Dacorum Borough Council

Strategic Flood Risk Assessment (SFRA)
Level 2

Berkhamsted and Hemel Hempstead

June 2008

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Contents Amendment Record

This report has been issued and amended as follows:

Issue	Revision	Description	Date	Signed
1	1	First Draft	29/02/08	AK
2	1	Final	14/05/08	AK
2	2	Correction accordance with Environment Agency comments	02/06/08	AK

Contents

Appendix E: TUFLOW Modelling Approach

Appendix F: Breach Locations and Proposed Development

Appendix G: TUFLOW Modelling Flood Depth

Appendix H: TUFLOW Modelling Water Velocity

Appendix I: TUFLOW Modelling UK Hazard Maps

Appendix J: Combined Flood Map and Hazard Map

Figures

Tables

Executive Summary

In October 2007, Dacorum Borough Council commissioned Halcrow Group Limited to produce a Level 2 Strategic Flood Risk Assessment (SFRA) in accordance with Planning Policy Statement 25 (PPS25) and its Companion Guide, Making Space for Water (2003) and the Thames Catchment Flood Management Plan (2007). This study comprises detailed hydraulic modelling of the River Gade at Hemel Hempstead and breach modelling of the Grand Union Canal at Berkhamsted. Hemel Hempstead and Berkhamsted are both situated in Dacorum Borough Council, West Hertfordshire. This study refines and builds upon the work undertaken during the Level 1 SFRA which identified these two areas requiring further assessment. This study therefore focuses these two areas only. The Environment Agency has been consulted with throughout the study to ensure that the technical approach meets, and where possible, exceeds best practice.

The main watercourse in Hemel Hempstead is the River Gade which flows from north to south through the town centre. A one-dimensional (1-D) ISIS model was constructed of the River Gade to further refine the estimate of flood risk through Hemel Hempstead town centre, taking into account blockage scenarios for the Flood Relief Culvert. Several blockage scenarios were modelled – 'undefended' (100% blockage), defended (0% blockage) and 75% blockage (i.e. 75% of the flow will be directed down the River Gade). Modelling results indicate that three areas at risk of flooding are within or intersect with proposed development areas identified by the Borough Council - Leighton Buzzard Road, Moor End Road and Waters Road.

The town of Berkhamsted is situated alongside the River Bulbourne and the Grand Union Canal. To assess the consequences of breach of the Grand Union Canal on adjacent development, TuFlow model was constructed of the Grand Union Canal and the River Bulbourne through Berkhamsted. Four critical breach locations were identified and modelled based on a review of the topography and land use behind the Grand Union Canal. The results of the hydraulic assessment of each breach analysis have been mapped and the flood hazard assessed in accordance with current best-practice guidance (Defra/Environment Agency's 'Flood Risk to People - Guidance Document', 2006).

Most of the culvert on the River Bulbourne causes a significant back up of water during breach of the Grand Union Canal, which subsequently results in rapid inundation of the surrounding areas. Following a breach, the raised embankment at Stag Lane creates a

barrier to the flow resulting in water backing up and rapidly inundating the area upstream which has recently been developed for residential purposes.

All the proposed development areas identified by the Borough were found to be outside the 'risk areas', denoted as the area between the Grand Union Canal and the River Bulbourne which would be severely inundated with flood water if a breach of the canal occurred.

A number of policy recommendations are made for Hemel Hempstead and Berkhamsted based on detailed hydraulic modelling results from the Level 2 SFRA. For Hemel Hempstead this includes guidance for Development Control and potential developers required to produce site-specific Flood Risk Assessments. For Berkhamsted the topographic nature of the land behind the canal leads to rapid inundation from flood flows resulting from breach of the Grand Union Canal, creating hazardous conditions. Therefore a number of restrictions should be applied to any non-allocated 'windfall' sites within the modelled flood extent.

It is important to note that the Environment Agency are not the statutory consultee for canal flooding, hence the LPA in consultation with British Waterways will be responsible for assessing the Flood Risk Assessments produced in the areas at risk of canal breach. The LPA would need to provide guidance for all development areas that fall outside the Environment Agency's remit.

The Level 2 SFRA should be retained as a 'living' document and reviewed and revised where required in light of emerging policy guidance on 'other sources of flooding'.

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1 Introduction

1.1 *Project Overview*

Halcrow Group Ltd has been requested by Dacorum Borough Council to undertake a Level 2 Strategic Flood Risk Assessment (SFRA), focussing on residual risk from a breach of the Grand Union Canal in Berkhamsted and the residual risk from blockage or collapse of the Hemel Hempstead flood relief culvert. This refines and builds upon the work undertaken during the Level 1 SFRA which included a broad scale assessment of flood risk, using existing data, across the whole of the borough and from all sources.

During the Level 1 SFRA it was identified that blockage or collapse of the flood relief culvert may pose a residual risk to the town centre of Hemel Hempstead. As part of the Level 2 assessment, a one dimensional (1-D) ISIS model has been developed for the River Gade between Gadesbridge Park (above Queensway) and its confluence with the Grand Union Canal to determine flood risk for areas within Hemel Hempstead town centre. The flood extents for key return periods (1 in 20, 100, 100 plus climate change and 1000 years to represent Flood Zone 3b, Flood Zone 3a and Flood Zone 2) were determined and mapped, and the outputs used to inform appropriate flood risk management policies for the area.

During the Level 1 SFRA it was also considered that breaching or overtopping of the Grand Union Canal could pose a residual flood risk to the town of Berkhamsted. Broad areas of uniform flood risk were identified in Level 1 study (refer to ***Dacorum Level 1 SFRA – Volume II, Tile E4***). In this Level 2 SFRA the 2-Dimensional software TUFLOW has been used to produce peak flood extents, depths and flow velocities, and based on this information to assign a UK flood hazard classification in the study area. The refined assessment of flood risk has then been used to inform appropriate flood risk management policies for the areas affected.

This Level 2 SFRA has been prepared in accordance with best practice, Planning Policy Statement 25: Development and Flood Risk (PPS25). The Environment Agency's Development Control and Flood Risk Mapping team have also been consulted at all stages of the assessment, and both modelling and mapping methodologies are consistent with the Environment Agency requirements for a Level 2 Strategic Flood Risk Assessment.

1.2 Flood Risk Management Strategies - Environment Agency

The Environment Agency advocates a strategic approach to flood risk management on a 'whole catchment' basis. The work undertaken and recommendations provided in this Level 2 assessment are therefore in accordance with the Thames Catchment Flood Management Plan (2007) or Thames CFMP. A brief overview of the CFMP and the main recommendations for flood risk management is provided below.

1.2.1 Thames CFMP

The Thames CFMP is a high-level strategic planning document through which the Environment Agency will work with other stakeholders to identify and agree policies for long-term flood risk management over the next 50 to 100 years. It contains key messages for the region as a whole, and more specifically for chalk tibutaries to the Colne, such as the Rivers Gade and Bulbourne. The Level 1 study reviewed the key messages from the Thames Region CFMP and the key points are summarised below.

<u>The four main messages:</u>

- Flood defences cannot be built to protect everything;
- Climate change will be the major cause of increased flood risk in the future;
- The floodplain is our most important asset in managing flood risk; and
- Development and urban regeneration provide a crucial opportunity to manage the risk.

<u>Key messages for the Colne tributaries and Wye from the Thames CFMP Policy Unit:</u>

- Safeguard the existing undeveloped natural floodplain through the appropriate application of the sequential test within PPS25
- Reduce the consequences of flooding through continued action to raise public awareness of flooding, tailoring the advice and approach (e.g. community based) to ensure those 'at risk' take appropriate action to respond to flooding.
- Continue to reduce the impact of low order urban flooding (up to a 10% to 20% AEP flood – 1in 10 to 1 in 5 year return period) by maintaining conveyance where it both effective and sustainable to do so. There are

watercourses throughout the policy unit where previous alterations associated with the development have led to pinch points and other restrictions to the conveyance of water. It may be possible to alleviate the impacts from some of these.

- Through urban areas, to naturalise the river where practical by removing culverts, trash screens, artificial channel and bank lining where possible. This will contribute to reducing the maintenance burden in the future by removing unnecessary structures and improving the river environment.
- A growing proportion of the housing stock is made resilient or resistant to all forms of flooding. It must be recognised that this is a long-term objective.
- To gain a more complete understanding of surface water and drainage related flooding so that any future improvements are part of a wider strategy for addressing these sources of flooding. A Surface Water Management Plan (SWMP) or Integrated Urban Drainage Plan (IUDP) could define the future approach. This is particularly important in the urban centres (for example Hemel Hempstead and High Wycombe) in this policy unit because of both the existing and future risk.

1.3 Strategic Flood Risk Assessment

1.3.1 SFRA Aims

The aims of PPS25 planning policy on development and flood risk are to ensure that flood risk is taken into account at all stages of the planning process to avoid inappropriate development in areas at risk of flooding, and to direct development away from areas at highest risk. Where new development is necessary in such areas, under exceptional circumstances, the policy aims to make the development 'safe' without increasing flood risk elsewhere and, where possible, reducing flood risk overall. 'Safe' in the context of this study means that dry pedestrian access to and from developments is possible without passing through the 0.1% (1 in 1000 year) plus climate change flood extent (fluvial) or the 0.5% (1 in 200 year) tidal flood extent, and emergency vehicular access is possible (PPS25, 2006).

The aim of a SFRA therefore is to map all forms of flood risk and use this as an evidence base to locate new development primarily in low flood risk areas (Zone 1). Much of this work has been completed as part of the Level 1 assessment with recommendations for additional Level 2 work required to fully guide the planning and development control processes.

- Flood Zone 1 (Low Probability): This zone comprises land assessed as having less than a 1 in 1000 year annual probability of river or sea flooding in any year (>0.1%)

- Flood Zone 2 (Medium Probability): This zone comprises land assessed as having between a 1 in 100 (1%) and 1 in 1000 (0.1%) annual probability of river flooding or between a 1 in 200 (0.5%) and 1 in 1000 annual probability of sea flooding in any one year.

