far enough below the surface to allow sufficient space for infiltration devices. A site investigation would be needed to determine this. If not, it is recommended that runoff be discharged into the neighbouring watercourse using attenuation devices to control the rate and volume of runoff to greenfield characteristics. Green roofs are also recommended for use as attenuation storage; the volumes provided are typically small and thus significant only for smaller storms, however they provide other useful benefits such as encouraging biodiversity and improving air quality. Further information on calculating storage can be found in the Environment Agency Green Roof Toolkit at: http://www.environment-agency.gov.uk/business/sectors/91967.aspx. Rainwater harvesting is also recommended, with the additional benefit of reducing reliance on mains water supply – as a result it cannot normally be counted as part of the storage volumes as tanks are not completely emptied between events, but it does provide some informal storage potential. The site is not in a source protection zone so water quality for runoff discharged from/infiltrated on site may be less stringent. Nevertheless, depending on the surface the runoff flows over, treatment may still be appropriate to avoid creating a local pollution problem. Whilst no concerns are currently expressed over the condition of the site's defences, they are reliant upon maintenance continuing in the future to ensure capacity is maintained and that there are no blockages or collapse. Future planning applications need to consider how adequate maintenance of the defences will take place over the life of the development. The redevelopment could be used as an opportunity to open up the culvert below the site, with hydraulic modelling used to ensure that the effect, in combination with the other defences, will keep the site safe in order to pass the Exception Test. A Flood Risk Assessment needs to assess the impact of potential blockage of the 339m long culvert that crosses beneath the site. Blockages need to be assessed in particular at the inlet of the culvert which is located upstream from the site. Ideally the effect of 25%, 50%, 75% and 100% blockages at the inlet of the culvert should be considered. The likelihood of these percentages of blockage needs to be assessed by visiting the site and assessing the likely sources of potential blockages (for example upstream trees, trolleys, tipping, etc). Any modelling would ideally include a 2D surface model and explicit representation of manholes along the culvert.
Allocation Recommendation	It is recommended to allocate this site with the provision that the above recommendations are followed.

12 South Tolpits Lane

Site	South Tolpits Lane
ID	ST
Area	6.7 ha
Current land use	Greenfield, with a few buildings
Proposed land use	Proposed allocation for housing with an indicative capacity of 50 dwellings.
NPPF vulnerability	The NPPF classification for housing is 'more vulnerable'. It would therefore be acceptable in Flood Zones 1 and 2, require the Exception Test for Flood Zone 3a, and would not be permitted in Flood Zone 3b.
Watercourses	The River Colne runs along most of the southern border of the site. There are also several lakes along the rest of the southern border and south of the river. One of the lakes is connected to a drain which runs along the site's south-eastern border.
Historical fluvial flooding	Fluvial flooding has occurred along the River Colne in July 1987. The two lakes just south of the site are indicated as 'flooded' during October 1987 – the water remains in the lakes (apart from a small area between them).
Flood Zones and Flood Extents	The site currently has 4% of its area within Flood Zone 2 and 12% in Flood Zone 3. The remainder of the site is Flood Zone 1 (see Figure 12-1 below).



Site	South Tolpits Lane
Flood Zones and Flood Extents (continued)	The latest Environment Agency flood mapping study indicates that the 1 in 20 year flood extent taking account of defences covers about 9% of the site area (these model extents can be considered as Flood Zone 3b). Flood Zones 3b and 3a cover therefore 9% and 3% of the site area respectively. The latest flood mapping study also indicates that the effect of climate change (by comparing the flood extents between the 1 in 100 year event and the 1 in 100 year plus climate change event) are small within the study area. The estimated increase in area of the 1 in 100 year flood extents is only 1% of the site area.
Flood Hazard	The hazard map for the 1 in 100 year plus climate change map taking account of defences, indicates small hazard areas ('risk for some' and 'risk for most' hazards, coloured in yellow and orange respectively) encroaching to the south of the site, as shown in Figure 12-2 below. 

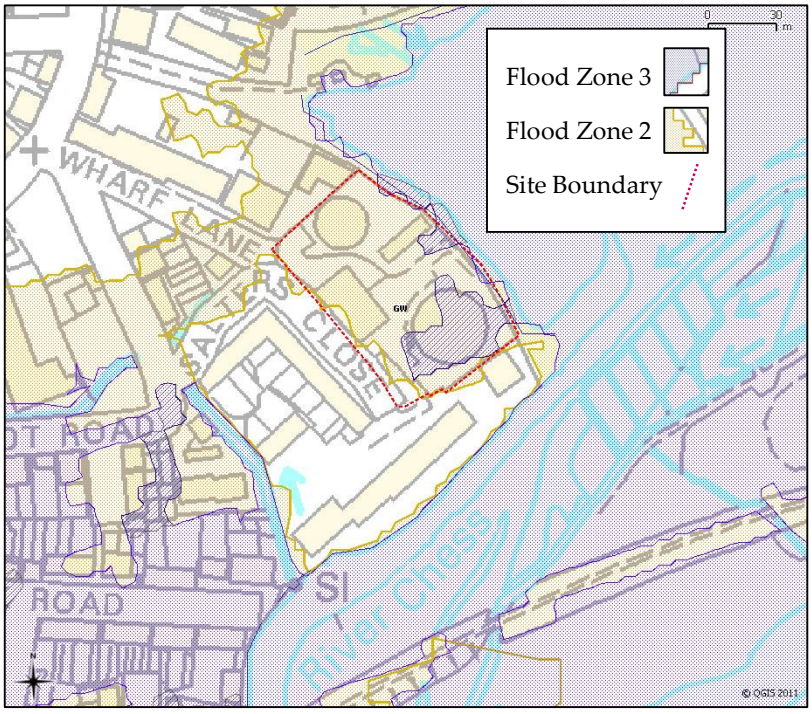
Site	South Tolpits Lane
Flood Depths and flow velocities	The 1 in 100 year event taking account of climate change and defences indicates that the site will flood up to 0.6m deep (dark blue areas shown in the Figure 12-3 below). The light blue areas indicate shallow flooding of around 0.2m deep. The red areas within the lake are very deep. Flow velocities within the site are estimated to be very small and less than 0.1m^3/s. 
Defences	The site has no defences. The flood storage areas in the Colne catchment are all well upstream of the site so any effect cannot be that significant.
Access	Access to Tolpits Lane, along the site's northern border, remains clear in all flood events.
Flood Warning	The site lies on the edge of the "The River Colne at Watford including Bushey" flood warning area, which encroaches a little way into the southern part of the site.
Historical surface water flooding	None
Surface water modelling	The AStSWF indicates surface water flooding will mainly flow along the rivers and lakes to the south of the site; encroaching only a few metres into the site. Most of the flooded area within the site is of 'intermediate' or 'less' susceptibility, with just a few small patches of 'more' susceptibility. There is also a small patch of 'less' susceptible in the site's north-west corner. The FMfSW shows even less flooding, with the flooded areas nearest the site appearing to be contained within the channels and lakes. As the AStSWF and FMfSW outlines are determined from national-scale mapping, it is important to compare them to local data as a reality check. No historical surface water flooding is recorded for the site, which may mean the site is not susceptible, but surface water incidents traditionally have rarely been recorded and thus it may be that the site has flooded but no record exists.
Historical groundwater flooding	None

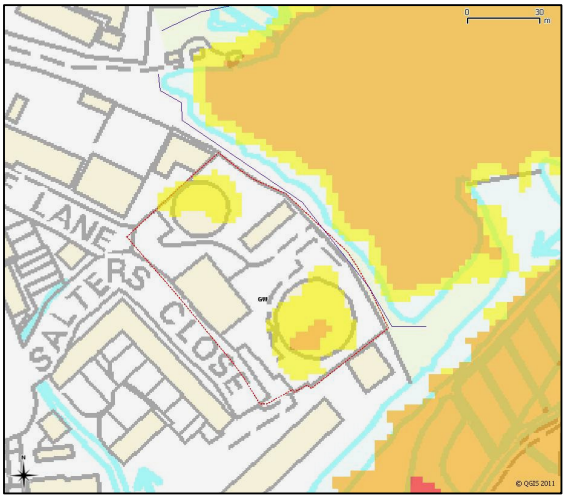
Site	South Tolpits Lane
Geology and Groundwater mapping	The site is underlain by Chalk bedrock with superficial deposits of Sand and Gravel in the north-west of the site and Alluvium along the southern border. These geologies are permeable and therefore pose a risk of groundwater flooding. The AStGWF suggests that the site lies within an area where the geology and groundwater levels may make the site susceptible to groundwater emerging, which is consistent with the permeable geology in combination with the site's location in the river valley where the low topography and nearby watercourse mean that groundwater levels are likely to be close to the surface. The south of the site, where most of the surface water flooding occurred is low-lying but the north begins to slope upwards so groundwater levels may be a bit further below the surface resulting in a slight reduction in the risk of groundwater emergence. However, basements may still be at risk.
Source Protection Zone	The site is in source protection zone 1, defined as the 50 day travel time from any point below the water table to the source. This zone has a minimum radius of 50 metres.
Summary of flood risk	Most of the site (84%) is in Flood Zone 1, 4% in Flood Zone2, 3% in Flood zone 3a and 9% in Flood Zone 3b. Only a small proportion of the site may be at risk of surface water flooding. The site is potentially at high risk of groundwater flooding, although the slightly raised position of the northern part may help reduce the risk in that area.
Development recommendations	Due to the relatively large size of Flood Zone 1 and the similarity of Flood Zones 2 and 3, it is recommended that housing is placed only in Flood Zone 1, with only water compatible uses in the higher risk flood zones. As well as avoiding the need for the Exception Test, this results in less loss of space for floodwater along the river corridor and means all housing has the lowest level of flood risk. Ground floor finished floor levels should be set 0.3m above the 1 in 100 year with climate change flood level, as estimated from the latest flood mapping outputs from the Environment Agency. For any buildings within Flood Zone 2 and 3, flood resilient design to be adopted for at least the lower 0.3m height of the ground floor. Access to Tolpits Lane, along the site's northern border, remains clear in all flood events. This route should be used for safe access to/egress from the site. It is recommended that future Flood Risk Assessments allow for designing the development for potential high groundwater levels. This could be achieved for example by making the lower 0.3m height of the ground floors flood resilient. Due to the risk of groundwater flooding, habitable basements are not recommended for this site. Any surface strategies for the proposed development need to be robust to ensure adequate protection against surface water flood risk. As the surface water outlines fall only within the Flood Zone 2 and 3 area, these floor levels will already be sufficiently raised based on fluvial flood heights. For the rest of the site, floor levels should be raised 0.15m above proposed surrounding ground levels. Site layouts should be designed to ensure that the flow of surface water runoff, to infiltration or discharge locations as appropriate, is not impeded, and so that the safe access routes are maintained.

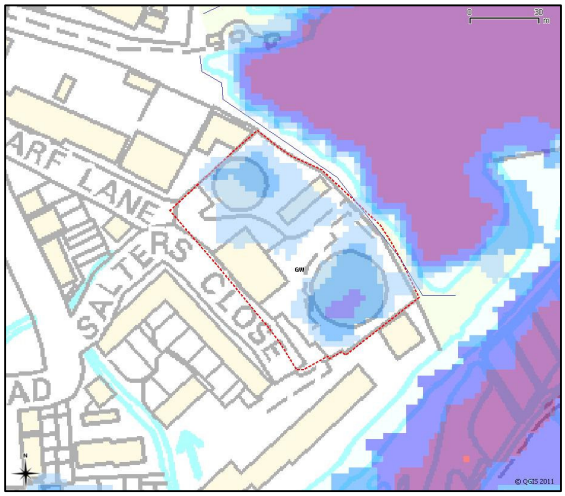
Site	South Tolpits Lane
Development recommendations (continued)	It is recommended that SUDS be employed to manage surface runoff, in accordance with the surface water management train and the guidance in "Preliminary rainfall runoff management for developments". Drainage proposals must ensure no increase in the peak rate of stormwater runoff leaving the site, the volume of runoff leaving the site, or the pollution load to receiving waters from stormwater runoff for the lifetime of the development, including an allowance for the effects of climate change. It is possible that groundwater levels may be far enough below the surface in at least the north part of the site to allow sufficient space for infiltration devices. A site investigation would be needed to determine this. If not, it is recommended that runoff be discharged into the neighbouring watercourse using attenuation devices to control the rate and volume of runoff to greenfield characteristics. Green roofs are also recommended for use as attenuation storage; the volumes provided are typically small and thus significant only for smaller storms, however they provide other useful benefits such as encouraging biodiversity and improving air quality. Further information on calculating storage can be found in the Environment Agency Green Roof Toolkit at: http://www.environment-agency.gov.uk/business/sectors/91967.aspx. Rainwater harvesting is also recommended, with the additional benefit of reducing reliance on mains water supply – as a result it cannot normally be counted as part of the storage volumes as tanks are not completely emptied between events, but it does provide some informal storage potential. The impact of blockages of nearby drains on flood risk to the site needs to be assessed as part of a Flood Risk Assessment. As the site is in source protection zone 1, it is particularly important to ensure a high water quality of surface runoff discharging from the site, including treatment where necessary, to avoid contamination of the groundwater source since there is very little time for natural degradation and dilution of pollutants in the soil. Even if discharged to the river, contamination may affect the aquifer as the river is in hydraulic connectivity. Naturally, a high water quality will also benefit the river itself.
Allocation Recommendation	It is recommended to allocate this site with the provision that the above recommendations are followed.

13 Gas Works, Salters Close, Rickmansworth

Site	Gas Works, Salters Close, Rickmansworth
ID	GW
Area	0.6 ha
Current land use	Industrial
Proposed land use	Proposed allocation for housing with an indicative capacity of 20 dwellings.
NPPF vulnerability	The NPPF classification for housing is 'more vulnerable'. It would therefore be acceptable in Flood Zones 1 and 2, require the Exception Test for Flood Zone 3a, and would not be permitted in Flood Zone 3b.
Watercourses	The River Chess runs past the east and west of the site, about 30m away. The Town Ditch, which runs from the River Chess to the River Colne, passes about 70m away from the site's western border. There is also a lake just beside the site's eastern border.
Historical fluvial flooding	None
Flood Zones and Flood Extents	The site currently has 72% of its area within Flood Zone 2 and 21% in Flood Zone 3a (7% in Flood Zone 1). There is no Flood Zone 3b as the 1 in 20 year flood extents taking account of defences from the latest flood mapping outputs do not encroach into the site (see Figure 13-1 below).