- Flood Zone 3 (High): This zone comprises land assessed as having a 1 in 100 or greater annual probability of river flooding or a 1 in 200 (0.5%) probability of flooding from the sea in any one year.

- Flood Zone 3b (Functional Floodplain): This zone comprises land where water has to flow or be stored in times of flood. SFRAs should identify this Flood Zone (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, or at another probability to be agreed between the LPA and the Environment Agency, including water conveyance routes).

Where development cannot be located in Flood Zone 1 the planning authority will need to apply the Sequential Test to land use allocations and, where necessary, the Exception Test. In addition, it allows a planning authority to:

- Prepare appropriate policies for the management of flood risk;
- Inform the sustainability appraisal so that flood risk is taken account of when considering options and in the preparation of strategic land use policies;
- Identify the level of detail required for site-specific Flood Risk Assessments (FRAs), and
- Determine the acceptability of flood risk in relation to emergency planning capability.

The findings of a SFRA will feed directly into the preparation of Local Development Documents, including the Core Strategy and Site Allocation Development Plan Documents (DPDs).

1.3.2 *Level 2 Strategic Flood Risk Assessment*

According to the PPS25 Practice Guide (***Section 2.36 to 2.42***), the principal purpose of a Level 2 SFRA is to facilitate the application of the Exception Test. This test is applied when there are an insufficient number of suitably available sites for development within zones of lower flood risk or due to possible increases in flood risk arising from climate change.

For the Exception Test to be passed:

a) It must be demonstrated that the development provides wider sustainability benefits to the community which outweigh flood risk, informed by a SFRA where one has been prepared. If the Development Plan Document has reached the 'submission' stage (see Figure 4 of PPS12: Local Development Frameworks) the benefits of the development should contribute to the Core Strategy's Sustainability Appraisal;

b) The development should be on developable previously-developed land or, if it is not on previously developed land, that there are no reasonable alternative sites on developable previously-developed land; and,

c) A flood risk assessment must demonstrate that the development will be safe, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

It is possible that Council will need to apply the Exception Test as several indicative sites fall within Flood Zone 3, although it is not possible to fully determine this until the Sequential Test process has been undertaken.

This increased scope of the Level 2 assessment involves a more detailed review of flood hazard (flood probability, flood depth, flood velocity, rate of onset of flooding) taking into account the presence of flood risk management measures such as flood defences (e.g. Hemel Hempstead Flood Relief Culvert). This also includes 2D modelling and breach/overtopping analysis for certain locations where the residual risk of failure of existing water retaining structures may impact on future development (e.g. areas adjacent to the Grand Union Canal in Berkhamsted).

Level 2 SFRA outputs include:

- An appraisal of the condition of flood defence infrastructure and likely future policy;
- An appraisal of the probability and consequence of breach or overtopping of flood defence infrastructure;
- Maps showing distribution of flood risk across zones;
- Guidance on appropriate policies for ensuring sites satisfy parts a) and b) of the Exception Test as described above; and the requirements for satisfying part c); and
- Guidance on the preparation of FRAs for sites with varying flood risk across the flood zone.

This Level 2 SFRA, in conjunction with the Level 1 SFRA, will enable Dacorum Borough Council to fully apply a Sequential Test approach at the site allocation level (vulnerable uses within the site to be directed to areas at the lowest probability of flooding in the first instance) and will inform policies and practices to ensure that where necessary any development in such areas satisfies the requirements of the Exception Test.

1.4 Background to study areas

Hemel Hempstead and Berkhamsted are both situated in Dacorum Borough Council, West Hertfordshire. The main watercourse in Hemel Hemsptead is the River Gade (Main River status) which flows from north to south through the town centre (comprising a mixture of retail, residential, civic and amenity land uses) and then joins the Grand Union Canal approximately 1km downstream. Further downstream the Gade then confluences with the River Bulbourne.

Within Berkhamsted the main watercourse is the River Bulbourne. The town is situated alongside the Grand Union Canal which was built in the 19th century for the purpose of industrial transport and also the River Bulbourne which runs adjacent to the canal (including sections of canalised river).

Both watercourses are chalk tributaries to the Upper Colne River.

1.5 Aims & Objectives

In August 2007 a Level 1 Strategic Flood Risk Assessment (SFRA) was produced by Halcrow for Dacorum Borough Council in accordance with PPS25. Following

this study the Borough identified the need for a Level 2 SFRA in order to facilitate application of the Exception Test (possible future site allocations were identified in zones of higher flood risk). This study focuses on proposed development in Hemel Hempstead town centre adjacent to the River Gade and in low-lying areas adjacent to River Bulbourne/Grand Union Canal in Berkhamsted town.

1.5.1 *Aim*

The main aim of this Level 2 SFRA has been to develop detailed hydraulic models to refine the assessment of flood risk from;

- Breach of the Grand Union Canal embankment in Berkhamsted; and
- Blockage or collapse of the Hemel Hempstead flood relief culvert

1.5.2 *Main Tasks for Berkhamsted*

- Identify critical breach locations along the Grand Union Canal and develop a two dimensional hydraulic model
- Run simulations for the breach scenarios
- Produce flood maps showing:
  - (i) Flood Extent
  - (ii) Flood Depth
  - (iii) Flood Velocity
  - (iv) UK Flood Hazard – derived from flood depth, velocity and UK hazard debris factor.

The use of a 2-D model enables extraction of components (iii) to (iv) above which cannot be obtained from a 1-D model alone.

1.5.3 *Main Tasks for Hemel Hempstead*

- Identify blockage or collapse scenarios of the Hemel Hempstead flood relief culvert
- Develop a simplified hydrological model for the River Gade
- Develop a 1-D ISIS model for the River Gade and run simulations for the 20, 100, 100 plus climate change and 1000 year return periods
- Produce flood maps showing the flood extent

2 Hemel Hempstead

2.1 *Overview*

The Level 1 SFRA recommended a detailed assessment of the residual risk of failure (i.e. collapse) or significant blockage of the Hemel Hempstead flood relief culvert potentially resulting in flooding of residential, commercial and industrial properties through the centre of Hemel Hempstead. This section details the approach adopted to assess the residual risk in Hemel Hempstead and presents the results for the proposed development areas 1, 2, 3 and 4-7, as identified by the borough.

The Environment Agency has been consulted at all stages of the study to ensure that the technical approach meets, and where possible, exceeds best practice.

2.2 *Background*

2.2.1 *The Hemel Hempstead Flood Relief Culvert*

The Hemel Hempstead Flood Relief Culvert was constructed in 1959 to provide flood defence to Hemel Hempstead, Apsley and parts of Kings Langley. The scheme involved the construction of a relief culvert from Bury Mill (located on the River Gade, to the north of Hemel Hempstead) to Kings Park Industrial Estate (in Kings Langley, also on the River Gade).

There is little information available for the Flood Relief Culvert, including ownership, although it is believed that the structure is owned by Thames Water as part of their sewerage infrastructure. The structure is therefore not listed in the Environment Agency's National Flood and Coastal Defence Database (NFCDD). Although requested from Thames Water as part of the Level 1 SFRA, no information has been provided on its maintenance regime, condition status or the location of connections. Information has been requested from Thames Water by the Environment Agency as part of a study on the Upper Colne River but has not been provided.

It is known that there are inflows along the length of the culvert from the River Bulbourne and from numerous surface water drains. Furthermore, it is known that with the present inlet weir configuration (located at Bury Mill, Hemel Hempstead), the majority of flow from the River Gade is directed through the culvert rather than the river channel, which flows through the centre of Hemel Hempstead. This

suggests that flooding of residential, commercial and industrial properties could occur in the event of a failure (i.e. collapse) or significant blockage.

2.2.2 *Proposed Development Areas*

Dacorum Borough Council has identified a number of Development Areas in their Development Plan Document which are located within the town centre of Hemel Hempstead. These are (also see ***Appendix D***):

- Development Area 1: Hemel Hempstead Town Centre (located between Queensway and Bridge Street)
- Development Area 2: Moor End Road
- Development Area 3: Two Waters Road (south of the roundabout)
- Development Area 4: Cotterells (adjacent to the statue)
- Development Area 5: East of Hemel Hempstead Hospital
- Development Area 6: South of Hemel Hempstead Hospital
- Development Area 7: Adjacent to industrial estate (St Albans Road)

Development Area 1 is our main focus for this study and is to be redeveloped as part of the 'Hemel Hempstead 2020 – regeneration vision'. The remaining Development Areas to be put forward as representations to developers as potential development sites. A detailed examination of the effect of residual risk at each of the site allocations is summarised below.

2.3 Assessment of Residual Risk

2.3.1 *Hydrological Inputs*

The hydrological inputs to the assessment are derived using the Flood Estimation Handbook (FEH) (Volume 3 & 4). The catchment has been schematised into two sub-catchments representing the two types of flow responses experienced through the catchment. Sub-catchment 1 (SC1) represents the baseflow component from the upstream rural catchment area, a relatively slow response with characteristically low peaks. Sub-catchment 2 (SC2) represents the quick flow component from the urban catchment area through the centre of Hemel Hempstead representing the artificial influence of urban runoff, a relatively quick response with characteristically high peaks. Design flow estimates at the gauging station (donor) and the sub catchments (SC1 and SC2) were undertaken following standard FEH procedures, including statistical analysis and rainfall-runoff modelling (***Table 1***). Design flow estimates were derived for input into the 1-Dimensional Hydraulic

model following standard FEH procedures with appropriate reconciliation between the two estimates.

Return Periods (yrs)	**2**	**5**	**10**	**20**	**50**	**100**	**200**	**1000**
Flow from Rural Catchment (SC1) (m^3/s)	0.9	1.1	1.4	1.8	2.2	2.4	2.8	4.1
Flow from Urban Catchment (SC2) (m^3/s)	1.0	1.5	1.8	2.1	2.5	2.8	3.4	4.5

Table 1: Peak Flows during various flood flows

A detailed technical review of hydrological approach is provided in ***Appendix A***.