Site	Gas Works, Salters Close, Rickmansworth
Flood Zones and Flood Extents (continued)	The hatching within Flood Zone 3a in the site area (see figure above) indicates that the site is actually protected by defences (in particular the Chess Wall) for the 1 in 100 year flood event. This protected hatched area is defined as an Area Benefiting from Defences (ABD). Although the 1 in 100 year flood extents taking account of defences do not show flooding of the site, this will not be the case for the same run taking account of climate change. The outputs indicate that around 80% of the site will be flooded in the future and only a narrow fringe to the west will not be flooded. As this climate change case also takes account of the presence of defences (located along the north eastern boundary of the site), this means that flooding would occur as a result of overtopping of the Chess wall.
Flood Hazard	The hazard map for the 1 in 100 year plus climate change map taking account of defences, indicates small hazard areas ('risk for some' and 'risk for most' hazards, coloured in yellow and orange respectively), as shown in the Figure 13-2 below. It may be worth noting that this high hazard may be due to LiDAR filtering of the gas storage tanks, resulting in artificial holes within the DTM. The site boundary is shown in red highlight. Although these results are not critical for the development, it will be important that the detailed design of the development takes account of these hazards (in particular assessing a detailed topographic survey of the site to assess the likely hazard within the boundary). 

Site	Gas Works, Salters Close, Rickmansworth
Flood Depths and Flow Velocities	The 1 in 100 year event taking account of climate change and defences indicates that the site will flood up to 0.5m deep (dark blue area in Figure 13-3 below). Less deep areas of 0.3m are shown in blue and shallow areas (around 0.1-0.2m) in light blue. Flow velocities are less than 0.05m/s. As mentioned previously LiDAR filtering may be the cause of the low points of the site and as such the actual likely maximum depths may be less than the 0.5m depths modelled. 
Defences	The latest update of the National Flood and Coastal Defence Database (NFCDD) from the Environment Agency indicates the presence of a raised defence running between the edge of the site and the lake to the north east of the site. This small height defence (around 0.2m) is called the Chess wall and it forms part of the River Chess Flood Alleviation Scheme. The defence has a design standard of 100 years. As the defence protects areas within the site these areas are called Areas Benefiting from Defences (ABDs). No concerns are currently expressed over this defence, however inspection is recommended to make sure, with any detected weaknesses being identified and resolved prior to development.
Access	Access from the site to Salters Lane and Wharf Close remains clear during a 1 in 100 year event but both are flooded by the 1 in 1000 year. Assuming the defences are in place, access remains clear for the 1 in 100 year climate change scenario (no outputs are available for the undefended case).
Flood Warning	The site lies within the "River Chess at Loudwater" and the "River Colne at Rickmansworth" flood warning areas.
Historical surface water flooding	None within the site, however surface water flooding has been experienced over a large area between Talbot Road and High Street, to the west of the site.
Surface water modelling	The AStSWF indicates surface water flooding of 'intermediate' susceptibility over most of the site, and flooding of 'less' susceptibility along the western border. The FMfSW does not predict any flooding on site. As the AStSWF and FMfSW outlines are determined from national-scale mapping, it is important to compare them to local data as a reality check. No historical surface water flooding is recorded for the site, which may mean the site is not susceptible, but surface water incidents traditionally have rarely been recorded and thus it may be that the site has flooded but no record exists.
Historical groundwater flooding	None

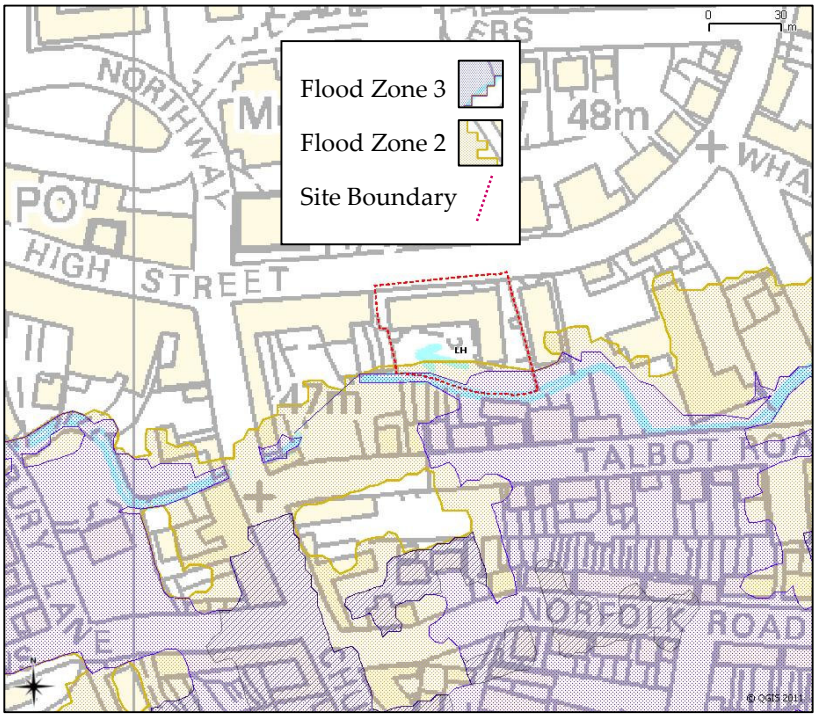
Site	Gas Works, Salters Close, Rickmansworth
Geology and Groundwater mapping	The site is underlain by Chalk bedrock and superficial deposits of Alluvium. These geologies are permeable and therefore pose a risk of groundwater flooding. Whilst no groundwater flooding incidents have been recorded on site, one has occurred just 440m away in at least the same superficial geology layers, and the bedrock, although a different type of Chalk, is likely to behave similarly. The AStGWF suggests that the site lies within an area where the geology and groundwater levels may make the site susceptible to groundwater emerging, which is consistent with the permeable geology in combination with the site's location in the river valley where the low topography and nearby watercourse mean that groundwater levels are likely to be close to the surface.
Source Protection Zone	The site is in source protection zone 1, defined as the 50 day travel time from any point below the water table to the source. This zone has a minimum radius of 50 metres.
Summary of flood risk	Most of the site is in Flood Zone 2 (72%) and 3a (21%). Housing is required to pass the Exception Test to be located in Flood Zone 3a. The site may be at risk of surface water flooding. The site is potentially at high risk of groundwater flooding.

Site	Gas Works, Salters Close, Rickmansworth
Development recommendations	A sequential approach is required when planning the layout of buildings within the site. It is recommended that only the Flood Zone 1 then 2 part of the site are used for housing due to their relatively large combined area. In the event that the Flood Zone 3a area is proved to be absolutely required for housing, there will be a need to develop robust mitigation measures to ensure the passing of the Exception Test. Ground floor finished floor levels should be 0.3m above the 1 in 100 year with climate change flood level, as estimated from the latest flood mapping outputs from the Environment Agency. For any buildings within Flood Zone 2 and 3, flood resilient design to be adopted for at least the lower 0.5m height of the ground floor. Independently of the spatial allocation of land uses within the site, the Chess wall defence will need to be raised to ensure that the development is protected for the 1 in 100 year event taking account of climate change (for year 2115). As mentioned above if such an event occurred in 100 years time, without raising of the defence, the site would flood by about 80%. The crest level of the defence needs to include a freeboard for uncertainties and wave allowance. In order to avoid the excluded flood water from increasing flood risk elsewhere, compensation storage will need to be provided. Ideally level-for-level compensation storage should be provided on site, but if necessary a suitable nearby site may be used with over compensation of storage – modelling would be needed to ensure no increase in flood risk elsewhere. Either way, it is important that present development takes this future issue into consideration now so as to ensure that land will be available – ideally the storage area could be built now in readiness. It is likely that there will be a need for the developer to take responsibility for the defence in terms of its maintenance and/or future upgrades. The CFMP for this area does not give certainty that defences will be retained in the long term and therefore the responsibility will need to lie with the developer. Future planning applications need therefore to ensure maintenance of the defence with continuous monitoring to ensure the condition is maintained over the life of the development. Access from the site to Salters Close and Wharf Lane remains clear during a 1 in 100 year event taking account of climate change; this route should therefore be used for safe access and egress. It is recommended that future Flood Risk Assessments allow for designing the development for potential high groundwater levels. This could be achieved for example by making the lower 0.3m height of the ground floors flood resilient. Due to the risk of groundwater flooding, habitable basements are not recommended for this site. Any surface strategies for the proposed development need to be robust to ensure adequate protection against surface water flood risk. Finished floor levels of properties beyond Flood Zone 3a with climate change to be set 0.3m above proposed surrounding ground levels as a precaution since the town centre is known to have suffered historical flooding. Site layouts should be designed to ensure that the flow of surface water runoff, to infiltration or discharge locations as appropriate, is not impeded, and so that the safe access routes are maintained.

Site	Gas Works, Salters Close, Rickmansworth
Development recommendations (continued)	Even if there is currently no risk of surface water flooding on site, it is recommended that SUDS be employed to manage surface runoff, in accordance with the surface water management train and the guidance in "Preliminary rainfall runoff management for developments" in order to ensure flood risk is not worsened on site or to the surrounding area. Drainage proposals must ensure no increase in the peak rate of stormwater runoff leaving the site, the volume of runoff leaving the site, or the pollution load to receiving waters from stormwater runoff for the lifetime of the development, including an allowance for the effects of climate change. Analysis of the site suggests that groundwater levels may be too high for infiltration SUDS and therefore it is recommended that runoff be discharged into the neighbouring watercourse using attenuation devices to control the rate and volume of runoff to greenfield characteristics. Green roofs are also recommended for use as attenuation storage; the volumes provided are typically small and thus significant only for smaller storms, however they provide other useful benefits such as encouraging biodiversity and improving air quality. Further information on calculating storage can be found in the Environment Agency Green Roof Toolkit at: http://www.environment-agency.gov.uk/business/sectors/91967.aspx. Rainwater harvesting is also recommended, with the additional benefit of reducing reliance on mains water supply – as a result it cannot normally be counted as part of the storage volumes as tanks are not completely emptied between events, but it does provide some informal storage potential. As the site is in source protection zone 1, it is particularly important to ensure a high water quality of surface runoff discharging from the site, including treatment where necessary, to avoid contamination of the groundwater source since there is very little time for natural degradation and dilution of pollutants in the soil. Even if discharged to the river, contamination may affect the aquifer as the river is in hydraulic connectivity. Naturally, a high water quality will also benefit the river itself. The impact of blockages of nearby drains on flood risk to the site needs to be assessed as part of a Flood Risk Assessment.
Allocation Recommendation	It is recommended to only provisionally allocate this site until detailed modelling /assessment demonstrates that the Exception Test can be passed.

14 Langwood House, High Street, Rickmansworth

Site	Langwood House, High Street, Rickmansworth
ID	LH
Area	0.3 ha
Current land use	Offices
Proposed land use	Proposed allocation for housing with an indicative capacity of 15 dwellings.
NPPF vulnerability	The NPPF classification for housing is 'more vulnerable'. It would therefore be acceptable in Flood Zones 1 and 2, require the Exception Test for Flood Zone 3a, and would not be permitted in Flood Zone 3b.
Watercourses	The Town Ditch, which runs from the River Chess to the River Colne, runs along the site's southern border. The River Chess is about 210m to the south-east and the River Colne about 430m to the south-west.
Historical fluvial flooding	None

Site	Langwood House, High Street, Rickmansworth
Flood Zones	The site currently has 9% of its area within Flood Zone 2 and 11% in Flood Zone 3a (see Figure 14-1 below). The remainder of the site is Flood Zone 1 (there is no Flood Zone 3b as the watercourse remains in-bank for the 1 in 20 year event taking account of defences).  The flood mapping outputs from the Environment Agency model indicates that the effects of climate change for the 1 in 100 year event, will result in an increase of around 5% (when compared to the total site area) of flooding of the site. The design of the development needs to take account of this. The hatching within Flood Zone 3a shows ABDs (there are none within the site).
Flood Hazard	The outputs of the Environment Agency flood mapping model for the 1 in 100 year event taking account of climate change and defences indicate that there is no flood hazard within the site. The reason for this is that the flooding on the southern part of the site is only shallow and with low velocities.
Flood Depths and Flow Velocities	The maximum depth of flooding within the site is estimated as less than 0.3m and flood velocities less than 0.2m3/s.
Defences	The latest update of the National Flood and Coastal Defence Database (NFCDD) from the Environment Agency indicates the presence of a twin culvert (0.5m diameter) located downstream from the site and along the Town Ditch. Blockage of this culvert could result in increased flood risk to the site due to water backing up. No concerns are currently expressed over this defence however it is reliant upon maintenance continuing in the future, to ensure capacity is maintained and that there are no blockages or collapse.
Access	Access to the High Street remains clear in all fluvial flood events. However, the flooded area for the historical surface water event suggests that access along the High Street was cut off at the time.

Site	Langwood House, High Street, Rickmansworth
Flood Warning	The southern part of the site is within the "River Chess at Loudwater" and the "River Colne at Rickmansworth" flood warning areas.
Historical surface water flooding	The site lies within a major surface water flooding area. The majority of the drainage systems in Rickmansworth drain into the Town Ditch (70% of highway drainage). The conveyance capacity of the Town Ditch is limited by: its dimensions, poor maintenance (siltation), use as a water feature in back gardens and numerous flat culverts (Bury Lane) and bridge crossings. When the Town Ditch reaches full capacity during a flood event, the surface water drainage systems cannot discharge into the ditch causing backup and flooding of commercial properties on the High Street and properties in adjoining roads (Ebury Road and Wensum Way).
Surface water modelling	The AStSWF indicates surface water flooding of 'less' and 'intermediate' susceptibility in the southern part of the site. The FMfSW predicts only a little shallow flooding in the south-east corner of the site for the 1 in 30 and 1 in 200 year scenarios. Both modelled flood maps appear to underpredict surface water flooding on site, and in the surrounding area, compared to the historical flooding.
Historical groundwater flooding	None
Geology and Groundwater mapping	The site is underlain by Chalk bedrock with superficial deposits of Alluvium over most of the site and Sand and Gravel along the northern border. These geologies are permeable and therefore pose a risk of groundwater flooding. Whilst no groundwater flooding incidents have been recorded on site, one has occurred just 500m away in at least the same superficial geology layers, and the bedrock, although a different type of Chalk, is likely to behave similarly. The AStGWF suggests that the site lies within an area where the geology and groundwater levels may make the site susceptible to groundwater emerging, which is consistent with the permeable geology in combination with the site's location in the river valley where the low topography and nearby watercourse mean that groundwater levels are likely to be close to the surface. Groundwater flooding is most likely to reach appreciable depths in the parts of the site where surface water flooding is indicated - historical records suggest all of the site.
Source Protection Zone	The site is in source protection zone 1, defined as the 50 day travel time from any point below the water table to the source. This zone has a minimum radius of 50 metres.
Summary of flood risk	Most of the site is in Flood Zone 1 but about a tenth is in Flood Zone 3a for which housing would be required to pass the Exception Test. The site is at high risk of surface water flooding due to the lack of capacity (and/or poor maintenance) of the Town Ditch which results in backing up of surface water drains and flooding of the High Street and the site. The site is potentially at high risk of groundwater flooding.

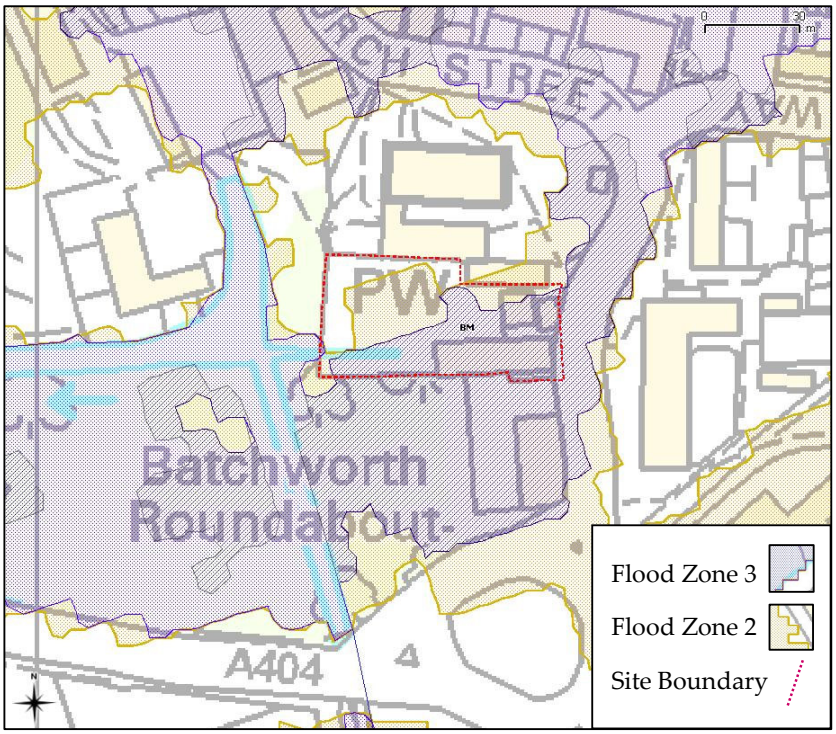
Site	Langwood House, High Street, Rickmansworth
Development recommendations	A sequential approach is recommended in planning the layout of buildings within the site. If possible, it is recommended that only the Flood Zone 1 then Flood Zone 2 parts of the site are used for housing as it appears that there is sufficient land available in order to avoid the need for the Exception Test which will probably require expensive measures such as defences or land raising with flood storage compensation. Furthermore, the CFMP does not have a strong policy for retaining defences in this area. Ground floor finished floor levels should be 0.3m above the 1 in 100 year with climate change flood level, as estimated from the latest flood mapping outputs from the Environment Agency.

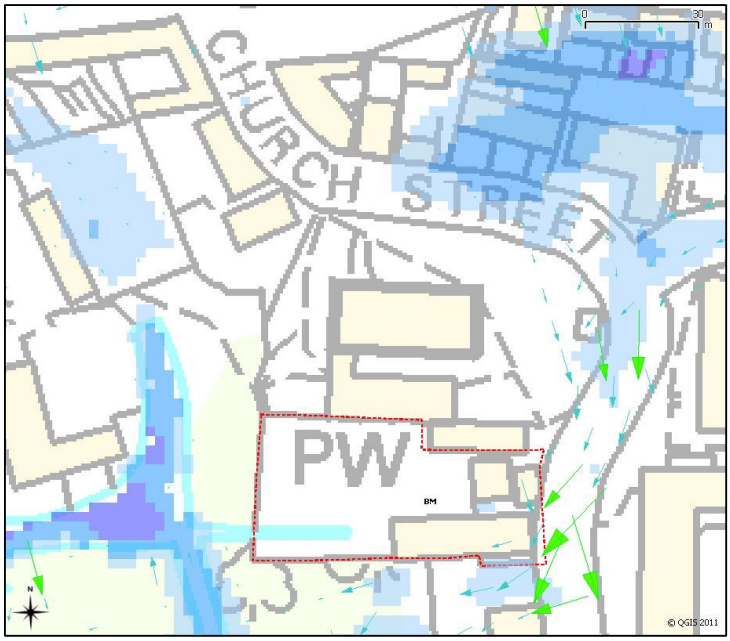
Site	Langwood House, High Street, Rickmansworth
Development recommendations (continued)	For any buildings within Flood Zones 2 and 3, flood resilient design to be adopted for at least the lower 0.5m height of the ground floor. It is recommended that future Flood Risk Assessments allow for designing the development for potential high groundwater levels. This could be achieved for example by making the lower 0.3m height of the ground floors flood resilient. Due to the risk of groundwater flooding, habitable basements are not recommended for this site. As Hertfordshire County Council is a Lead Local Flood Authority (LLFA) and responsible for surface water flooding, they will need to be consulted on the local flood risk in the area, which directly affects the site. If there is any scheme to relieve surface water flooding in the area promoted by the LLFA, the developer may need to contribute towards it. Due to the high risk of surface water flooding in the site (unless there is a scheme in place by the LLFA or the developer proposes significant improvements to the Town Ditch), it is recommended that the finished floor levels of buildings are placed 0.6m above surrounding ground levels. The layout of the buildings should allow for corridors where surface runoff can flow from the High Street towards the Town Ditch. Whilst no concerns are currently expressed over the condition of the Town Ditch culvert downstream from the site, it is reliant upon maintenance continuing in the future to ensure capacity is maintained and that there are no blockages or collapse. Future planning applications need therefore to ensure maintenance of the defence with continuous monitoring to ensure the condition is maintained over the life of the development. Detailed 2d surface water modelling which includes the pipe network system may be required to demonstrate that the site is safe from surface water flood risk and that there is no increase of flood risk elsewhere. The modelling needs to also consider the blockage conditions of culverts on the Town Ditch. Ideally the effect of 25%, 50%, 75% and 100% blockages should be considered. The likelihood of these percentages of blockage needs to be assessed by visiting the site and assessing the likely sources of potential blockages (for example upstream trees, trolleys, tipping, etc). Access to the High Street remains clear in all fluvial flood events. However, the flooded area for the historical surface water event suggests that access along the High Street was cut off at the time. Evacuation plans need to consider for this eventuality and make use, if possible, of improved estimates of surface water flood depths, hazards and velocities. It is recommended that SUDS be employed to manage surface runoff, in accordance with the surface water management train and the guidance in "Preliminary rainfall runoff management for developments". Drainage proposals must ensure no increase in the peak rate of stormwater runoff leaving the site, the volume of runoff leaving the site, or the pollution load to receiving waters from stormwater runoff for the lifetime of the development, including an allowance for the effects of climate change.

Site	Langwood House, High Street, Rickmansworth
Development recommendations (continued)	In view of the history of surface water flooding, the Exception Test is recommended to be passed in relation to surface water flood risk. This is appropriate as it will ensure that surface water risk is not only not increased elsewhere, but reduced where possible. Analysis of the site suggests that groundwater levels may be too high for infiltration SUDS and therefore it is recommended that runoff be discharged into the neighbouring watercourse using attenuation devices to control the rate and volume of runoff to greenfield characteristics. Green roofs are also recommended for use as attenuation storage; the volumes provided are typically small and thus significant only for smaller storms, however they provide other useful benefits such as encouraging biodiversity and improving air quality. Further information on calculating storage can be found in the Environment Agency Green Roof Toolkit at: http://www.environment-agency.gov.uk/business/sectors/91967.aspx Rainwater harvesting is also recommended, with the additional benefit of reducing reliance on mains water supply – as a result it cannot normally be counted as part of the storage volumes as tanks are not completely emptied between events, but it does provide some informal storage potential. As the site is in source protection zone 1, it is particularly important to ensure a high water quality of surface runoff discharging from the site, including treatment where necessary, to avoid contamination of the groundwater source since there is very little time for natural degradation and dilution of pollutants in the soil. Even if discharged to the river, contamination may affect the aquifer as the river is in hydraulic connectivity. Naturally, a high water quality will also benefit the river itself.
Allocation Recommendation	It is recommended to allocate this site with the provision that the above recommendations are followed.

15 Bridge Motors, Church Street, Rickmansworth

Site	Bridge Motors, Church Street, Rickmansworth
ID	BM
Area	0.3 ha
Current land use	Industrial
Proposed land use	Proposed allocation for housing with an indicative capacity of 20 dwellings.
NPPF vulnerability	The NPPF classification for housing is 'more vulnerable'. It would therefore be acceptable in Flood Zones 1 and 2, require the Exception Test for Flood Zone 3a, and would not be permitted in Flood Zone 3b.
Watercourses	A drainage channel emerges within the site and flows west to join another drainage channel, which runs from the River Chess to the River Colne and passes within 20m of the site's south-west corner. The Town Ditch drainage channel, also passing between these two rivers, passes the site 180m to the north. The River Chess curves around the east and south of the site, about 140m either way. The Grand Union Canal passes about 150m to the south of the site.
Historical fluvial flooding	None

Site	Bridge Motors, Church Street, Rickmansworth
Flood Zones	The site currently has 30% of its area within Flood Zone 2 and 51% is in Flood Zone 3a (see Figure 15-1 below). The remainder of the site is Flood Zone 1 (there is no Flood Zone 3b as the watercourse remains in-bank for the 1 in 20 year event taking account of defences). 
Flood Zones (continued)	The hatching within Flood Zone 3a in the site area (see figure above) indicates that the site is actually protected by defences for the 1 in 100 year flood event. This protected hatched area is defined as an Area Benefiting from Defences (ABD). The flood mapping outputs from the Environment Agency model indicate no flooding of the site for the 1 in 100 year flood event, taking account of defences. The effect of climate change of the same event will however result in flooding of around 20% of the site area (eastern side).

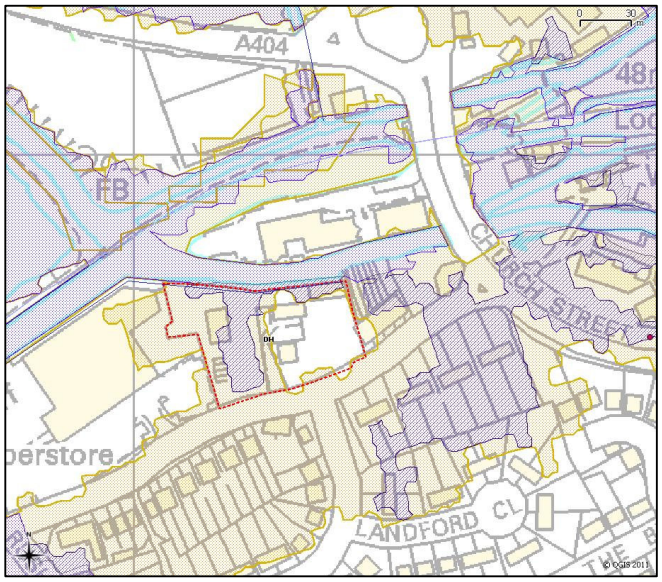
Site	Bridge Motors, Church Street, Rickmansworth
Flood Hazard, Flood Depths and Flow Velocities	The outputs of the Environment Agency flood mapping model for the 1 in 100 year event taking account of climate change and defences indicate that there is no flood hazard within the site. The reason for this is that flood depths and flow velocities are very small and are confined to a small area in the eastern part of the site, where flooding enters from Church Street (Figure 15-2 to the right). The flow arrows indicate main flow directions. Green arrows indicate high flow velocities of 0.5-1m/s along Church Street and light blue arrows within the site indicate flow velocities of around 0.2m/s. The depth of flooding shown as light blue in the small blue rectangle within the site is around 0.1m. 
Defences	This site is heavily dependent on the main defences to the north of Church Street, as if these breached, there may not be safe access along Church Street (Flood Zone 3 covers the entire site including Church Street opposite the site). Currently there are no concerns over the main defences however it is reliant upon maintenance continuing in the future. The latest update of the National Flood and Coastal Defence Database (NFCDD) from the Environment Agency indicates the presence of a 2m wide and 1.5m culvert running beneath the A404 to the south of the site. Blockage of this culvert could result in increased flood risk to the site due to water backing up. No concerns are currently expressed over this defence, however it is reliant upon maintenance continuing in the future to ensure capacity is maintained and that there are no blockages or collapse.
Access	Part of the site is benefiting from defences in the area (in the sense that should these not work during a 1 in 100 year event, flooding of the bottom half of the site would occur). Provided the defences in the area work, vehicular access should be possible from the site by travelling south down Church Street and onto the A404. It is important to note that due to the high flow velocities along Church Street, safe access may not be possible for all (in particular people, children and elderly).
Flood Warning	The site lies within the "River Chess at Loudwater" and the "River Colne at Rickmansworth" flood warning areas.
Historical surface water flooding	None