2.3.2 *Hydraulic Modelling Approach*

The ISIS 1D modelling software package was used to construct a model of the River Gade reach running through Hemel Hempstead. The upstream limit of the model is Charter House, along the A4146 Road (Gadebridge Park) – (Grid reference 505271, 207812) and the downstream end is at the confluence of River Gade with the Grand Union Canal at Heat Park. Recently surveyed data of hydraulically significant channel sections and control structures along the River Gade were used to construct the model. The specification of the River Gade survey is given in ***Appendix B.*** Additional infill channel sections were derived from photogrammetry data and bed levels adjusted using interpolation from surveyed sections.

For a Level 2 SFRA the assessment of flood risk should take account of the presence of flood defences. There is a residual risk associated with blockage or collapse of the culvert which would affect the volume of water being passed along the River Gade through Hemel Hempstead. Therefore a number of blockage scenarios were modelled for the Hemel Hempstead Flood Relief Culvert.

The 'undefended' scenario should ignore the presence of flood defences. This equates to 100% blockage of the culvert, therefore directing all flows through

Hemel Hempstead. Inclusion of the Hemel Hempstead flood relief culvert (0% blockage) would represent the 'defended' scenario.

For the purposes of this study, the 'undefended' (100% blockage) and 'defended' (0% blockage) scenarios were modelled, as well as 75% blockage of the culvert (i.e. 75% of the flow will be directed down the River Gade).

Mapping results show the 75% blockage scenario; this is considered to be 'conservative'. This approach was agreed with the Environment Agency and Dacorum Borough Council, given the uncertainty associated with the condition and future maintenance of the Hemel Hempstead Flood Relief Culvert. It is important to note that the 'undefended' scenario (100% blockage) results reveal little difference in flood extents to the 75% blockage scenario.

Different blockage scenarios were modelled by adjusting the spill levels into the flood relief culvert. The spill was removed for the 'undefended' scenario (100% blockage) and the level was raised by 400mm for the 75% blockage scenario. Simulations were runs for 20 year, 100 year, 100 year plus climate change and 1000 year flood events. A discussion of the detailed technical approach for hydraulic modelling of the River Gade is given in ***Appendix C***.

The full results of the hydraulic assessment of the blockage/collapse scenarios for the Hemel Hempstead flood relief culvert have been mapped and are given in ***Appendix D.***

2.4 Model Results

The aim of the hydraulic modelling is to assess the residual risk associated with collapse or blockage of the flood relief culvert. Therefore, hydraulic modelling results consider flooding from the River Gade only and do not incorporate any other forms of flooding. The results of the hydraulic modelling have indicated that there are three critical areas (see ***Appendix D***) at risk of flooding should a blockage or collapse of the Hemel Hempstead flood relief culvert occur (based on the 75% blockage scenario – i.e. 75% of the flow will be directed down the Gade). These areas are:

- Leighton Buzzard Road, Hemel Hempstead (see Development Area 1)
- Moor End Road, Hemel Hempstead (see Development Area 2)
- Waters Road, Hemel Hempstead (see Development Area 3)

These three critical areas are within or intersect with three of the Development Areas identified by the Borough Council where development may be proposed.

a) Development Area 1: Hemel Hempstead Town Centre (located between Queensway and Bridge Street)

The modelled results show that the north-western edge of the site allocation (including an area of Leighton Buzzard Road) would be at risk of flooding during the 1 in 20 year event (Maximum water level 83.97 mAOD). As such in accordance with PPS25 this area will be classified as Flood Zone 3b. In addition there is a limited area within the site (opposite the entrance to Bury Road) which will be classified as Flood Zone 3a (Maximum water level 84.00 mAOD) and Flood Zone 2 (Figure 1). The remainder of the site allocation will be classified as Flood Zone 1. The maximum water velocity at this location is approximately 1.0m/s during 1 in 100 year flood flow.

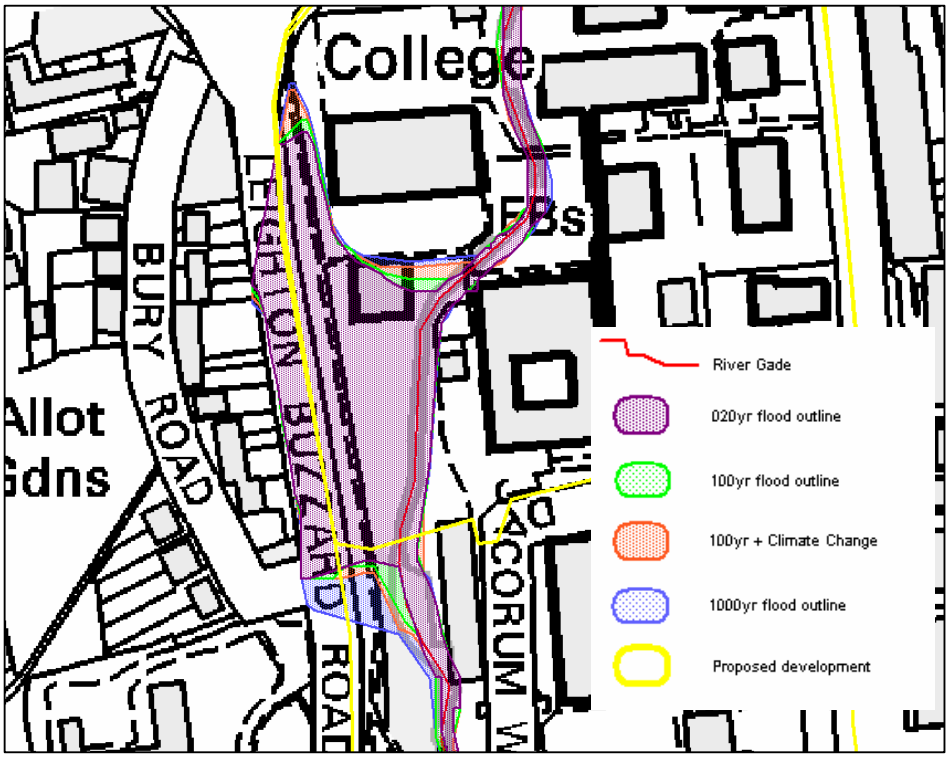


Figure 1: Flooding at Leighton Buzzard Road, Hemel Hempstead

b) Development Area 2: Moor End Road

The modelled results show that a very limited area on the western side of the site allocation (including parts of Moor End Road and Statue area) will flood during the 1 in 20 year event (Maximum water level 81.42 mAOD), and hence in accordance with PPS25 this area within the site boundary will be classified as Flood Zone 3b. A greater percentage of the site allocation on the western aide will flood in the 1 in 100 year and 1 in 1000 year event and as such will be classified as Flood Zone 3a (Maximum water level 81.54mAOD) and Flood Zone 2. The remainder of the site allocation will be classified as Flood Zone 1 (Figure 2). The maximum water velocity at this location is approximately 0.1m/s during 1 in 100 year flood flow (i.e. almost standing water).

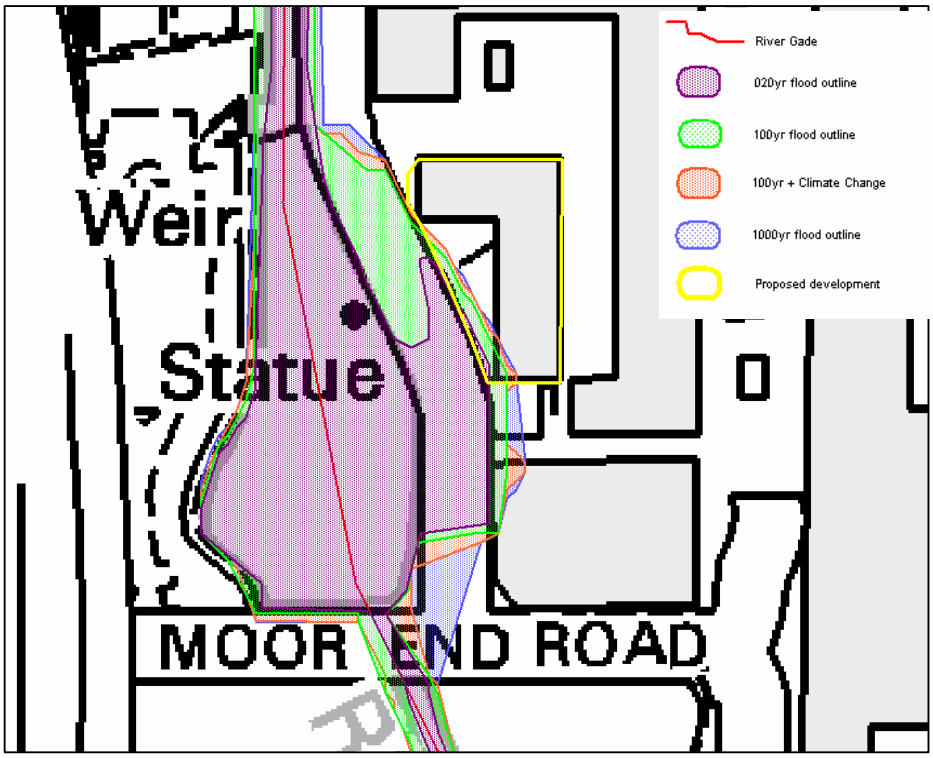


Figure 2: Flooding at Moor End Road, Hemel Hempstead

c) Development Area 3: Two Waters Road (south of the roundabout)

The modelled results show that a significant part (approximately 50%) of the site allocation (including parts of adjoining roads at the roundabout) will flood in the 1 in 20 year event (Maximum water level 80.85mAOD), and hence in accordance with PPS25 will be classified as Flood Zone 3b. The remainder of the site allocation will flood in the 1 in 100 year event (Maximum water level 81.00mAOD), and as such will be classified as Flood Zone 3a (Figure 3). The maximum water velocity at this location is approximately 1.0m/s during 1 in 100 year flood flow.

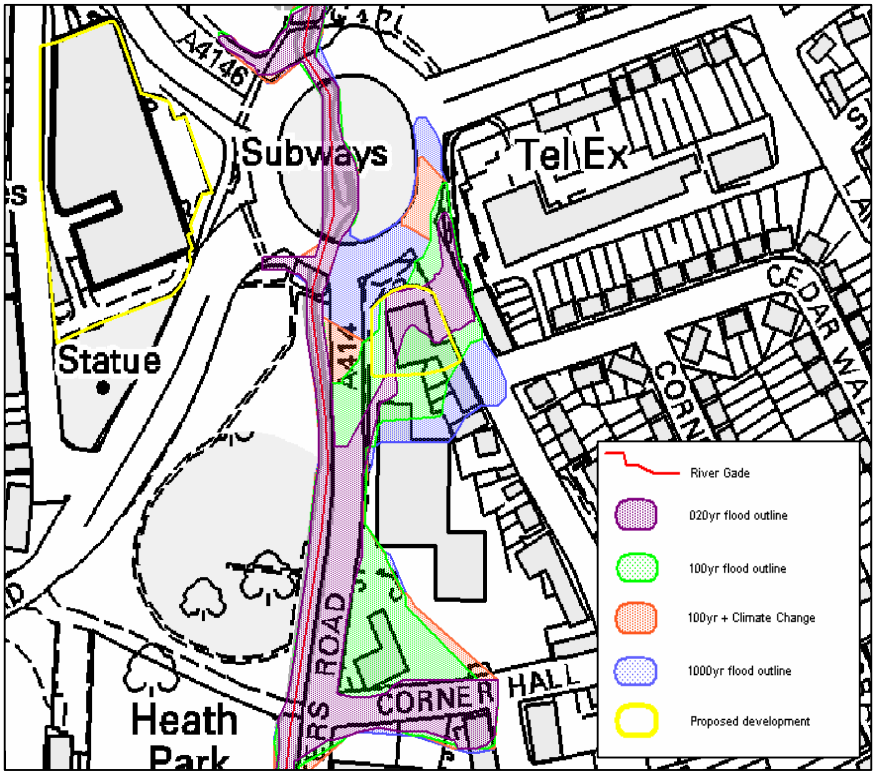


Figure 3: Flooding at Waters Road and Corner Hall, Hemel Hempstead

d) Development Areas 4 – 7

The modelled results show the remaining Development Areas (4 to 7) are classified as Flood Zone 1 and therefore are not at risk of fluvial flooding from the River Gade (Figure 4). However, if any development were proposed this would require carrying out a flood risk assessment for the sites in Flood Zone 1 with an area greater than 1 hectare to assess the impact of the development on surface water drainage and flood risk downstream.

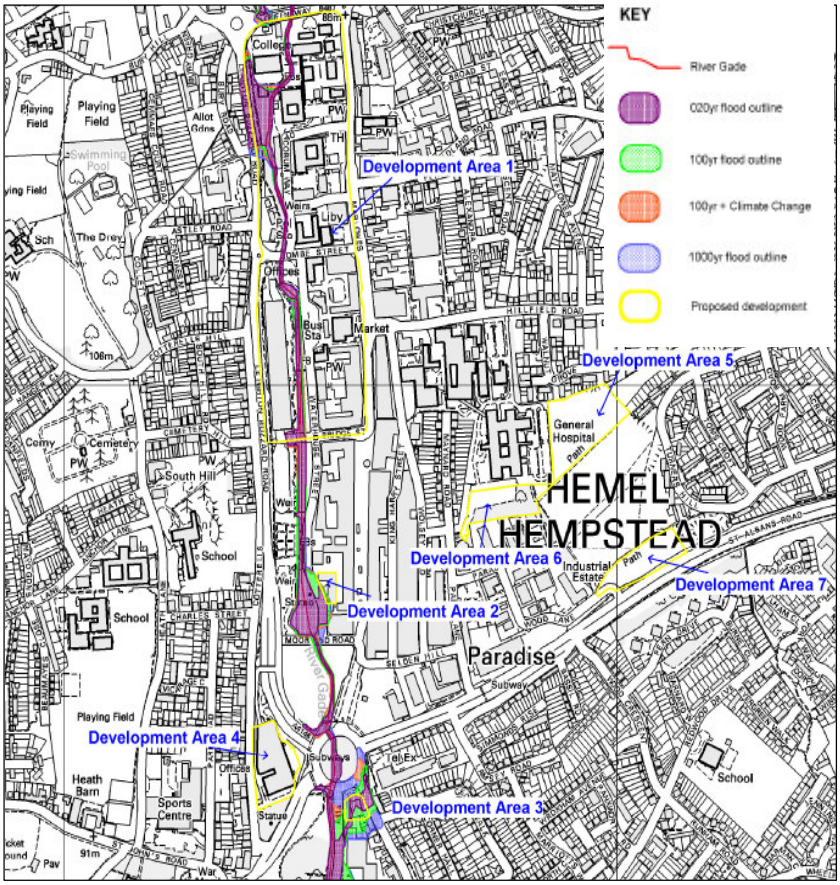


Figure 4: Development Areas 4-7

3 Berkhamsted

3.1 *Overview*

The Level 1 SFRA recommended a detailed assessment of the residual risk of overtopping or breach of the Grand Union Canal. If the Canal embankment failed or overtopped there could be significant damage to existing adjacent residential properties and commercial premises, as well as the potential for loss of life. This section of the report details the approach adopted to assess the residual risk in Berkhamsted and provides results for four critical breach locations which were identified from a detailed topographical model and following a site walkover.

3.1.1 *Background*

As part of the Level 1 SFRA British Waterways were consulted to determine the risk of flooding from the Grand Union Canal. Although British Waterways considered the risk of breach or overtopping to be relatively low (there are no historical records of canal overtopping or breach in this area), there are significant sections of embankment in Berkhamsted which are up to 3m higher than surrounding ground levels. If these sections of embankment failed or were overtopped there could be significant damage to adjacent residential properties and commercial premises. This Level 2 SFRA refines the existing flood hazard information presented in the Level 1 SFRA report to ensure that any future allocated or non-allocated 'windfall' developments include appropriate mitigation against any residual risks. The outputs also provide an assessment of the residual flood risk to existing commercial and residential properties, which can be used to inform the Borough's emergency plans.

3.1.2 *Development Areas*

Dacorum Borough Council has identified a number of broad Development Areas for potential development in their Development Plan Document which are located within Berkhamsted town centre (***see Appendix F***).

3.2 *Assessment of Residual Risk*

3.2.1 *Modelling Approach*

A linked 1-Dimensional / 2-Dimensional model was created using the ESTRY (1-D) and TUFLOW (2-D) modelling packages. The model which comprises the Grand Union Canal and River Bulbourne running through Berkhamsted, has an upstream limit at the junction of Wharf Lane and Dudswell Lane – (Grid reference

496590, 209733) and downstream limit at the confluence of the River Bulbourne with the Grand Union Canal just upstream of the junction between London Road (A4251) and Bank Mill Lane (***see Appendix F***).

The 2-D TUFLOW model was developed to represent the urban floodplain and the 1-D ESTRY model to represent the River Bulbourne. In the 1-D model the bed levels in the River Bulbourne were obtained from LiDAR.. These two model components were then combined to form one dynamically linked model to assess the consequences of a breach of the Grand Union Canal.

In the 2-D TUFLOW model, the Grand Union Canal was represented as a series of lakes, each lake being a section of the Canal contained between two lock gates. The breach was represented in the combined model as a weir unit passing water from the lake (Grand Union Canal) into the floodplain (Berkhamsted).

This approach is considered appropriate as breach is highly unlikely and therefore assuming a concurrent flood event in the River Bulbourne (Joint Probability Study) would be overly conservative and beyond the scope of the current study.

Further technical details of the TUFLOW modelling are provided in ***Appendix E***.

3.2.2 *Breach locations*

Topographic analysis of the land behind the Grand Union Canal was carried out as part of the Level 1 SFRA to define broad low-lying areas adjacent to the Canal with a residual risk of flooding. Following a site walkover, four 'critical' breach locations were identified along the Canal. These breach locations were selected as those which if breached would cause the most significant flood damages. For other less critical areas not covered it is considered important to develop a generic approach for assessing the impact of a breach (see section 3.4.6).

The selected breach locations are (Figure 5):

- Breach 1: North of Mandelyns Road;
- Beach 2: North of Valley Road;
- Beach 3: North of Delton Road; and
- Breach 4: North of Bridge Street.

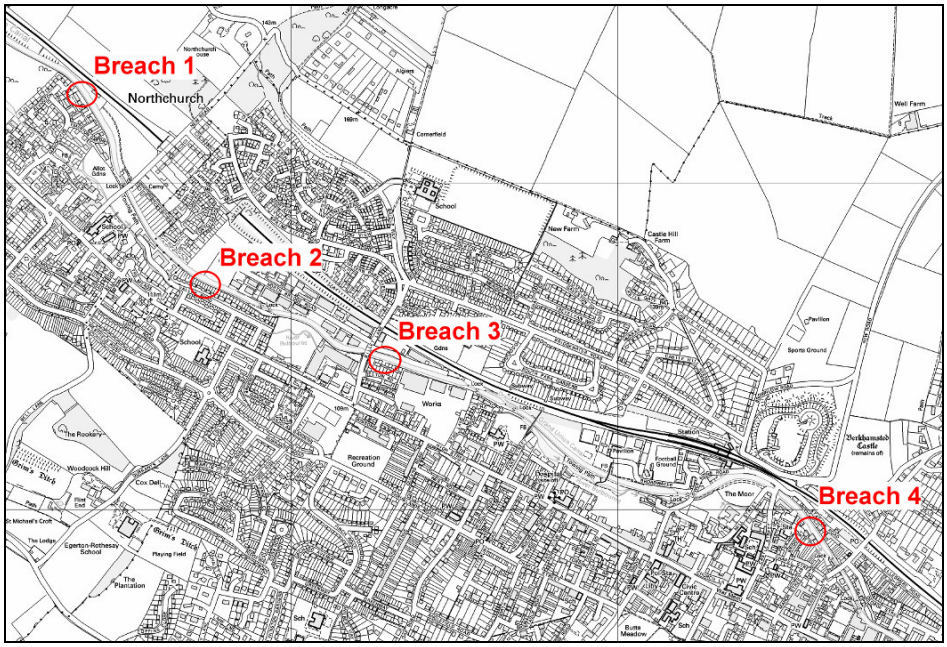


Figure 5: Model Beach Locations

These four breaches were modelled following the Environment Agency's Guidance for SFRAs (***see Appendix F***), assuming a 20 metre breach width and a metre depth to adjacent ground level.