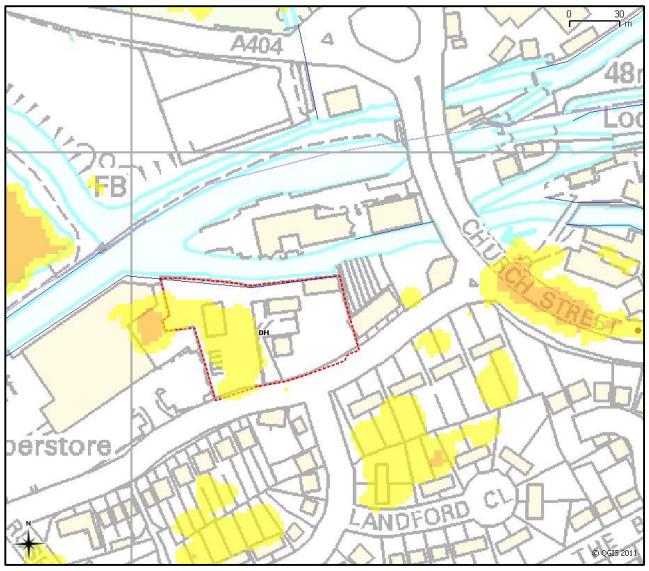
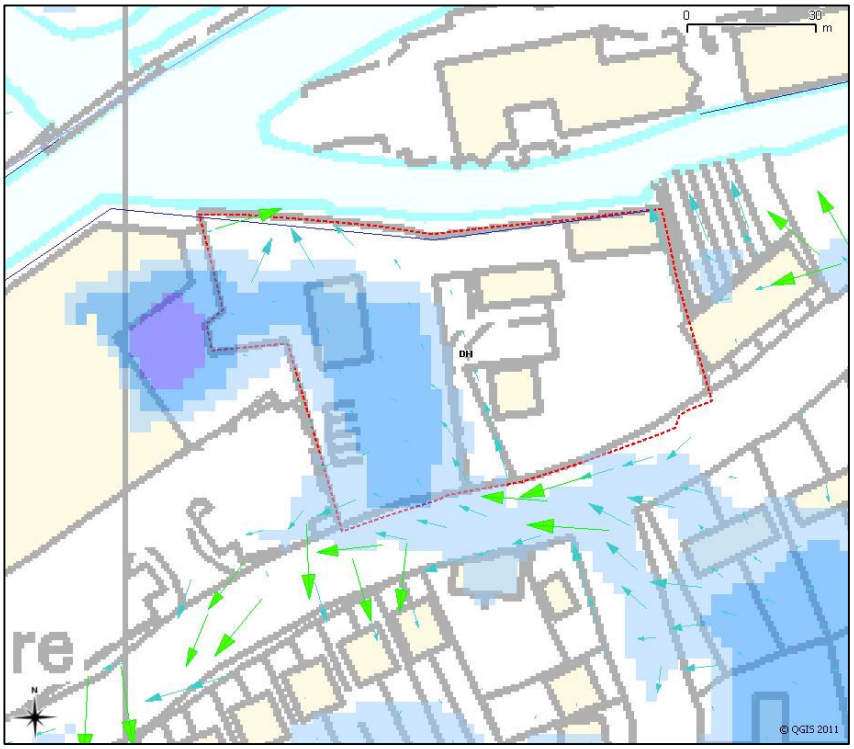
Site	Bridge Motors, Church Street, Rickmansworth
Surface water modelling	According to the AStSWF the most of the site is at 'intermediate' susceptibility to surface water flooding. The borders of the site are at 'less' susceptibility. The FMfSW does not indicate any surface water flooding on site. As the AStSWF and FMfSW outlines are determined from national-scale mapping, it is important to compare them to local data as a reality check. No historical surface water flooding is recorded for the site, which may mean the site is not susceptible, but surface water incidents traditionally have rarely been recorded and thus it may be that the site has flooded but no record exists.
Historical groundwater flooding	None
Geology and Groundwater mapping	The site is underlain by Chalk bedrock and superficial deposits of Alluvium. Both of these geologies are permeable and therefore pose a risk of groundwater flooding. Whilst no groundwater flooding incidents have been recorded on site, one has occurred just 315m away in at least the same superficial geology layers, and the bedrock, although a different type of Chalk, is likely to behave similarly. The AStGWF suggests that the site lies within an area where the geology and groundwater levels may make the site susceptible to groundwater emerging, which is consistent with the permeable geology in combination with the site's location in the river valley where the low topography and nearby watercourse mean that groundwater levels are likely to be close to the surface. Whilst the surface water modelling gives conflicting results, given the site's similar geology and topography to other sites that appear at risk, it is considered that there is a risk of groundwater flooding.
Source Protection Zone	The site is in source protection zone 1, defined as the 50 day travel time from any point below the water table to the source. This zone has a minimum radius of 50 metres.
Summary of flood risk	Most of the site is in Flood Zone 2 and 3a. The site may be at some risk of surface water flooding. The site is potentially at high risk of groundwater flooding.
Development recommendations	A sequential approach is required to allocate different land use vulnerabilities in the site in relation to flood risk. It is strongly recommended that only Flood Zone 1 and then Flood Zone 2 are used for housing. In the event that the Flood Zone 3a area is required, the planning application will need to pass the Exception Test. A key element of the Exception Test will be to demonstrate how defences located elsewhere (those defences that are currently defending an area of the site and allow safe access) outside the development will be maintained and upgraded in the next 100 years. The CFMP for this location does not give any certainty that defences will be retained in the long term. Future planning applications need to propose how adequate maintenance of the defences will take place (in particular through contributions) over the life of the development.

Site	Bridge Motors, Church Street, Rickmansworth
Development recommendations (continued)	Whilst no concerns are currently expressed over the condition of the culvert downstream from the site, it is reliant upon maintenance continuing in the future to ensure capacity is maintained and that there are no blockages or collapse. Future planning applications need to propose how adequate maintenance of the culvert will take place over the life of the development. Ground floor finished floor levels should be 0.3m above the 1 in 100 year with climate change flood level, as estimated from the latest flood mapping outputs from the Environment Agency. For any buildings within Flood Zones 2 and 3, flood resilient design to be adopted for at least the lower 0.5m height of the ground floor. Provided the defences in the area work, vehicular access should be possible from the site by travelling south down Church Street and onto the A404. It is important to note that due to the high flow velocities along Church Street, safe access may not be possible for all (in particular people, children and elderly). A flood risk assessment needs therefore to demonstrate that by changing the access arrangements, safe access by foot can be achieved for everyone. It is recommended that future Flood Risk Assessments allow for designing the development for potential high groundwater levels. This could be achieved for example by making the lower 0.3m height of the ground floors flood resilient. Due to the risk of groundwater flooding, habitable basements are not recommended for this site. Any surface strategies for the proposed development need to be robust to ensure adequate protection against surface water flood risk. Finished floor levels of properties beyond Flood Zone 3a with climate change to be set 0.3m above proposed surrounding ground levels as a precaution since the town centre is known to have suffered historical flooding. Site layouts should be designed to ensure that the flow of surface water runoff, to infiltration or discharge locations as appropriate, is not impeded, and so that the safe access routes are maintained. Even if there is currently no risk of surface water flooding on site, it is recommended that SUDS be employed to manage surface runoff, in accordance with the surface water management train and the guidance in “Preliminary rainfall runoff management for developments” in order to ensure flood risk is not worsened on site or to the surrounding area. Drainage proposals must ensure no increase in the peak rate of stormwater runoff leaving the site, the volume of runoff leaving the site, or the pollution load to receiving waters from stormwater runoff for the lifetime of the development, including an allowance for the effects of climate change.

Site	Bridge Motors, Church Street, Rickmansworth
Development recommendations (continued)	Analysis of the site suggests that groundwater levels may be too high for infiltration SUDS and therefore it is recommended that runoff be discharged into the neighbouring watercourse using attenuation devices to control the rate and volume of runoff to greenfield characteristics. Green roofs are also recommended for use as attenuation storage; the volumes provided are typically small and thus significant only for smaller storms, however they provide other useful benefits such as encouraging biodiversity and improving air quality. Further information on calculating storage can be found in the Environment Agency Green Roof Toolkit at: http://www.environment-agency.gov.uk/business/sectors/91967.aspx. Rainwater harvesting is also recommended, with the additional benefit of reducing reliance on mains water supply – as a result it cannot normally be counted as part of the storage volumes as tanks are not completely emptied between events, but it does provide some informal storage potential. As the site is in source protection zone 1, it is particularly important to ensure a high water quality of surface runoff discharging from the site, including treatment where necessary, to avoid contamination of the groundwater source since there is very little time for natural degradation and dilution of pollutants in the soil. Even if discharged to a nearby watercourse, contamination may affect the aquifer as the river is in hydraulic connectivity. Naturally, a high water quality will also benefit the river itself. Flood Risk Assessments need to consider the effects of drain blockages on flood risk to the site. Blockages should in particular be assessed for the 2m wide and 1.5m culvert running beneath the A404 to the south of the site. Ideally the effect of 25%, 50%, 75% and 100% blockages should be considered. The likelihood of these percentages of blockage needs to be assessed by visiting the site and assessing the likely sources of potential blockages (for example upstream trees, trolleys, tipping, etc).
Allocation Recommendation	It is recommended to only provisionally allocate this site until a flood risk assessment demonstrates that the Exception Test can be passed.

16 Depot, Harefield Road, Rickmansworth

Site	Depot, Harefield Road, Rickmansworth
ID	DH
Area	0.6 ha
Current land use	Industrial
Proposed land use	Proposed allocation for housing with an indicative capacity of 25 dwellings.
NPPF vulnerability	The NPPF classification for housing is 'more vulnerable'. It would therefore be acceptable in Flood Zones 1 and 2, require the Exception Test for Flood Zone 3a, and would not be permitted in Flood Zone 3b.
Watercourses	One of the branches of the River Colne runs along the site's northern border and the Grand Union Canal passes about 50m to the north of the site.
Historical fluvial flooding	None
Flood Zones and Flood Extents	The site currently has 37% of its area within Flood Zone 2 and 25% in Flood Zone 3a (see Figure 16-1 below). The remainder of the site is Flood Zone 1 (there is no Flood Zone 3b as the watercourse remains in-bank for the 1 in 20 year event taking account of defences). Flood Zone 3 Flood Zone 2 Site Boundary  The hatching within Flood Zone 3a in the site area indicates that the site is actually protected by defences (in particular by a small height embankment along the northern boundary of the site). This protected hatched area is defined as an Area Benefiting from Defences (ABD). Although the 1 in 100 year flood extents taking account of defences do not show flooding of the site, this will not be the case for the same run taking account of climate change. The outputs indicate that around 40% of the site (the western side) will be flooded in the future. As this climate change case also takes account of the presence of defences (located along the northern boundary of the site), this means that flooding would occur as a result of overtopping of these.

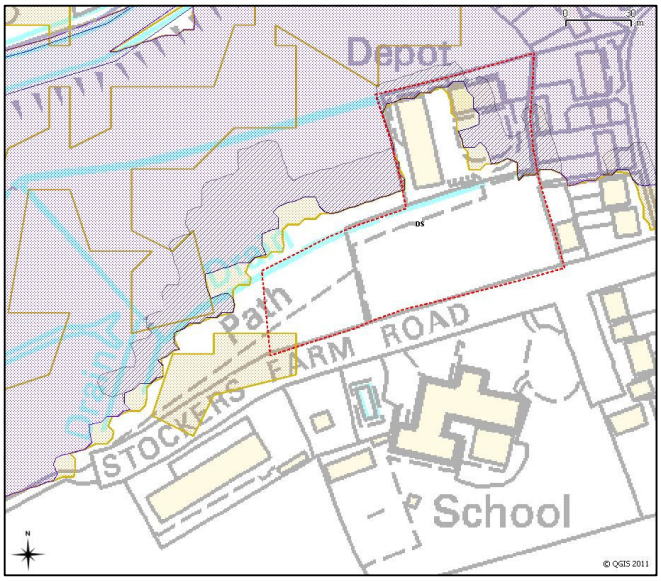
Site	Depot, Harefield Road, Rickmansworth
Flood Hazard	The hazard map for the 1 in 100 year plus climate change map taking account of defences, indicates a low hazard area ('risk for some' coloured in yellow) covering 30% of the site area. Although these results (see Figure 16-2 below) are not critical for the development, it will be important that the detailed design of the development takes account of these hazards. The effect of a breach of the small height (around 0.2m) embankment along the northern boundary of the site (for the same 1 in 100 year plus climate change run taking account of defences) does not change the flood hazard, flood depths and flow velocities as the main mechanism of flooding is flooding from the south (see flood depths and flow velocities figure in the next row of this table). 
Flood Depths and Flow Velocities	The flood depths and flow velocities for the 1 in 100 year event taking account of climate change and defences is shown in Figure 16-3 below. 

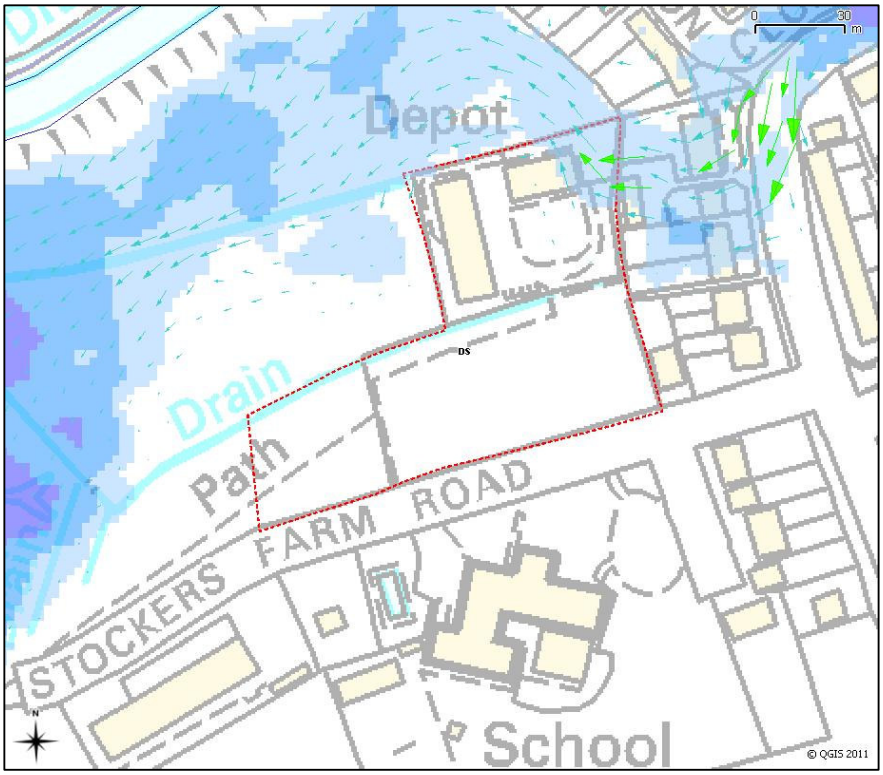
Site	Depot, Harefield Road, Rickmansworth
Flood Depths and Flow Velocities (continued)	The flow arrows indicate main flow directions which in this case are mainly from south to north within the site. Flow velocities shown in light blue enter the site from the south at a 0.2m/s rate, they cross the site at a rate of 0.05m/s and leave the site to the north at 0.4m/s rate. There is only one green arrow to the north of the site which means that the flow rate is between 0.5m/s and 1m/s. The depth of flooding shown as light blue within the site varies between 0.2-0.3m and the blue areas within the site vary between 0.3 to 0.4m.
Defences	As mentioned above there is a small height defence running alongside the northern boundary of the site, which offers a 1 in 20 year standard of protection. The NFCDD database notes in particular concerns in the area over the condition of flap gates on the defence as many are damaged and need to be repaired or replaced. The flap gates cover local drains that outfall into the river, to prevent water flowing up them when river levels are high.
Access	Access to Harefield road to the south of the site remains clear for the 1 in 100 year flood event however not for the climate change event as shown in the flood zones and flood extents figure above. The depth of flooding in the road is however 0.2m and some velocities are high and of the order of 0.5m3/s. There is therefore safe vehicular access however no safe access for elderly, people with wheelchairs and children. Where possible access routes should avoid the hazardous area. At Church Street for example, it is recommended that cars turn left, to avoid the hazardous area to the right, and then left along Riverside Drive which is above the level of flooding.
Flood Warning	The southern half of the site is within the "The River Colne at Rickmansworth including Batchworth, Money Hill and Maple Cross" flood warning area.
Historical surface water flooding	None
Surface water modelling	According to the AStSWF the southern half of the site is at 'intermediate' susceptibility to surface water flooding. The borders of the site are at 'less' susceptibility. The FMfSW indicates much less flooding, with just shallow flooding for the 1 in 200 and 1 in 30 year scenarios in the south-west of the site. As the AStSWF and FMfSW outlines are determined from national-scale mapping, it is important to compare them to local data as a reality check. No historical surface water flooding is recorded for the site, which may mean the site is not susceptible, but surface water incidents traditionally have rarely been recorded and thus it may be that the site has flooded but no record exists.
Historical groundwater flooding	None
Geology and Groundwater mapping	The site is underlain by Chalk bedrock and superficial deposits of Alluvium. Both of these geologies are permeable and therefore pose a risk of groundwater flooding. Whilst no groundwater flooding incidents have been recorded on site, one has occurred just 280m away in the same geology layers. The AStGWF indicates that less than 25% of the 1km square in which the site lies has geology and groundwater levels that may make the site susceptible to groundwater emerging. However, the site's low-lying position in the river valley makes it more than likely to be in the emergence area. Groundwater flooding is most likely to reach appreciable depths in the parts of the site where surface water flooding is indicated.