The extent of inundation of urban areas through Berkhamsted by breach of the Canal is dependent on the volume of water contained between two sets of locks. A critical breach location has been defined for each of the four TUFLOW domains. Each breach (20 metre wide weir) will release the equivalent volume of water to that contained in the canal between a set of locks.

A head-time downstream boundary was set up at the confluence of River Bulbourne and the Grand Union Canal, based on a constant water depth of 1.0 metre in the canal. This is represented in the linked 1-D model as a weir unit spilling water into the Grand Union Canal from the River Bulbourne.

3.3 UK Flood Hazard

In addition to the TUFLOW outputs of depth and velocity, the UK Flood Hazard is also calculated by the model. The output includes a grid of Flood Hazard derived from the flood depth and velocity outputs and a debris factor. The Hazard and its associated classification is calculated within TUFLOW. The methodology for these calculations is given below.

The UK Flood Hazard is calculated using the following equation from DEFRA (2006) R&D Outputs: Flood Risks to People Phase Two Draft (FD2321/ TR2).

Hazard = d x (v + 0.5) + DF

Where **d** = depth (m)

V = velocity (m/s)

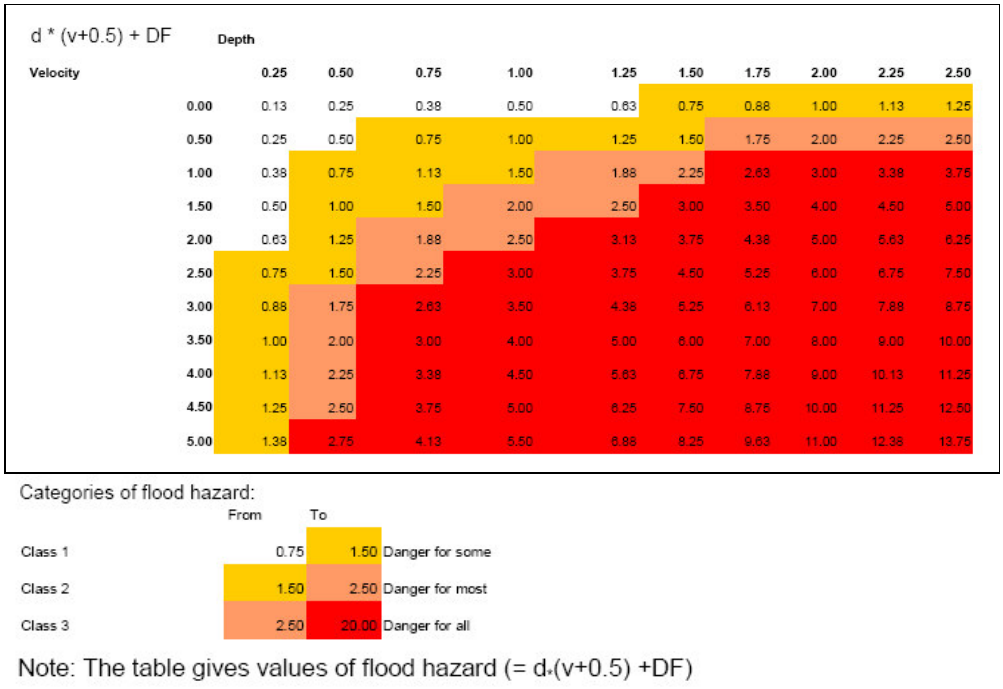
DF = Debris Factor

A conservative DF of 1.0 for urban areas has been applied in this study, as advised by FD2321/ TR2 (2006). The value obtained for the Hazard is then used to assign a hazard category.

Based on the value of the Hazard for a given area, a Hazard Classification is then assigned. The Flood Hazard Classifications are as shown in ***Figure 6*** from FD2321/ TR2 (2006) are divided into three Classes. These Classes of risk are:

- Class 1: Danger for some – Flood zone with deep or fast flowing water that presents a hazard for some people (i.e. children)
- Class 2: Danger for most – Flood zone with deep or fast flowing water that presents a hazard for <u>most</u> people
- Class 3: Danger for all – Flood zone with deep or fast flowing water that presents a hazard for <u>all</u> people

For example, if peak water depths are 1.0 m for example, for velocities less than 1.0 m/s, the flooding is considered to present 'Danger for some'. For velocities between 1.0 m/s and 2.0 m/s the flooding is considered to present 'Danger for most'. For velocities greater than 2.0 m/s the flooding is considered to present 'Danger for all'.



d * (v+0.5) + DF

Velocity \ Depth	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
0.00	0.13	0.25	0.38	0.50	0.63	0.75	0.88	1.00	1.13	1.25
0.50	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
1.00	0.38	0.75	1.13	1.50	1.88	2.25	2.63	3.00	3.38	3.75
1.50	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
2.00	0.63	1.25	1.88	2.50	3.13	3.75	4.38	5.00	5.63	6.25
2.50	0.75	1.50	2.25	3.00	3.75	4.50	5.25	6.00	6.75	7.50
3.00	0.88	1.75	2.63	3.50	4.38	5.25	6.13	7.00	7.88	8.75
3.50	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
4.00	1.13	2.25	3.38	4.50	5.63	6.75	7.88	9.00	10.13	11.25
4.50	1.25	2.50	3.75	5.00	6.25	7.50	8.75	10.00	11.25	12.50
5.00	1.38	2.75	4.13	5.50	6.88	8.25	9.63	11.00	12.38	13.75

Categories of flood hazard:

	From	To	
Class 1	0.75	1.50	Danger for some
Class 2	1.50	2.50	Danger for most
Class 3	2.50	20.00	Danger for all

Note: The table gives values of flood hazard (= d.(v+0.5) +DF)

Figure 6: UK Flood Hazard Classification

3.4 ***Results***

3.4.1 *Flood Maps*

The results of the hydraulic assessment of each breach analysis have been mapped. The flood depths, water velocities and UK Flood Hazard Maps for each individual breach location are provided in ***Appendices G, H and I, respectively***. The combined residual flood extent and UK Hazard Flood Maps are given in ***Appendix J.***

3.4.2 *Results for Breach 1to the north of Mandelyns Road*

The low-lying areas north of the B4506 would be at risk of flooding during a breach of the Grand Union Canal to the north of Mandelyns Road (Figure 7). The maximum water velocity varies between 0.7m/s and 1.2m/s within the existing developed areas (see ***Appendix H***). Following breach the water rapidly enters the low-lying areas adjacent to the River Bulbourne and flows downstream. The culvert under the B4506 causes significant water to back up, which subsequently results in rapid inundation at the Allotment Gardens opposite Kite Field Road. The maximum water depth upstream of B4506 would be around 1.0m within 30 minutes of a breach of the Grand Union Canal (see ***Appendix G***). Sections of Alynton and Madelyn Road, as well as the allotment gardens and several existing developments are classified as 'Danger for most' in accordance with current best-practice guidance (see ***Appendix I***).

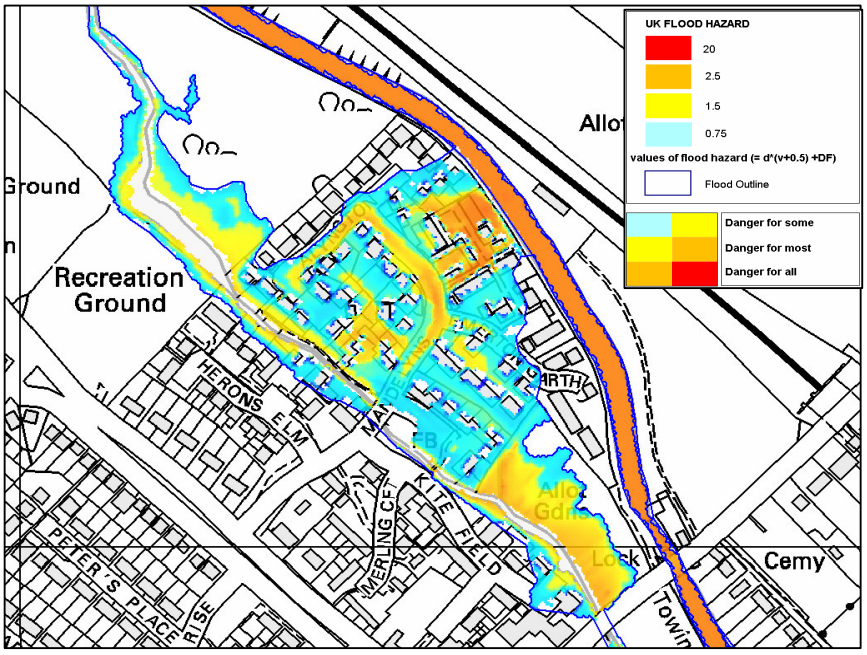


Figure 7: High Residual Risk Area between the Grand Union Canal and Herons Elm Street, Berkhamsted

3.4.3 *Results for Breach 2 to the north of Valley Road*

The low-lying areas between the B4506 and Billet Lane would be at risk of flooding during a breach of the Grand Union Canal to the north of Valley Road (see Figure 8). The maximum water velocity varies between 0.7m/s and 0.9m/s within the existing developed areas around Valley Road (see ***Appendix H***). Following breach the water rapidly enters the low-lying areas adjacent to the River Bulbourne and flows downstream. The maximum water depth upstream of the culvert would be around 1.0m within 30 minutes of the breach of the Grand Union Canal (see ***Appendix G***). The gardens alongside the Meads and a significant section of Valley Road, including several houses are classified as 'Danger for most' (see ***Appendix I***).

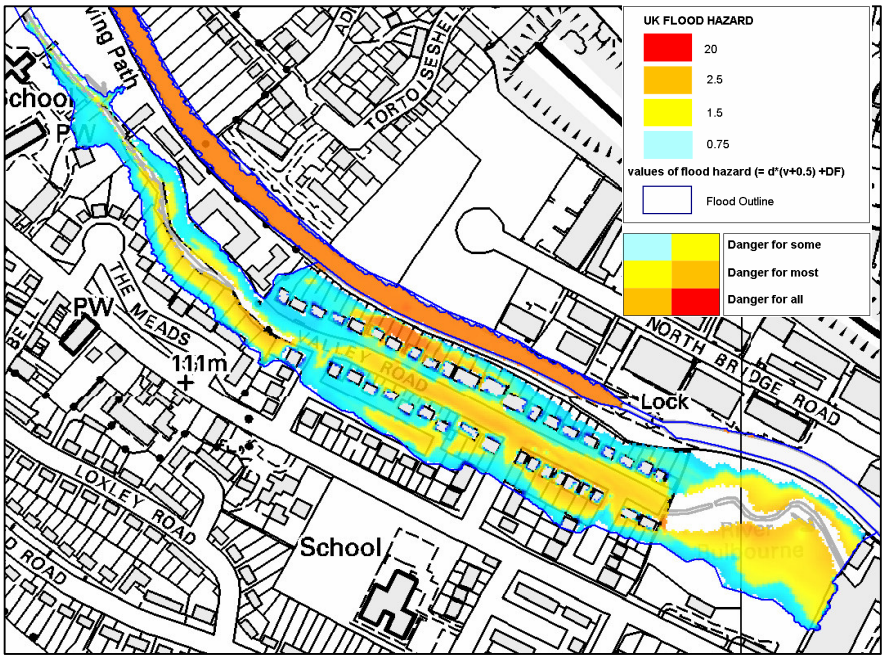


Figure 8: High Residual Risk Area between the Grand Union Canal and High Street, Berkhamsted

3.4.4 *Results for Breach 3 to the north of Delton Road*

The low-lying areas between Billet Lane and Park Street would be at risk of flooding following a breach in the Grand Union Canal to the north of Delton Road (see Figure 9). The maximum water velocity varies between 0.9m/s and 1.2m/s within the existing developed areas around Delton Road and Stag Lane (see ***Appendix H***). Following breach the water would rapidly inundate the low-lying areas adjacent to the River Bulbourne and then continue to flows downstream. The raised embankment of Stag Lane causes a barrier to the flow resulting in water backing up and rapidly inundating the area upstream which has recently been developed for residential purposes. The maximum water depth within this area would be around 1.0m within 30 minutes of breach of the Grand Union Canal (see ***Appendix G***). Several houses on either side of Belton Road, as well as the recent Stag Lane development are classified as 'Danger for most' (see ***Appendix I***).

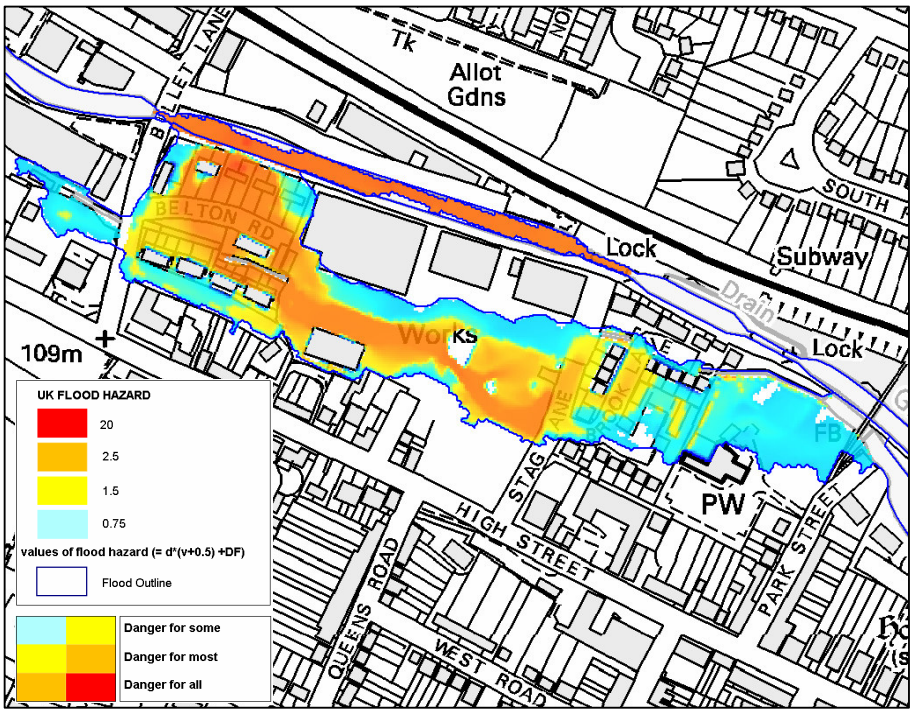


Figure 9: High Residual Risk Area between the Grand Union Canal, Billet Lane and High Street, Berkhamsted

3.4.5 *Results for Breach 4 to the north of Bridge Road*

The low-lying areas between Bridge Street and Ravens Lane would be at risk of flooding following a breach in the Grand Union Canal to the north of Bridge Street (see Figure 10). The maximum water velocity varies between 0.3m/s and 0.5m/s within the existing developed areas around Ravens Lane (see ***Appendix H***). However the velocity adjacent to the location at breach could be as high as 1.2m/s. Following breach the water would rapidly inundate the low-lying areas adjacent to the River Bulbourne and continue to flow downstream, potentially causing damage to properties along Chapel Lane (classified as 'Danger for Some') and Holliday Street (classified as 'Danger for most') (see ***Appendix I***) . The maximum water depth would be around 0.5m within 30 minutes of breach at Grand Union Canal (see ***Appendix G***).

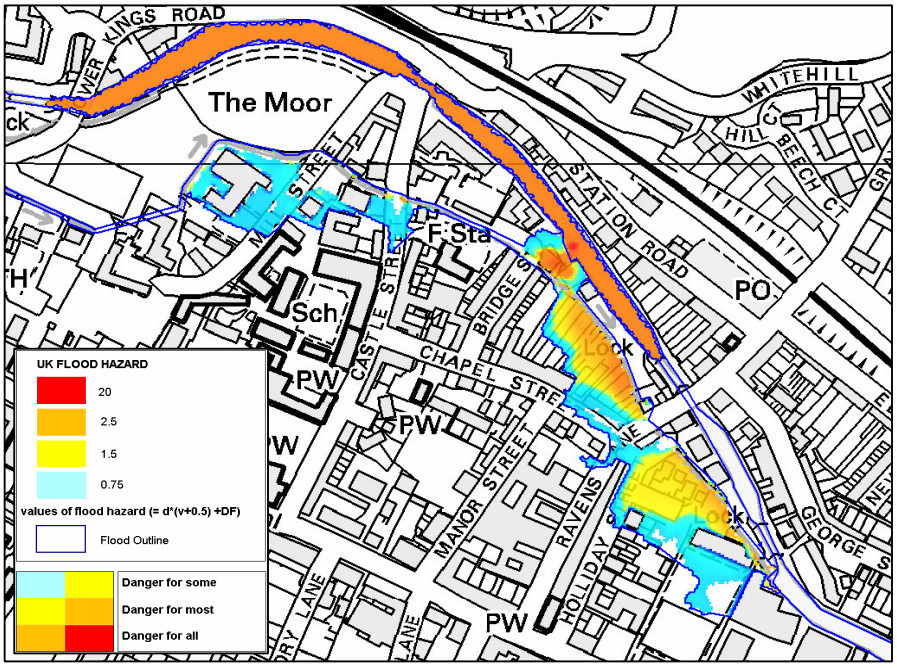


Figure 10: High Residual Risk Area between the Grand Union Canal, Chapel Street and Ravens Lane, Berkhamsted

3.4.6 *Results Summary*

The results of the breach analysis have clearly indicated that the area bound between the Grand Union Canal and the River Bulbourne can be classified as 'Danger for most' following breach of the Canal, as a result of the relatively high water velocities. The low-lying areas adjacent to the River Bulbourne can also be classified as 'Danger for most', following breach of the Canal, as a result of the significant water depths (of up to 1.0m within 30 minutes).

During the assessment it was found that the presence of raised road embankments (and the culverts designed for standard fluvial flooding) crossing the Bulbourne could cause water to backup resulting in significant flood depths in low lying areas behind these structures (see ***Appendix J***). Following a breach of the Canal, due to a combination of the flood depths, velocities and debris expected, large areas adjacent to the Canal and River would be hazardous, posing significant risk to people and property within the impact zone. Inundation rates would be quick with an extensive area of residential and commercial buildings becoming flooded to depths of up to 1.0m within 30 minutes with a maximum velocity of 1.2m/s.

It should be noted that only a limited number of critical breach locations were modelled during this study based on a walk over survey and review of the local topography. Thus for other less critical areas not covered it is considered important to develop a generic model for assessing the impact of a breach. From the analysis, it was noted that there are rapid inundation zone (high velocities and depth), which forms next to the breach and also high depth zone in the low-lying area in the River Bulbourne floodplain (see ***Appendix J***).