Site	Depot, Harefield Road, Rickmansworth
Source Protection Zone	The site is in source protection zone 1, defined as the 50 day travel time from any point below the water table to the source. This zone has a minimum radius of 50 metres.
Summary of flood risk	75% of the site area is outside the high risk flood zone (Flood Zone 3). Much of the site may be at risk of surface water flooding, although this is likely to be shallow. The site is potentially at high risk of groundwater flooding.
Development recommendations	A sequential approach is required to allocate different land use vulnerabilities in the site in relation to flood risk. It is strongly recommended that only Flood Zone 1 and then Flood Zone 2 are used for housing. In the event that the Flood Zone 3a area is required, the planning application will need to pass the Exception Test. A key element of the Exception Test will be to demonstrate how defences located elsewhere (those defences that are currently defending an area of the site) outside the development will be maintained and upgraded in the next 100 years. The CFMP for this location does not give any certainty that defences will be retained in the long term. Future planning applications need to propose how adequate maintenance of the defences will take place over the life of the development. Future planning applications need to undertake a detailed assessment of the defence condition with restoration works if necessary, particularly in regard to flaps gates, and provision made to ensure its maintenance into the future so that it can be relied upon for the lifetime of the development. If raising the defence to provide a higher standard of protection is required, then level-for-level compensation storage will need to be provided. Ideally this would be provided on site but if necessary a suitable alternative site may be used. Hydraulic modelling outputs will need to demonstrate that the proposed compensation storage ensures that flood risk is not increased elsewhere. Either way, it is important that the development takes this future issue into consideration now so as to ensure that land will be available. Ground floor finished floor levels should be 0.3m above the 1 in 100 year with climate change flood level, as estimated from the latest flood mapping outputs from the Environment Agency. For any buildings within Flood Zones 2 and 3, flood resilient design to be adopted for at least the lower 0.5m height of the ground floor. Access to Harefield Road to the south of the site shows shallow flooding for the 1 in 100 year plus climate change event, which is safe vehicular access although not dry. Where possible access routes should avoid the hazardous area. The hazard remains 'safe access for all' provided the direction of travel is west to Church Street, then north to the roundabout and then along Riverside Drive. A flood risk assessment needs to demonstrate that by changing the access arrangements, safe access by foot can be achieved for everyone.

Site	Depot, Harefield Road, Rickmansworth
Development recommendations (continued)	It is recommended that future Flood Risk Assessments allow for designing the development for potential high groundwater levels. This could be achieved for example by making the lower 0.3m height of the ground floors flood resilient. Due to the risk of groundwater flooding, habitable basements are not recommended for this site. Any surface strategies for the proposed development need to be robust to ensure adequate protection against surface water flood risk. Finished floor levels of properties beyond Flood Zone 3a with climate change to be set 0.3m above proposed surrounding ground levels as a precaution since the town centre is known to have suffered historical flooding. Site layouts should be designed to ensure that the flow of surface water runoff, to infiltration or discharge locations as appropriate, is not impeded, and so that the safe access routes are maintained. It is recommended that SUDS be employed to manage surface runoff, in accordance with the surface water management train and the guidance in "Preliminary rainfall runoff management for developments". Drainage proposals must ensure no increase in the peak rate of stormwater runoff leaving the site, the volume of runoff leaving the site, or the pollution load to receiving waters from stormwater runoff for the lifetime of the development, including an allowance for the effects of climate change. Analysis of the site suggests that groundwater levels may be too high for infiltration SUDS and therefore it is recommended that runoff be discharged into the neighbouring watercourse using attenuation devices to control the rate and volume of runoff to greenfield characteristics. Green roofs are also recommended for use as attenuation storage; the volumes provided are typically small and thus significant only for smaller storms, however they provide other useful benefits such as encouraging biodiversity and improving air quality. Further information on calculating storage can be found in the Environment Agency Green Roof Toolkit at: http://www.environment-agency.gov.uk/business/sectors/91967.aspx. Rainwater harvesting is also recommended, with the additional benefit of reducing reliance on mains water supply – as a result it cannot normally be counted as part of the storage volumes as tanks are not completely emptied between events, but it does provide some informal storage potential. As the site is in source protection zone 1, it is particularly important to ensure a high water quality of surface runoff discharging from the site, including treatment where necessary, to avoid contamination of the groundwater source since there is very little time for natural degradation and dilution of pollutants in the soil. Even if discharged to the river, contamination may affect the aquifer as the river is in hydraulic connectivity. Naturally, a high water quality will also benefit the river itself. The impact of blockages of nearby drains on flood risk to the site needs to be assessed as part of a Flood Risk Assessment.
Allocation Recommendation	It is recommended to allocate this site with the provision that the above recommendations are followed.

17 Depot, Stockers Farm, Rickmansworth

Site	Depot, Stockers Farm, Rickmansworth
ID	DS
Area	0.9 ha
Current land use	Mainly industrial, plus a greenfield area
Proposed land use	Proposed allocation for housing with an indicative capacity of 60 dwellings.
NPPF vulnerability	The NPPF classification for housing is 'more vulnerable'. It would therefore be acceptable in Flood Zones 1 and 2, require the Exception Test for Flood Zone 3a, and would not be permitted in Flood Zone 3b.
Watercourses	The Grand Union Canal passes about 100m to the north of the site. Two drainage channels run through the site, although the northern one is culverted, emerging immediately west of the site.
Historical fluvial flooding	Flooding occurred from the two drainage channels in July 1987, encroaching on the south-west corner of the site. Flood Zone 2 takes also account of the extents of that event.
Flood Zones	The site currently has 4% of its area within Flood Zone 2 and 16% in Flood Zone 3a (see Figure 17-1 below). The remainder of the site is Flood Zone 1 (there is no Flood Zone 3b as the watercourse remains in-bank for the 1 in 20 year event taking account of defences). Flood Zone 3 Flood Zone 2 Site Boundary The hatching within Flood Zone 3a in the north east corner of the site indicates that the site is partially protected by defences for the 1 in 100 year flood event. This protected hatched area is defined as an Area Benefiting from Defences (ABD).  The 1 in 100 year event from the Environment Agency flood mapping model indicates flooding on the north east corner of the site, covering approximately 5%-10% of the site area. The effect of climate change of the same event will however result in flooding of around 15%-20% on the north east corner of the site area.

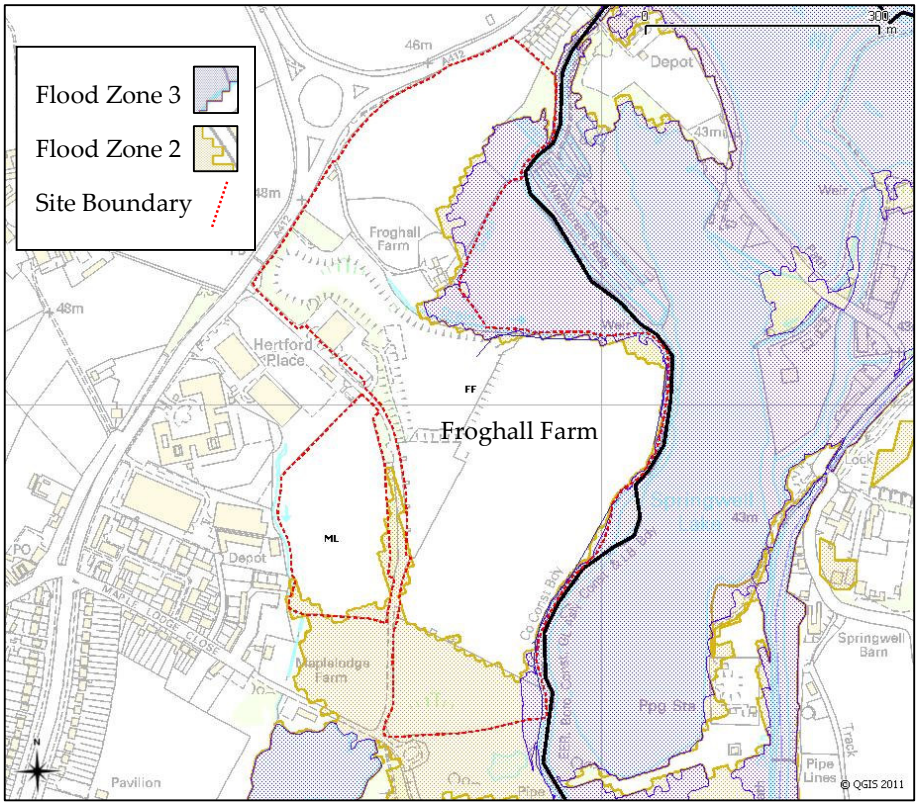
Site	Depot, Stockers Farm, Rickmansworth
Flood Hazard	The outputs of the Environment Agency flood mapping model for the 1 in 100 year event taking account of climate change and defences indicate that there is no flood hazard within the site. The reason for this is that flood depths and flow velocities are very small (see flood depths and flow velocities in the next row of this table).
Flood Depths and Flow Velocities	The flood depths and flow velocities for the 1 in 100 year event taking account of climate change and defences is shown in Figure 17-2 below.  The flow arrows indicate main flow directions which in this case are mainly from south-east to north-west within the site. Flow velocities shown in light blue within the site range between 0.2m/s to 0.4m/s. Green arrows within the site range between 0.5m/s and 1m/s. The depth of flooding shown as light blue within the site varies between 0.14-0.17m.
Defences	The latest update of the National Flood and Coastal Defence Database (NFCDD) from the Environment Agency indicates the presence of a raised defence along the Grand Union canal to the north of the site. This offers a 1 in 5 year standard of protection. In regard to the condition of the defence, concerns have been raised over cracks in garden walls acting as defences to nearby houses.
Access	Access to Stockers Farm Road to the east, and then south down Harefield Road, remains clear in all flood events. Access should be secured in this safe area.
Flood Warning	A small part of the site, in the north-east corner, is within the "The River Colne at Rickmansworth including Batchworth, Money Hill and Maple Cross" flood warning area.
Historical surface water flooding	None

Site	Depot, Stockers Farm, Rickmansworth
Surface water modelling	According to the AStSWF the whole site is at risk of surface water flooding. Most of the site is classified as 'less' susceptible but the areas nearest the drainage channels are 'intermediate' susceptibility. The FMfSW indicates that most of the site is at risk of shallow flooding during a 1 in 200 year event with patches of deep flooding in the north-east and west. During a 1 in 30 year event, the west and north-east of the site is at risk of shallow flooding but there is no deep flooding. As the AStSWF and FMfSW outlines are determined from national-scale mapping, it is important to compare them to local data as a reality check. No historical surface water flooding is recorded for the site, which may mean the site is not susceptible, but surface water incidents traditionally have rarely been recorded and thus it may be that the site has flooded but no record exists.
Historical groundwater flooding	None
Geology and Groundwater mapping	The site is underlain by Chalk bedrock and superficial deposits of Alluvium. Both of these geologies are permeable and therefore pose a risk of groundwater flooding. Whilst no groundwater flooding incidents have been recorded on site, one has occurred 740m away in the same geology layers. The AStGWF suggests that the site lies within an area where the geology and groundwater levels may make the site susceptible to groundwater emerging - this applies to 25-50% of the area of the 1km square the site lies in. Given the site's permeable geology in combination with the site's location in the river valley where the low topography and nearby watercourse mean that groundwater levels are likely to be close to the surface, it is likely the site is within the relevant 25-50% of the area. Groundwater flooding is considered most likely in the parts of the site where surface water flooding is indicated.
Source Protection Zone	The site is in source protection zone 2, defined by a 400 day travel time from a point below the water table. This zone has a minimum radius of 250 or 500 metres around the source, depending on the size of the abstraction.
Summary of flood risk	Most of the site is in Flood Zone 1 but about a fifth is in Flood Zone 3a. Virtually all of the site may be at risk of surface water flooding, including some deep flooding during more extreme events. The site is potentially at high risk of groundwater flooding.