These zones have been described in a precautionary manner as low-lying areas bounded between River Bulbourne and the Grand Union Canal and are generally classified as 'Danger for most' (See Figure 11). It is important to note that variations in topography, distance from the breach or built structures may affect the level of hazard varying between 'Danger for some' and 'Danger for most'.

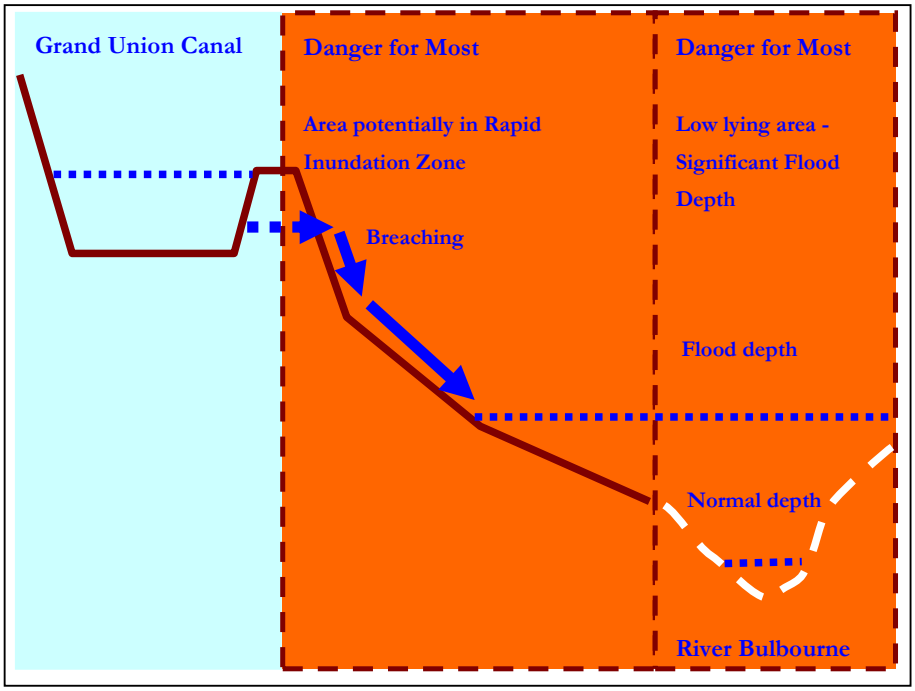


Figure 11: Level of Risk in a Breach of the Grand Union Canal

The risk of damage to property and the potential threat to people behind the Grand Union Canal embankments following a breach should be considered during future development within these areas, and in future updates to emergency response plans.

4 Policy Recommendations

4.1 Overview

This chapter provides recommendations to enhance the existing flood risk management policies outlined in the Level 1 SFRA report[1]. This includes guidance for Development Control and potential developers required to produce site-specific Flood Risk Assessments.

The following recommendations are in line with PPS25 and are in accordance with the broad objectives of the Colne tributaries and Wye from the Thames CFMP Policy Unit for this area.

4.2 Hemel Hempstead

4.2.1 *Planning Recommendations for the Development Areas*

- *Development Area 1 (Hemel Hempstead Town Centre) and Development Area 2 (Moor End Road)*

Future development within proposed Development Area 1 and Development Area 2 (see ***Appendix D*** for location) will require application of the sequential approach at the site level (sequential design) to ensure that the more vulnerable development (i.e. residential housing) is located within an area of the site which is at least risk of flooding (i.e. Flood Zone 1). Areas at higher risk of flooding should ideally be set-aside as open space for amenity and potential environmental enhancements to satisfy the requirements of the Sequential Test (see Table D.3. of PPS25 for other uses). The vulnerability from other sources of flooding should be considered as well as the effect of the new development on surface water runoff (See guidance in Development Areas 4-7 below).

- *Development Area 3*

Future development within Development Area 3 (located within Flood Zone 3b and 3a - see ***Appendix D*** for location) will be dependent on the vulnerability classification of the 'use' proposed, as advocated by PPS25 (see Table D.3. of PPS25). Development in Flood Zone 3b will be restricted to Water compatible use to satisfy the requirements of the Sequential Test. For Essential infrastructure uses it is necessary to ensure that the requirements of the Exception Test are satisfied. Development in Flood Zone 3a will be restricted to Water compatible use or Less Vulnerable use to satisfy the requirements of the Sequential Test. For More vulnerable use it is necessary to ensure that the requirements of the Exception Test

are satisfied. The Exception Test will need to demonstrate that the development will provide wider sustainability benefits and will not increase flood risk at the site or surrounding the site (See Section). It is also recommended that the sequential approach is applied at the site level (sequential design) to ensure that the more vulnerable development (i.e. residential housing) is located within an area of the site which is at least risk of flooding (i.e. Flood Zone 1). Areas at higher risk of flooding should ideally be set-aside as open space for amenity and potential environmental enhancements. Site specific FRA may show that this proposed development area may not be developable because the whole area is in the floodplain.

- *Development Areas 4 – 7*

Future development within Development Areas 4 to 7 (see ***Appendix D*** for location), within the Low Probability Flood Zone 1 should look to reduce the overall level of flood risk in the area and beyond through the layout and form of the development. There is no significant flood risk constraint on the 'use' proposed for future developments within the Low Probability Flood Zone 1, although for sites greater than one hectare or above, the vulnerability from other sources of flooding should be considered as well as the effect of the new development on surface water runoff. Typically, a Flood Risk Assessment will be required to demonstrate that runoff from the site is reduced, thereby reducing surface water flood risk. This will involve the use of SUDS techniques which should take into account the local geological and groundwater conditions (see ***Level 1 SFRA*** for SUDS guidance). For sites larger than one hectare, the post development runoff volumes and peak flow rates should be attenuated (1 in 100 year + climate change) to the Greenfield (pre-development) condition or at least to mimic the surface water flows arising from the site prior to the proposed development.

For the purposes of development control, detailed policies will need to be set out to ensure that flood risk is taken account for both allocated and non-allocated 'windfall' sites. The following policy objectives are recommended for all sites in Hemel Hempstead:

- **Application of the Sequential Test** - Use the Sequential Test to locate all new development (site allocations) in least risky areas, giving highest priority to Flood Zone 1. Where the Sequential Test alone cannot deliver acceptable sites, the Exception Test will need to be applied (See Section 1.3.2).

- **Protect the functional floodplain (in Greenfield and previously developed areas) –** Avoid development in the Greenfield functional floodplain in the first instance. Identify opportunities for making space for water on previously developed areas by reinstating the functional floodplain.

- **Site Layout** - apply the sequential approach within the development site by locating the most vulnerable elements of a development in the lowest flood risk areas in the first instance. For example, the use of low-lying ground in **Development Area 1** and **Development Area 2** for recreation, amenity and environmental purposes can provide an effective means of flood risk management as well as providing connected green spaces with consequent social and environmental benefits.

- **Enhance and restore the river corridor** - identify opportunities to undertake river restoration and enhancement as part of a development to make space for water. For example in **Development Area 1** there is potential for naturalisation of the upper reaches of the River Gade that runs through the town centre - a more natural two-stage channel could be created with marginal and in-channel planting favoured by chalk rivers & weirs could be removed to create a more naturalised flow

- **Set development back from rivers -** any riverside developments should leave a minimum 8 metre wide as undeveloped buffer strip. For example, in **Development Area 1 and 2** development should be set back from the river maintaining the river and its floodplain as an enhancement feature

- **Reduce surface water runoff from new developments –** any development larger than one hectare must ensure that post development runoff volumes and peak flow rates are attenuated to the Greenfield (pre-development) condition. SUDS should also be a requirement for all new development and space should be specifically set-aside for SUDS and used to inform the overall site layout

- **Sequential approach to the release of development land** - Brownfield land should be developed in advance of Greenfield sites For example **Development Area 1, 2 and 3** are all potential redevelopments within Brownfield land and provide an opportunity to create a buffer zone and improve public accessibility to the river corridor (NB. In the first instance, the sequential test should be applied prior to considering the release of land to determine which type of land is the safer option in terms of flood risk).

• **Maintenance of existing flood defences** – existing flood defences should be maintained to a high standard. For example, it is recommended that the Hemel Hempstead Flood Relief culvert is surveyed to fully determine its condition and is regularly maintained to reduce the risk of blockage or collapse. This will require future consultation between the borough and the owners of the culvert, Thames Water

• **Ensure a development is 'Safe' -** For residential developments to be classed as 'safe', dry pedestrian access should be provided to and from the development without crossing through the 1 in 100 year plus climate change floodplain. For example, in **Development Area 1** and **2** both of the adjacent roads are flooded (Leighton Buzzard Road and Moor Road) and therefore other access/egress routes will need to be designed as part of the development.

4.2.2 *Requirements for a Flood Risk Assessment*

The following reflects the minimum requirements under PPS25 for a Flood Risk Assessment (reference should be made to Tables D.1-D.3 in PPS25) which should work towards achieving the goals of the Thames CFMP:

Future Development within Flood Zone 1 – **Development Areas 1, 2 and 4 -7**

In this zone, developers and local authorities should realise opportunities to reduce the overall level of flood risk in the area and beyond through the layout and form of the development. There is no significant flood risk constraint placed upon future developments within the Low Probability Flood Zone 1, although for sites greater than one hectare or above, the vulnerability from other sources of flooding should be considered as well as the effect of the new development on surface water runoff.

Typically, a Drainage Impact Assessment will be required to demonstrate that runoff from the site is reduced, thereby reducing surface water flood risk. This will involve the use of SUDS techniques which should take into account the local geological and groundwater conditions (see ***Level 1 SFRA*** for SUDS guidance). For sites larger than one hectare, the post development runoff volumes and peak flow rates should be attenuated to the Greenfield (pre-development) condition.

Future Development within Flood Zone 2

Land use within Medium Probability Flood Zone 2 should be restricted to the 'essential infrastructure', 'water compatible', 'less vulnerable' and 'more vulnerable' category. Where other planning pressures dictate that 'highly vulnerable' land uses should proceed, it will be necessary to ensure that the requirements of the Exception Test are satisfied (see Section 1.3.5). The following should be considered:

- A detailed site-specific Flood Risk Assessment should be prepared in accordance with PPS25 and Council Development Control policies (e.g. future DPD). The Flood Risk Assessment should demonstrate a positive reduction in flood risk through new development and provide a statement to explain how this is achieved.

- Floor levels should be situated above the 1% (100 year) plus climate change predicted maximum level plus a minimum freeboard of 300mm

- The development should be safe, meaning that dry pedestrian access to and from the development should be possible above the 1 in 100 year plus climate change flood level and emergency vehicular access should be possible during times of flood.

- SUDS should be implemented to ensure that runoff from the site (post development) is reduced. For sites greater than one hectare the post development runoff volumes and peak flow rates should be attenuated to the Greenfield (pre-development) condition for both Greenfield and brownfield sites. Space should be set-aside for SUDS.

- The proposed development should be set-back from the watercourse with a minimum 8m wide undeveloped buffer zone, to allow appropriate access for routine maintenance and emergency clearance.

- The developer should contact the Environment Agency to establish whether culvert blockage scenarios need modelling.

Future development within High Probability Flood Zone 3a - **Development Areas 1, 2 and 3**

Land use with High Probability Flood Zone 3a should be restricted to the 'less vulnerable' and 'water compatible' uses to satisfy the requirements of the

Sequential Test. For 'more vulnerable' and 'essential infrastructure' uses it is necessary to ensure that the requirements of the Exception Test are satisfied. The following should be considered:

- A detailed site-specific Flood Risk Assessment should be prepared in accordance with PPS25 and Council Development Control policies. The Flood Risk Assessment should demonstrate a positive reduction in flood risk through new development and provide a statement to explain how this is achieved. Properties situated within close proximity to formal defences or water retaining structures (reservoirs/canals) will require a detailed breach and overtopping assessment to ensure that the potential risk to life can be safely managed throughout the lifetime of the development. The nature of any breach failure analysis should be agreed with the Environment Agency.

- The development should not increase flood risk elsewhere, and opportunities should be taken to decrease overall flood risk (such as use of SUDS and deculverting). The can be achieved by developing land sequentially, with areas at risk of flooding favoured for green space.

- Floor levels should be situated above the 1% (100 year) plus climate change predicted maximum level plus a minimum freeboard of 300mm. Within defended the areas the maximum water level should be assessed from a breach analysis.

- The development should allow dry pedestrian access to and from the development above the 1 in 100 year plus climate change flood level and emergency vehicular access should be possible during times of flood. An evacuation plan should be prepared. With respect to new developments, those proposing the development should take advice from the LPA's emergency planning officer and for large-scale developments, the emergency services, when producing an evacuation plan as part of a FRA. All access requirements should be discussed and agreed with the Environment Agency.

- Basements should not be used for habitable purposes. Where basements are permitted for commercial use, it is necessary to ensure that the basement access points are situated 300 mm above the 1 in 100 year flood level plus climate change.

- SUDS should be implemented to ensure that runoff from the site (post development) is reduced. For sites greater than one hectare the post development runoff volumes and peak flow rates should be attenuated to the Greenfield (pre-development) condition for both Greenfield and brownfield sites.

- The proposed development should be set-back from the watercourse with a minimum 8m wide undeveloped buffer zone, to allow appropriate access for routine maintenance and emergency clearance.

- The developer should contact the Environment Agency to establish whether culvert blockage scenarios need modelling.

Future development within Functional Floodplain Zone 3b - **Development Areas 1, 2 and 3**

Development should be restricted to 'water-compatible uses' and 'essential infrastructure' to satisfy the requirements of the Sequential Test. 'Essential infrastructure' in this zone must ensure that the requirements of the Exception Test are satisfied and be designed and constructed to remain operational in times of flood and not impede water flow.

4.3 Berkhamsted

4.3.1 *Planning Recommendations*

All the Development Areas identified by the Borough were found to be outside the modelled flood extent (TUFLOW Boundary) (see Appendix F). However, the areas bound between the Grand Union Canal and the River Bulbourne would be severely inundated with flood water if a breach of the canal occurred.

It is recommended that the levels of risk identified in the flood hazard map are used to ensure that any allocated sites and windfall sites of a particular vulnerability classification are in acceptable locations, subject to the appropriate mitigation. It is advised that a sequential approach is applied to locate all development in least risky areas (prioritising low risk sites first and then higher risk areas if necessary) as advocated by PPS25.

All development (both allocated and windfall sites) falling in the identified hazard areas (See ***Appendix F***) will be subject to the Sequential Test as outlined in PPS25 (practice guide) to ensure the development is 'safe'. This will be undertaken in the

conventional way and to the LPA's satisfaction. Where the Sequential Test alone cannot deliver acceptable sites, the Exception Test will need to be applied. It is recommended that the LPA seek advice from the Planning Liaison team in the Environment Agency when applying the sequential test in the areas of breach identified.

4.3.2 *Requirements for a Flood Risk Assessment (FRA)*

If the Sequential Test is undertaken and the Exception Test is required then the developer would be required to undertake a FRA looking at, amongst other things, the condition of the canal (require consultation with British Waterways). The FRA would need to address a number of requirements in order to make it 'safe' (as advocated in the Exception Test). This should be done in consultation with British Waterways and EA where required. Any recommendations/actions that arise from these discussions will need to be proportionate to the development proposed. Any development would be expected to undertake FRA and look into implementing recommendations from the report in consultation with British Waterways and the LPA.

For the purposes of development control, detailed FRA and Sequential Test will be required to ensure that residual risk is taken account of appropriately for both allocated and non-allocated 'windfall' sites in the areas of breach identified (area bound between the Grand Union Canal and the River Bulbourne which would be severely inundated with flood water if a breach of the canal occurred.).

The following reflects the minimum requirements under PPS25for a Flood Risk Assessment which should work towards achieving the goals of the Thames CFMP:

- A detailed site-specific Flood Risk Assessment should be prepared in accordance with PPS25 and Council Development Control policies. The Flood Risk Assessment should demonstrate a reduction in flood risk through new development and provide a statement to explain how this is achieved. Vulnerable uses like care homes, hospitals and children's facilities situated within close proximity to the canal may require a more detailed breach and overtopping assessment to ensure that the potential risk to life can be safely managed throughout the lifetime of the development. In addition the risk of flooding from the Bulbourne should also be looked at as part of the FRA;

- Floor levels should be situated above the maximum water level assessed from a detailed breach analysis (including sufficient freeboard).

- The development should provide safe refuges above flood level. The maximum water level should be assessed from a detailed breach analysis

- SUDS should be implemented to ensure that runoff from the site (post development) is reduced. For sites greater than one hectare the post development runoff volumes and peak flow rates should be attenuated to the Greenfield (pre-development) condition for both Greenfield and brownfield sites.

- No habitable basements and residential ground floors below predicted flood levels should be provided in the areas identified as 'danger for all'. Elsewhere, basement and ground floor sleeping accommodation should not be provided until the LPA/British Waterways and the Environment Agency are satisfied that the risk is clearly understood and adequate mitigation measures have been put in place. Building on stilts could be constructed when replacing existing buildings. This again will require consultation between the Environment Agency, the British Waterways and the LPA.

- The development should allow dry pedestrian access to and from the development and emergency vehicular access should be possible during times of flood. An evacuation plan should be prepared. With respect to new developments, those proposing the development should take advice from the LPA's emergency planning officer and for large-scale developments, the emergency services, when producing an evacuation plan as part of a FRA. All access requirements should be discussed and agreed with the Environment Agency.

- For any development close to the Grand Union Canal, the embankment condition should be surveyed by the developer as a part of FRA. This will require consultation with British Waterways during the preparation of FRA. The British Waterways along with the Environment Agency is at present in the process of writing up the Flood and Water Control documents which should be consulted during FRA.

- Flood resilience/resistance measures (e.g. low permeability materials in external walls, hydraulic lime or ceramic tiles in internal walls, solid concrete floors, removable plastic fittings, anti-flooding devices to drainage system, etc) should be incorporated, if required, into the building design to minimise the consequences of flooding and facilitate reinstatement from the effects of

flooding sooner than conventional buildings. As advocated in PPS25 resilience and resistance measures should not be used to justify development in inappropriate locations. It is important to note that some flood proofing measures are rendered ineffective over certain depths of floodwaters hence advice on guidance should be sought form the Environment Agency and construction experts.

- Any new buildings should be of 'sound structural design' to withstand the impacts of a breach.

4.3.3 *Other Recommendations*

- The LPA emergency plan should be expanded to address the risk of canal breach. The findings from the breach analysis found in this report should be assessed in the context of the borough's emergency response plans.

- A robust evacuation plan should be implemented for all development in the breach area to include developing evacuation procedures in response to a warning and obtaining advice from the Local Authority Emergency Planning team and the emergency services.

It is important to note that the Environment Agency are not the statutory consultee for canal flooding, hence the LPA in consultation with British Waterways will be responsible for assessing the Flood Risk Assessments produced in the areas at risk of canal breach. The LPA would need to provide guidance for all development areas that fall outside the Environment Agency's remit.

The Level 2 SFRA should be retained as a 'living' document and reviewed and revised where required in light of emerging policy guidance on 'other sources of flooding'.

5 References

(1) Dacorum Borough Council, St Albans City & District Council, Three Rivers District Council, Watford Borough Council, Strategic Flood Risk Assessment, Volume I and Volume II, August 2007, by Halcrow

(2) East London, Strategic Flood Risk Assessment, June 2005, by Entec and JBA

(3) Westminster Borough Councill, Hydraulic Study, January 2008, by Halcrow

(4) Havering Strategic Flood Risk Assessment, November 2007, by JBA and Entec

(5) Flood Risk to People Guidance Document, Defra/Environment Agency, 2006