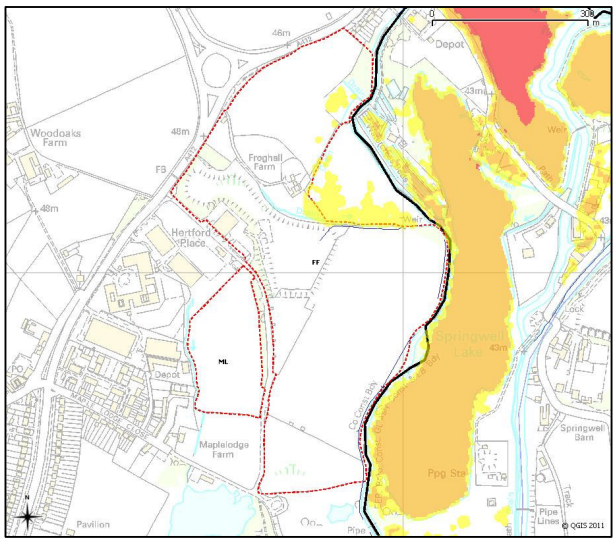
Site	Depot, Stockers Farm, Rickmansworth
Development recommendations	A sequential approach is required to allocate different land use vulnerabilities in the site in relation to flood risk. It is strongly recommended that only Flood Zone 1 and then Flood Zone 2 are used for housing. In the event that the Flood Zone 3a area is required, the planning application will need to pass the Exception Test. A key element of the Exception Test will be to demonstrate how defences located elsewhere (those defences that are currently defending an area of the site) outside the development will be maintained and upgraded in the next 100 years. The CFMP for this location does not give any certainty that defences will be retained in the long term. Future planning applications need to propose how adequate maintenance of the defences will take place over the life of the development. In regard to the condition of the defences, concerns have been raised over cracks in garden walls acting as defences to nearby houses in Heron close. Future planning applications need to explore options to improve defence reliability for both the proposed development and existing houses. Ground floor finished floor levels should be 0.3m above the 1 in 100 year with climate change flood level, as estimated from the latest flood mapping outputs from the Environment Agency. For any buildings within Flood Zones 2 and 3, flood resilient design to be adopted for at least the lower 0.5m height of the ground floor. Access to Stockers Farm Road to the east, and then south down Harefield Road, remains clear in all flood events. Access should be secured in this safe area. It is recommended that future Flood Risk Assessments allow for designing the development for potential high groundwater levels. This could be achieved for example by making the lower 0.3m height of the ground floors flood resilient. Due to the risk of groundwater flooding, habitable basements are not recommended for this site. Any surface strategies for the proposed development need to be robust to ensure adequate protection against surface water flood risk. Finished floor levels of properties beyond Flood Zone 3a with climate change to be set 0.3m above proposed surrounding ground levels as a precaution since the town centre is known to have suffered historical flooding. Site layouts should be designed to ensure that the flow of surface water runoff, to infiltration or discharge locations as appropriate, is not impeded, and so that the safe access routes are maintained.

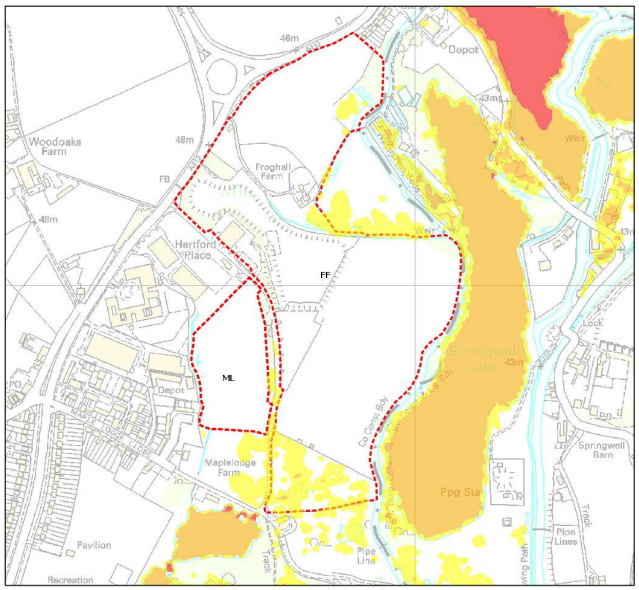
Site	Depot, Stockers Farm, Rickmansworth
Development recommendations (continued)	It is recommended that SUDS be employed to manage surface runoff, in accordance with the surface water management train and the guidance in "Preliminary rainfall runoff management for developments". Drainage proposals must ensure no increase in the peak rate of stormwater runoff leaving the site, the volume of runoff leaving the site, or the pollution load to receiving waters from stormwater runoff for the lifetime of the development, including an allowance for the effects of climate change. Analysis of the site suggests that groundwater levels may be too high for infiltration SUDS and therefore it is recommended that runoff be discharged into the neighbouring watercourse using attenuation devices to control the rate and volume of runoff to greenfield characteristics. Green roofs are also recommended for use as attenuation storage; the volumes provided are typically small and thus significant only for smaller storms, however they provide other useful benefits such as encouraging biodiversity and improving air quality. Further information on calculating storage can be found in the Environment Agency Green Roof Toolkit at: http://www.environment-agency.gov.uk/business/sectors/91967.aspx. Rainwater harvesting is also recommended, with the additional benefit of reducing reliance on mains water supply – as a result it cannot normally be counted as part of the storage volumes as tanks are not completely emptied between events, but it does provide some informal storage potential. As the site is in source protection zone 2, it is important to ensure a high water quality of surface runoff discharging from the site, including treatment where necessary, to avoid contamination of the groundwater source. Even if discharged to the river, contamination may affect the aquifer as the river is in hydraulic connectivity. Naturally, a high water quality will also benefit the river itself. The impact of blockages of nearby drains on flood risk to the site needs to be assessed as part of a Flood Risk Assessment. This will be in particular important for the drain that crosses through the middle of the site. Ideally the effect of 25%, 50%, 75% and 100% blockages should be considered. The likelihood of these percentages of blockage needs to be assessed by visiting the site and assessing the likely sources of potential blockages (for example upstream trees, trolleys, tipping, etc).
Allocation Recommendation	It is recommended to allocate this site with the provision that the above recommendations are followed.

18 Froghall Farm, Maple Cross

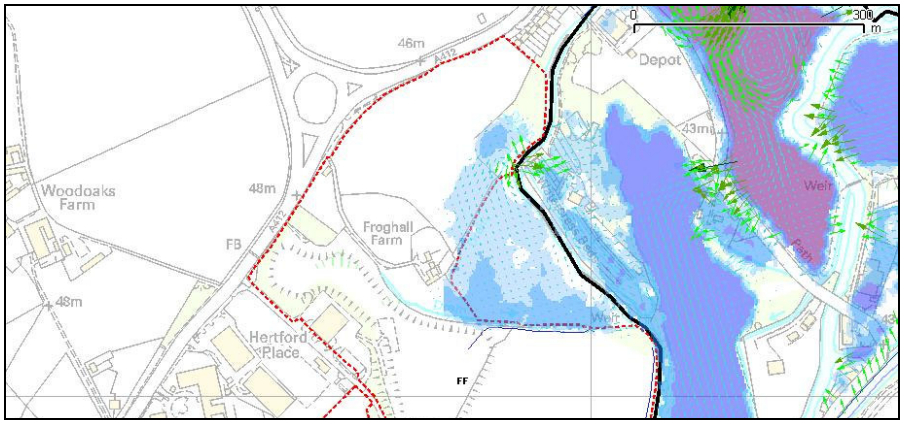
Site	Froghall Farm, Maple Cross
ID	FF
Area	22.3ha
Current land use	Predominantly greenfield, with a few buildings.
Proposed land use	Potential allocation for secondary school.
NPPF vulnerability	The NPPF classification for educational establishments is 'more vulnerable'. It would therefore be acceptable in Flood Zones 1 and 2, require the Exception Test for Flood Zone 3a, and would not be permitted in Flood Zone 3b.
Watercourses	One of the branches of the River Colne lies along most of the eastern border of the site. Another branch and the Grand Union Canal lie about 200m to the east, and a tributary of the River Colne about 160m to the west. Springwell Lake is located just beside the site's eastern border, and another lake just beyond. A couple of small drainage ditches run through the northern part of the site, draining into the River Colne.
Historical fluvial flooding	None
Flood Zones	 The site currently has 11% of its area within Flood Zone 2 and 8% in Flood Zone 3 (see Figure 18-1 above). Flood Zone 3 is divided into Flood Zone 3b (6%) and Flood Zone 3a (2%).

Site	Froghall Farm, Maple Cross
Flood Zones (continued)	The effect of climate change on the 1 in 100 year flood event based on the latest Environment Agency model is very small, so much that the flood extents would only change by 1% of the site area.
Flood Hazard	The hazard map for the 1 in 100 year plus climate change map taking account of defences, indicates a low hazard area ('risk for some' coloured in yellow) covering less than 5% of the site area (see Figure 18-2 to the right). This figure represents flooding of the site as a result of overtopping of the defences (as opposed to a defence breach). The effect of a breach of the embankment on the southern part of the development (for the 1 in 100 year plus climate change run taking account of defences) results in a hazard area on the southern part of the site that is predominantly 'danger for some' (coloured in yellow) covering about 8% of the site area, although there are a few small patches of 'danger for most' (coloured in orange) (see Figure 18-3 below). No breaches have been considered elsewhere as the ground within the site is relatively high when compared to the height of the defences.



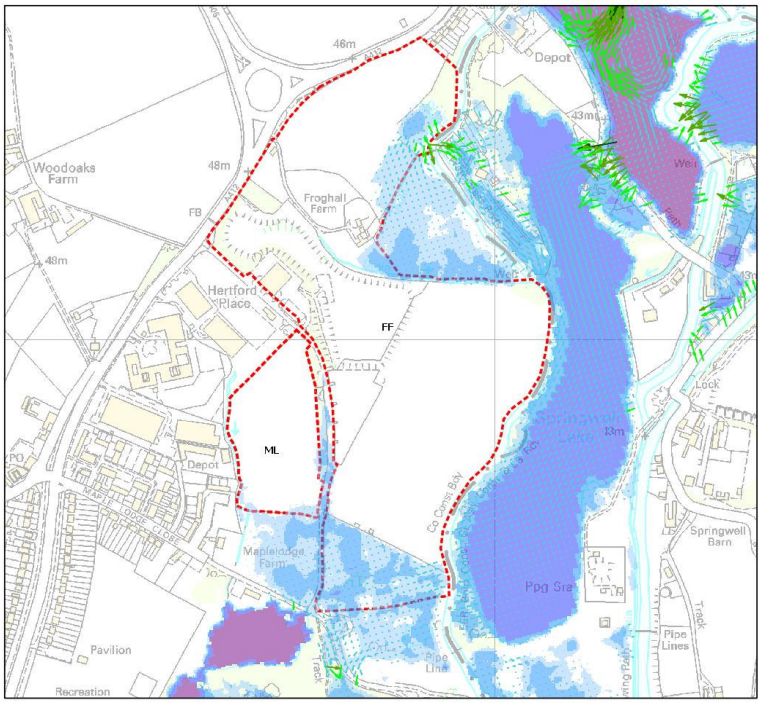


Site	Froghall Farm, Maple Cross
Flood Depths and Flow Velocities	The flood depths and flow velocities for the 1 in 100 year event taking account of climate change and defences is shown in Figure 18-4 below (from overtopping of the defences and not a breach).



The flow arrows indicate the main flow directions. These indicate that the banks are overtopped on the northern part of the site only. Green arrows indicate flow velocities between 0.5m-1m/s. Blue arrows indicate flow velocities of 0.1-0.4m/s. The flow arrows indicate that once floodwater overtops the bank, this mainly flows in a southern direction to the east of the farm.

The flood depths and velocities as a result of the breach of the embankment (for the 1 in 100 year plus climate change event) on the southern part of the development result in depths of 0.2m-0.5m and velocities generally below 0.5m/s, although there is some faster flowing water in the north-east (see Figure 18-5 below and enlarged figure in Appendix B).

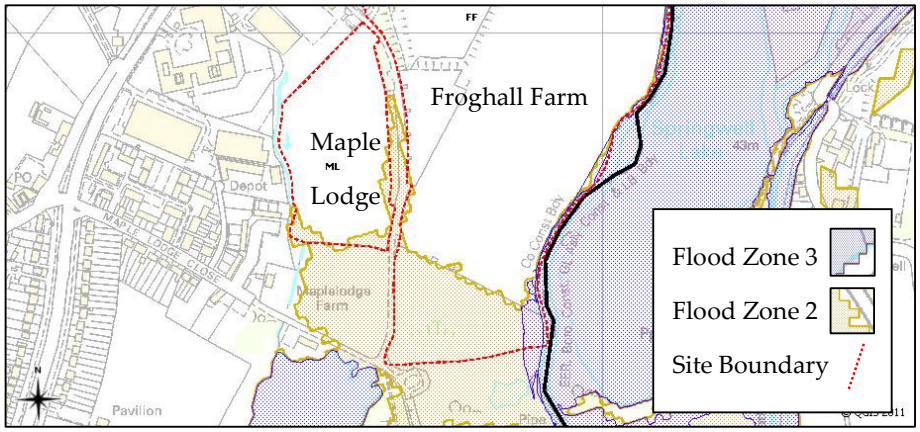


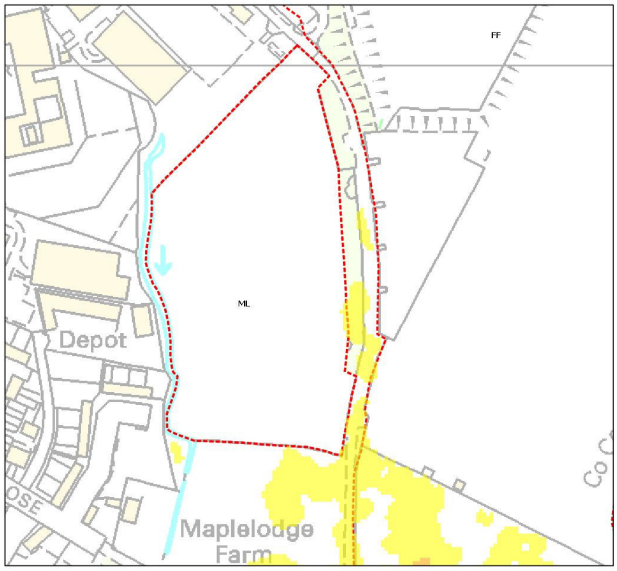
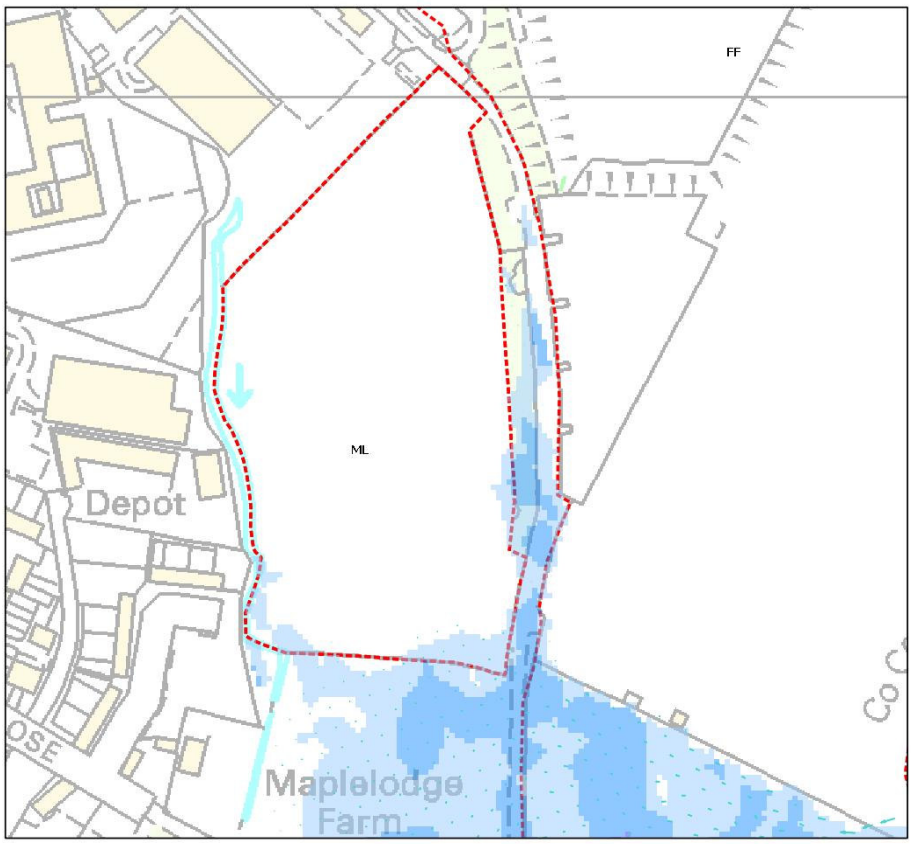
Site	Froghall Farm, Maple Cross
Defences	The latest update of the National Flood and Coastal Defence Database (NFCDD) from the Environment Agency indicates the presence of raised defences along the bank adjacent to the site. The NFCDD data raises the possibility that several of the defences may be surplus to requirements – the [undefended] flood zones appear to support this for all except the two furthest south, as no flooding is shown beside these defences for the 100 year event even though several have a design standard less than 100 years (and the maximum standard is 100 year). One of the embankment's kerbs has eroded away (not one of the potentially surplus defences).
Access	Access to Maple Lodge Close is cut off during a 1 in 1000 year event. However, access to the road near the centre of the site, and to the A412 along the site's north-west border remains clear. Both routes are clear during a 1 in 100 year plus climate change event.
Flood Warning	The northern and southern ends of the site are within the "River Colne at Rickmansworth including Batchworth, Money Hill and Maple Cross" flood warning area.
Historical surface water flooding	None
Surface water modelling	The AStSWF suggests that parts of the site, mainly along the southern, western and eastern borders are susceptible to surface water flooding due to runoff paths down Maple Lodge Close, from land to the north-west and along the river valley to the east. The flooding is mostly of the 'intermediate' susceptibility, but there are a couple of small areas of 'more' susceptibility flooding on the site border (and small scattered patches of 'less' susceptibility). The FMfSW suggests virtually the same pattern of flooding, particularly the 1 in 200 year shallow flooding. Deeper flooding occurs mainly along the western border and in the southern part of the site. As the AStSWF and FMfSW outlines are determined from national-scale mapping, it is important to compare them to local data as a reality check. No historical surface water flooding is recorded for the site, which may mean the site is not susceptible, but surface water incidents traditionally have rarely been recorded and thus it may be that the site has flooded but no record exists.
Historical groundwater flooding	None
Geology and Groundwater mapping	The site is underlain by Chalk bedrock with superficial deposits of Sand and Gravel in the north, and Alluvium over the rest of the site. These geologies are permeable and therefore pose a risk of groundwater flooding. The AStGWF suggests that the site lies within an area where the geology and groundwater levels may make the site susceptible to groundwater emerging, which is consistent with the permeable geology in combination with the site's location in the river valley where the low topography and nearby watercourse mean that groundwater levels are likely to be close to the surface. Groundwater flooding is most likely to reach appreciable depths in the parts of the site where surface water flooding is indicated.
Source Protection Zone	The site is in source protection zone 1, defined as the 50 day travel time from any point below the water table to the source. This zone has a minimum radius of 50 metres.

Site	Froghall Farm, Maple Cross
Summary of flood risk	Most of the site is in Flood Zone 1, at the lowest risk of flooding. A small proportion of the site is Flood Zone 3. Most of the site may not be at risk of surface water flooding apart from a few small patches. However, the southern, western and eastern borders are more likely to be at risk of deep flooding. The site is potentially at high risk of groundwater flooding.
Development recommendations	A sequential approach is required in planning the layout of buildings within the site. Given the close proximity of the flood zone outlines to each other, it is recommended that all buildings are constrained to the Flood Zone 1 area. The Flood Zone 2 and 3 areas, and areas at risk from breach, should then be used for land uses such as playing fields and outdoor spaces. Alternatively it could be beneficial to adjust the identified development area to Flood Zone 1 only to reduce FRA requirements, thus leaving the excluded area as natural land. The NFCDD data raises the possibility that several of the defences may be surplus to requirements – the flood zones appear to support this for all except the two defences furthest south, as no flooding is shown beyond these defences for the [undefended] 100 year event. The maximum design standard for the defences in question is 100 year and several have a design standard less than this. One of the embankment's kerbs has eroded away (not one of the potentially surplus defences). Future planning applications need to consider which reaches of defences are required to be maintained over the life of the development. Ground floor finished floor levels should be 0.3m above the 1 in 100 year with climate change flood level, as estimated from the latest flood mapping outputs from the Environment Agency. Access to either Maple Lodge Close or the A412 may be used during the 1 in 100 year with climate change event, however a preference is recommended for the A412 since Maple Lodge Close becomes cut off in more severe events such as the 1 in 1000 year. It is recommended that future Flood Risk Assessments allow for designing the development for potential high groundwater levels. This could be achieved for example by making the lower 0.3m height of the ground floors flood resilient. Due to the risk of groundwater flooding, habitable basements are not recommended for this site. Any surface strategies for the proposed development need to be robust to ensure adequate protection against surface water flood risk. As the surface water modelling outlines are more extensive than the fluvial outlines, and there is too little historical data to check the surface water modelling, it is recommended that floor levels of all properties be set at least 0.3m above proposed surrounding ground levels. Site layouts should be designed to ensure that the flow of surface water runoff, to infiltration or discharge locations as appropriate, is not impeded, and so that the safe access routes are maintained.

Site	Froghall Farm, Maple Cross
Development recommendations (continued)	It is recommended that SUDS be employed to manage surface runoff, in accordance with the surface water management train and the guidance in "Preliminary rainfall runoff management for developments". Drainage proposals must ensure no increase in the peak rate of stormwater runoff leaving the site, the volume of runoff leaving the site, or the pollution load to receiving waters from stormwater runoff for the lifetime of the development, including an allowance for the effects of climate change. The impact of blockages of nearby drains on flood risk to the site needs to be assessed as part of a Flood Risk Assessment. Analysis of the site suggests that groundwater levels may be too high for infiltration SUDS and therefore it is recommended that runoff be discharged into the neighbouring watercourse using attenuation devices to control the rate and volume of runoff to greenfield characteristics. Green roofs are also recommended for use as attenuation storage; the volumes provided are typically small and thus significant only for smaller storms; however they provide other useful benefits such as encouraging biodiversity and improving air quality. Further information on calculating storage can be found in the Environment Agency Green Roof Toolkit at: http://www.environment-agency.gov.uk/business/sectors/91967.aspx. Rainwater harvesting is also recommended, with the additional benefit of reducing reliance on mains water supply – as a result it cannot normally be counted as part of the storage volumes as tanks are not completely emptied between events, but it does provide some informal storage potential. As the site is in source protection zone 1, it is particularly important to ensure a high water quality of surface runoff discharging from the site, including treatment where necessary, to avoid contamination of the groundwater source since there is very little time for natural degradation and dilution of pollutants in the soil. Even if discharged to the river, contamination may affect the aquifer as the river is in hydraulic connectivity. Naturally, a high water quality will also benefit the river itself.
Allocation Recommendation	It is recommended to allocate this site with the provision that the above recommendations are followed.

19 Maple Lodge, Maple Cross

Site	Maple Lodge, Maple Cross
ID	ML
Area	3.3ha
Current land use	Greenfield
Proposed land use	Proposed employment allocation. Anticipated 16,000sqm B2/B8 floorspace capacity. Alternatively, whilst not currently intending to allocate, site has been considered as a housing site with an indicative capacity of 100 dwellings.
NPPF vulnerability	The NPPF classification for buildings used for financial, professional and other services, offices and general industry in 'less vulnerable'. These would therefore be acceptable in Flood Zones 1, 2 and 3a but would not be permitted in Flood Zone 3b. The NPPF classification for housing is 'more vulnerable'. It would therefore be acceptable in Flood Zones 1 and 2, require the Exception Test for Flood Zone 3a, and would not be permitted in Flood Zone 3b.
Watercourses	The River Colne and Grand Union Canal lie about 220m and 490m to the east, respectively, with Springwell Lake located between the two watercourses. A tributary of the River Colne runs along the site's western border, and there is another lake to the south of the site.
Historical fluvial flooding	None
Flood Zones	The site currently has 8% of its area within Flood Zone 2. The remainder of the site is Flood Zone 1 (see Figure 19-1 below).  Under the effects of climate change the 1 in 100 year event will still not reach the proposed site. For this event, there is therefore no hazard, flood depths or flow velocities that reach the site.
Flood Hazard	The effect of a breach of the river Colne embankment to the east of the site (for the 1 in 100 year plus climate change run taking account of defences) results in flooding of sufficiently low depths and velocity that there is only a little 'danger for some' hazard (coloured in yellow) along the site border (see Figure 19-2 below).

Site	Maple Lodge, Maple Cross
Flood Hazard (continued)	
Flood Depths and Flow Velocities	The flood depths and velocities as a result of the breach of the embankment (for the 1 in 100 year plus climate change event) on the southern part of the development result in depths of up to 0.2m and velocities of up to 0.5m/s (see Figure 19-3 below). 

Site	Maple Lodge, Maple Cross
Defences	The latest update of the National Flood and Coastal Defence Database (NFCDD) from the Environment Agency indicates the presence of raised defences along the bank of the River Colne to the east of the site. The defences are made of brick walls and further downstream earth embankments. These defences give in general a standard of protection of 100 years to the site. The NFCDD data raises the possibility that several of the defences may be surplus to requirements – the [undefended] flood zones appear to support this for all except the two furthest south, as no flooding is shown beside these defences for the 100 year event even though several have a design standard less than 100 years (and the maximum standard is 100 year). One of the embankment's kerbs has eroded away (not one of the potentially surplus defences).
Access	Access to Maple Lodge Close is cut off during a 1 in 1000 year event. However, access to the road at the northern corner of the site remains clear. Both remain clear in a 1 in 100 year with climate change event.
Flood Warning	A small part of the site, in the south-east corner, is within the "River Colne at Rickmansworth including Batchworth, Money Hill and Maple Cross" flood warning area.
Historical surface water flooding	None
Surface water modelling	According to the AStSWF the site lies along the path of runoff flowing down Maple Lodge Close to the west and from land to the north-west most of the site. As a result most of the site, particularly the south-east part, is susceptible to flooding although at only 'less' or 'intermediate' susceptibility. The FMfSW suggests the same directions for runoff flowing by the site, but causing less flooding within the site – most of the site flooding occurs along the borders, with just a little shallow flooding in the centre of the site.
Historical groundwater flooding	None
Geology and Groundwater mapping	The site is underlain by Chalk bedrock and superficial deposits of Alluvium. Both of these geologies are permeable and therefore pose a risk of groundwater flooding. The AStGWF suggests that the site lies within an area where the geology and groundwater levels may make the site susceptible to groundwater emerging, which is consistent with the permeable geology in combination with the site's location in the river valley where the low topography and nearby watercourse mean that groundwater levels are likely to be close to the surface. Given the presence of surface water flooding on site, groundwater flood depths may potentially reach appreciable depths.
Source Protection Zone	The site is in source protection zone 1, defined as the 50 day travel time from any point below the water table to the source. This zone has a minimum radius of 50 metres.
Summary of flood risk	The site is at relatively low fluvial flood risk and, being only flood zones 1 and 2, is suitable for the proposed uses. Part of the site may be at risk of surface water flooding, although deep flooding is likely to be relatively minor. The site is potentially at high risk of groundwater flooding.

Site	Maple Lodge, Maple Cross
Development recommendations	A sequential approach is required in planning the layout of buildings within the site. It is recommended that the most vulnerable buildings be placed in the Flood Zone 1 areas. It is also recommended that the Flood Zone 2 areas along the eastern and southern boundary of the site are left for water compatible uses. This is particularly important for the southern border which is at risk of flooding from a breach of the defence. The defence's eroded kerb should be replaced prior to development proceeding. The area is also reliant upon vegetation clearance to ensure channel conveyance is maintained. Access to either Maple Lodge Close or the road at the northern corner of the site may be used during the 1 in 100 year with climate change event, however a preference is recommended for the latter since Maple Lodge Close becomes cut off in more severe events such as the 1 in 1000 year. It is important that at least one of these routes is secure for future development. It is recommended that future Flood Risk Assessments allow for designing the development for potential high groundwater levels. This could be achieved for example by making the lower 0.3m height of the ground floors flood resilient. Due to the risk of groundwater flooding, habitable basements are not recommended for this site. Any surface strategies for the proposed development need to be robust to ensure adequate protection against surface water flood risk. As the surface water modelling outlines are more extensive than the fluvial outlines, and there is too little historical data to check the surface water modelling, it is recommended that floor levels of all properties be set at least 0.3m above proposed surrounding ground levels. Site layouts should be designed to ensure that the flow of surface water runoff, to infiltration or discharge locations as appropriate, is not impeded, and so that the safe access routes are maintained. It is recommended that SUDS be employed to manage surface runoff, in accordance with the surface water management train and the guidance in "Preliminary rainfall runoff management for developments". Drainage proposals must ensure no increase in the peak rate of stormwater runoff leaving the site, the volume of runoff leaving the site, or the pollution load to receiving waters from stormwater runoff for the lifetime of the development, including an allowance for the effects of climate change. Analysis of the site suggests that groundwater levels may be too high for infiltration SUDS and therefore it is recommended that runoff be discharged into the neighbouring watercourse using attenuation devices to control the rate and volume of runoff to greenfield characteristics. Green roofs are also recommended for use as attenuation storage; the volumes provided are typically small and thus significant only for smaller storms, however they provide other useful benefits such as encouraging biodiversity and improving air quality. Further information on calculating storage can be found in the Environment Agency Green Roof Toolkit at: http://www.environment-agency.gov.uk/business/sectors/91967.aspx. Rainwater harvesting is also recommended, with the additional benefit of reducing reliance on mains water supply – as a result it cannot normally be counted as part of the storage volumes as tanks are not completely emptied between events, but it does provide some informal storage potential.

Site	Maple Lodge, Maple Cross
Development recommendations (continued)	The impact of blockages of nearby drains on flood risk to the site needs to be assessed as part of a Flood Risk Assessment. As the site is in source protection zone 1, it is particularly important to ensure a high water quality of surface runoff discharging from the site, including treatment where necessary, to avoid contamination of the groundwater source since there is very little time for natural degradation and dilution of pollutants in the soil. Even if discharged to the river, contamination may affect the aquifer as the river is in hydraulic connectivity. Naturally, a high water quality will also benefit the river itself.
Allocation Recommendation	It is recommended to allocate this site with the provision that the above recommendations are followed.

20 Conclusions

Analysis of the sites indicates that all sites may be suitable for redevelopment based on the proposed land uses, provided that the allocations of land uses (based on different levels of vulnerability in relation to flood risk) within each site follow the recommendations in this study.

Some sites are, however, recommended to be only provisionally allocated pending further assessment undertaken. A summary of the allocation recommendations is summarised below.

Table 20-1: Summary of allocation recommendations

Site Name	Allocation Recommendation	Condition
Langley Wharf, Kings Langley	Yes	Follow recommendations in document
Masters Yard, Kings Langley	Yes	Follow recommendations in document
Happy Valley and Kings Park, Kings Langley	Yes	Follow recommendations in document
Home Park, Kings Langley	Yes	Follow recommendations in document
North East Baldwins Lane, Croxley Green	Yes	Follow recommendations in document
Croxley Green Station	Yes	Follow recommendations in document
The Barn, Solesbridge Lane, Chorleywood	Yes, provisionally	Demonstrate passing the Exception Test through modelling
Fairways Farm and Penfold Golf Course, Garston	Yes	Follow recommendations in document
Delta Gain, Carpenders Park	Yes	Follow recommendations in document
South Tolpits Lane	Yes	Follow recommendations in document
Gas Works, Salters Close, Rickmansworth	Yes, provisionally	Demonstrate passing the Exception Test through modelling
Langwood House, High Street, Rickmansworth	Yes	Follow recommendations in document
Bridge Motors, Church Street, Rickmansworth	Yes, provisionally	Demonstrate passing the Exception Test through modelling
Depot, Harefield Road, Rickmansworth	Yes	Follow recommendations in document
Depot, Stockers Farm, Rickmansworth	Yes	Follow recommendations in document
Froghall Farm, Maple Cross	Yes	Follow recommendations in document
Maple Lodge, Maple Cross	Yes	Follow recommendations in document

The outputs of this study provide the necessary evidence base for the planning authority to rank the sites in relation to flood risk and to undertake the Sequential Test of the NPPF. The outputs will also be used to assist the passing of the Exception Test of the NPPF for future planning applications.

21 Glossary

Aquifers: Underground layers of water-bearing permeable rock or drift deposits from which groundwater can be extracted. The Environment Agency categorise these into principal aquifers, which provide a high level of water storage on a strategic scale, and secondary aquifers which provide water on a more limited, local scale.

Catchment Flood Management Plan (CFMP): A strategic planning tool through which the Environment Agency seeks to work with other key decision-makers within a river catchment, to identify and agree policies for sustainable flood risk management.

Groundwater Source Protection Zones (SPZ): These are defined for groundwater resources such as wells, boreholes and springs used for public drinking water supply. The zones show the risk of contamination from any activities that might cause pollution in the area. The closer the activity, the greater the risk. The maps show three main zones, inner (SPZ1), outer (SPZ2) and total catchment (SPZ3), and occasionally a fourth zone of special interest (SPZ4) is applied in karstic areas where surface runoff from beyond the groundwater catchment can enter through features such as swallow holes.

Habitable Room: A room used as living accommodation within a dwelling but excludes bathrooms, toilets, halls, landings or rooms that are only capable of being used for storage. All other rooms, such as kitchens, living rooms, bedrooms, utility rooms and studies are counted.

LiDAR: 'Light Detection and Ranging' is an airborne terrain mapping technique which uses a laser to measure the distance between the aircraft and the ground. It therefore provides accurate topographical/contour mapping.

Main Rivers: Principal rivers or locally significant watercourses as defined by Section 93 of the Water Resources Act, 1991 and shown on a formal map held by the Environment Agency.

Mitigation: where flood risk cannot be avoided or controlled, mitigation measures should be applied to further reduce the risk of flooding and/or minimise the danger and damage caused by flooding to acceptable levels. This could include options such as non-habitable ground floors, resistant and resilient design, flood warning and evacuation plans.

Preliminary rainfall runoff management for developments: Research and Development Technical Report W5-074/A/TR1 Revision D, September 2005, published by the Environment Agency and Defra. This contains guidance on how developments are required to manage surface runoff so as to avoid increasing flood risk on site or elsewhere. A simplified methodology is provided for calculating greenfield runoff rates and estimating the approximate volumes required for attenuation, long term and treatment storage in order to ensure that the redeveloped site maintains the greenfield characteristics.

Resistant, Resilient and Repairable Building Construction: Flood resistant construction prevents water from entering the building. Where flood water is allowed to enter a building, flood resilient construction ensures minimal damage

from the water. Flood repairable construction enables easy repair and replacement of damaged elements.

Sustainable Drainage Systems (SUDS): encompass a variety of approaches (e.g. infiltration devices, permeable paving, basins, ponds, swales etc.) to managing surface water in a way which mimics natural systems, to help new developments achieve this objective. Furthermore, they can offer additional benefits of pollution reduction, and landscape and wildlife enhancement, which increase the sustainability of the SUDS device. The Flood and Water Management Act seeks to promote this approach by removing the automatic right to connect to the sewer system; this being subject to approval of the developer's drainage strategy which should by preference drain surface water to land (e.g. infiltration or storage and evaporation), then a watercourse, before resorting to the sewer system.

Surface Water Management Train (SUDS Management Train): a hierarchical approach to implementing SUDS in order to best reproduce natural drainage patterns. This recommends that the first choice of SUDS should be methods of 'prevention', i.e. preventing runoff increasing such as by retaining green areas or using acceptable alternatives to paving such as gravel which also allows infiltration. The next choice is for 'source control' where SUDS devices are employed to treat and dispose of rainfall where it falls, such as by infiltration devices. On sites with low permeability soil, infiltration may not be practically viable in which case SUDS are used to store runoff temporarily, providing treatment and attenuation, so that runoff can be released at a controlled rate. The next choice in the hierarchy is 'site control' where runoff may be moved around the development site, e.g. using SUDS features such as swales, to SUDS infiltration or attenuation devices at specific locations. The final choice is for 'regional control' where runoff is allowed to leave the site, ideally to an infiltration location elsewhere, if not then discharge into a watercourse is the next preferred options, with discharge into the sewer system being the last resort.

Appendix A

Data Register

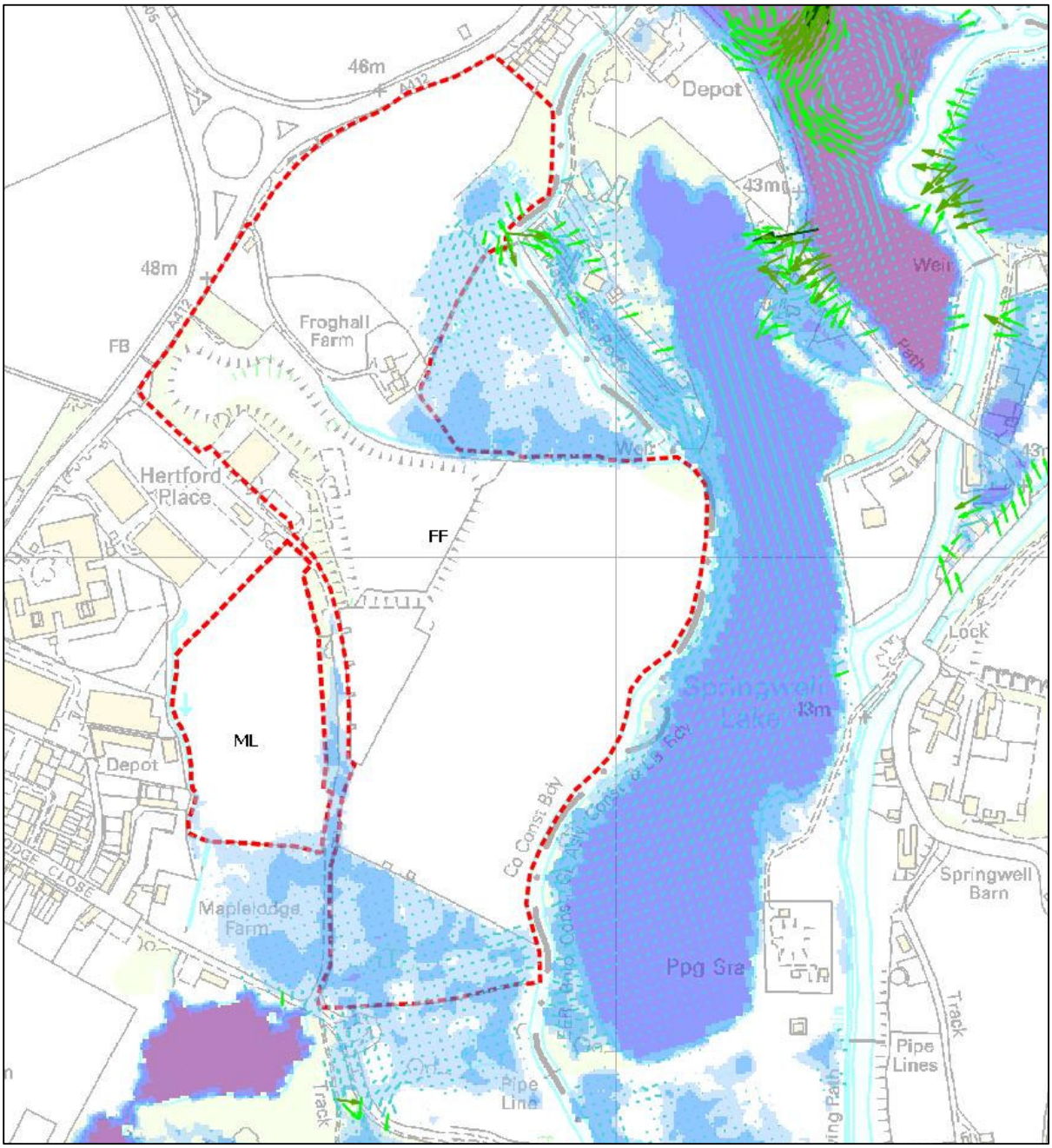
Appendix A Data Register

Data	Format	Source	Contribution to SFRA	Licensing	Date	Comments
Dacorum Borough Council St Albans City & District Council Three Rivers District Council Watford Borough Council Strategic Flood Risk Assessment (August 2007) GIS data	GIS	Halcrow	Flooding information		17/06/2011	Historical surface, groundwater and attributed fluvial flood data, GU_canal centre-line, and relevant defence and storage areas layers reused. Remaining layers updated.
Dacorum Borough Council St Albans City & District Council Three Rivers District Council Watford Borough Council Strategic Flood Risk Assessment (August 2007)	pdfs	Council website	Flooding information + policy		11/07/2011	From http://www.threerivers.gov.uk/Default.aspx/Web/StrategicFloodRiskAssessment
Dacorum Borough Council, St Albans City and District Council, Three Rivers District Council, Watford Borough Council, Welwyn Hatfield Borough Council Water Cycle Study Scoping Study	pdf	Council website	Flooding information + policy		11/07/2011	From http://www.threerivers.gov.uk/GetResource.aspx?file=WCS Scoping Study Final.pdf
Home Park FRA	pdf	District Council	Flooding information		08/07/2011	
Happy Valley FRA	pdf	District Council	Flooding information		08/07/2011	
Delta Gain FRA	pdf	District Council	Flooding information		08/07/2011	

Data	Format	Source	Contribution to SFRA	Licensing	Date	Comments
Delta Gain Sequential	pdf	District Council			08/07/2011	
Development Sites Information	doc	District Council	Proposed land uses for sites		08/07/2011	
TRDC OS Data July 2011	CD	District Council	OS mapping	yes - number 100018686	12/07/2011	Mastermap line and anno shape files, 10k tiffs
TRDC EA Datashare Data	CD	District Council	Flooding information	yes - on disk	12/07/2011	AStGWF, AStSWF, detailed river network, flood map, defences, fsa, ABDs, FMfSW, HFM, main rivers. Downloaded from Datashare on 11/7/11
NE2783OPP	CD	Environment Agency	Flooding and hydrogeological information	yes - on disk plus hardcopy	21/07/2011	GIS of Aquifers, Flood zones and Source protection zones. Modelling - report and model files but no results
3R Lidar data TL and TQ	2 CDs	District Council	Topography	yes - on disk	25/07/2011	dtm and dsm
Groundwater incidents	Excel	Environment Agency	Flooding information	Yes – with email	27/07/2011	Latest record of groundwater flooding

This page has been left intentionally blank.

Appendix B Enlarged version of Froghall Farm Flood Depths and Velocity for the 1 in 100 Year Plus Climate Change Breach Scenario



For details of your nearest Halcrow office, visit our website
halcrow.com

Halcrow