JBA consulting

Surface Water Management Plan for Brentwood

Final Report

January 2015

Essex County Council
County Hall
Chelmsford
Essex
CM11 1YS

Essex County Council

This page was left intentionally blank.

JBA Project Manager

David Kearney BSc MSc MCIWEM C.WEM
The Library
St Philips Courtyard
Church Hill
Coleshill
Birmingham
B46 3AD

Revision History

Revision Ref / Date Issued	Amendments	Issued to
Draft V1.0 (July 2013)		Jo Carrington (Essex County Council)
Draft V1.1 (October 2013)	Amendments made based on comments from Jo Carrington (Essex County Council)	Jo Carrington (Essex County Council)
Final v2.0	Amendments made based on comments from SWMP Stakeholders	Jo Carrington (Essex County Council)
Final v 3.0	Amendments made based on comments from SWMP Stakeholders	Jo Carrington (Essex County Council)
Final v 4.0	Inclusion of partner organisations (Appendix M)	Nicola China (Essex County Council)

Contract

This report describes work commissioned by Essex County Council. Essex County Council's representative for the contract was Jo Carrington. Daryl Taylor and Andrew Waite of JBA Consulting carried out this work.

Prepared by .... Daryl Taylor BEng MSc

Engineer

Andrew Waite BSc MRes

Assistant Analyst

Reviewed by .... David Kearney BSc MSc MCIWEM C.WEM

Principal Analyst

Purpose

This document has been prepared as a draft report for Essex County Council. JBA Consulting accepts no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned and prepared.

JBA Consulting has no liability regarding the use of this report Essex County Council.

Acknowledgements

We would like to acknowledge the assistance of Jo Carrington of Essex County Council for her assistance in carrying out this study. We would also like to thank Anglian Water and the Environment Agency for allowing their data to be used.

Carbon Footprint

A printed copy of the main text in this document will result in a carbon footprint of 586g if 100% post-consumer recycled paper is used and 586g if primary-source paper is used. These figures assume the report is printed in black and white on A4 paper and in duplex.

JBA is aiming to achieve carbon neutrality.

Executive Summary

Introduction

A Surface Water Management Plan (SWMP) is a plan that enables local communities and different organisations to gain a better understanding of flood risk and outlines the preferred surface water management strategy at a given location. Following guidance from Defra, the SWMP was conducted as a four stage process:

Preparation > Risk Assessment > Options > Implementation

The Level 1 Strategic Flood Risk Assessment (SFRA) for Brentwood Borough Council (2011) summarised that settlements such as Brentwood and Ingatestone may contain areas which are potentially vulnerable to surface water flooding. This SFRA mapped areas where surface water was a historical issue. The purpose of a SWMP is to provide a more detailed assessment of the risk from surface water flooding.

Preparation

In accordance with Defra guidance (2010), the Brentwood Borough has been prioritised as an area considered to be at significant risk of surface water flooding and an area where partnership working is considered essential to both understand and address surface water flooding concerns. The preparation stage consists of identifying key partners within the study area as well as providing an overview of flood history.

The key partners within the SWMP were:

- Essex County Council;
- Essex Highways
- Brentwood Borough Council;
- Anglian Water; and
- The Environment Agency.

Data provided by Essex County Council has been used with historical flood data from the SFRA to determine the historical flood events that have been recorded within the Borough.

Risk Assessment

The risk assessment has been broken into two parts. The first was an intermediate assessment across the whole of Brentwood Borough to determine the overall flood risk and to identify flooding hotspots which may require further analysis. When surface water flooding hotspots were identified, further modelling was carried out to understand the flooding mechanisms and risks in more detail.

The intermediate risk assessment was based around assessing the number of people and properties at risk using JBA Consulting's Flood Risk Metrics tool (Frism). Using this information and other sources of flood data, such as historic records from the Environment Agency and Anglian Water, a number of flooding hotspots were determined. These hotspots were based around three main areas; West Horndon, Ingatestone and Brentwood Town Centre.

Following identification of flooding hotspots, detailed models were created using InfoWorks ICM. The models were run with 30, 100 and 200-year rainfall events of various rainfall durations. In addition, the effects of climate change were investigated using the 100-year event. Outputs showing maximum flood depth and hazard have been produced as well as further analysis using Frism. A number of key areas were defined which were highlighted as having significant flood risk which might benefit from mitigation options.

Options

Based on the key areas a number options / measures were determined which could be implemented to reduce flood risk. Some of these options / measures were specific to a site, with some to be considered on a Borough-scale. Unfortunately it has not been possible for recommended options to be modelled. The lack of sufficient quality data and discrepancies in the data meant that it would not be possible to accurately model the impact of proposed options.

However, for each highlighted area an indication of possible mitigation measures have been detailed with an indicative costing. This should be refined based on improvements to the model as well more detailed site specific modelling.

Implementation & Review

The document establishes a long term action plan to manage surface water and will influence future capital investment, maintenance, land-use planning, emergency planning and future developments. A number of recommendations have been highlighted that include refining the modelling approach with the inclusion of more data or where data is currently missing. In particular some areas in the vicinity of watercourses have been highlighted as warranting further hydraulic modelling. This would help to further refine the recommended mitigations measures for an area. Currently indicative costs for measures have been provided where possible to assist in prioritisation of concept solutions but it is recommended that the proposed mitigation measures are pursued with a full outline and detailed design process. This should include a cost benefit assessment and use of threshold surveys for determining avoided damages.

Contents

Contents

List of Figures

List of Tables

Abbreviations

1D	1 dimensional
2D	2-dimensional
AMP	Asset Management Plan
ASTSWF	Areas Susceptible to Surface Water Flooding
CFMP	Catchment Flood Management Plan
EA	Environment Agency
FEH	Flood Estimation Handbook
Frism	JBA's Flood Risk Metrics Software
FWMA	The Flood and Water Management Act 2010
LLFA	Local Flood Risk Management
LFRMS	Local Flood Risk Management Strategy
m AOD	Metre Above Ordnance Datum
NPPF	National Planning Policy Framework
NRD	National Receptor Database
OS	Ordnance Survey
PFRA	Preliminary Flood Risk Assessment
PLP	Property Level Protection
SAB	SUDS Approval Body
SFRA	Strategic Flood Risk Assessment
SUDS	Sustainable Drainage Systems
SWMP	Surface Water Management Plan

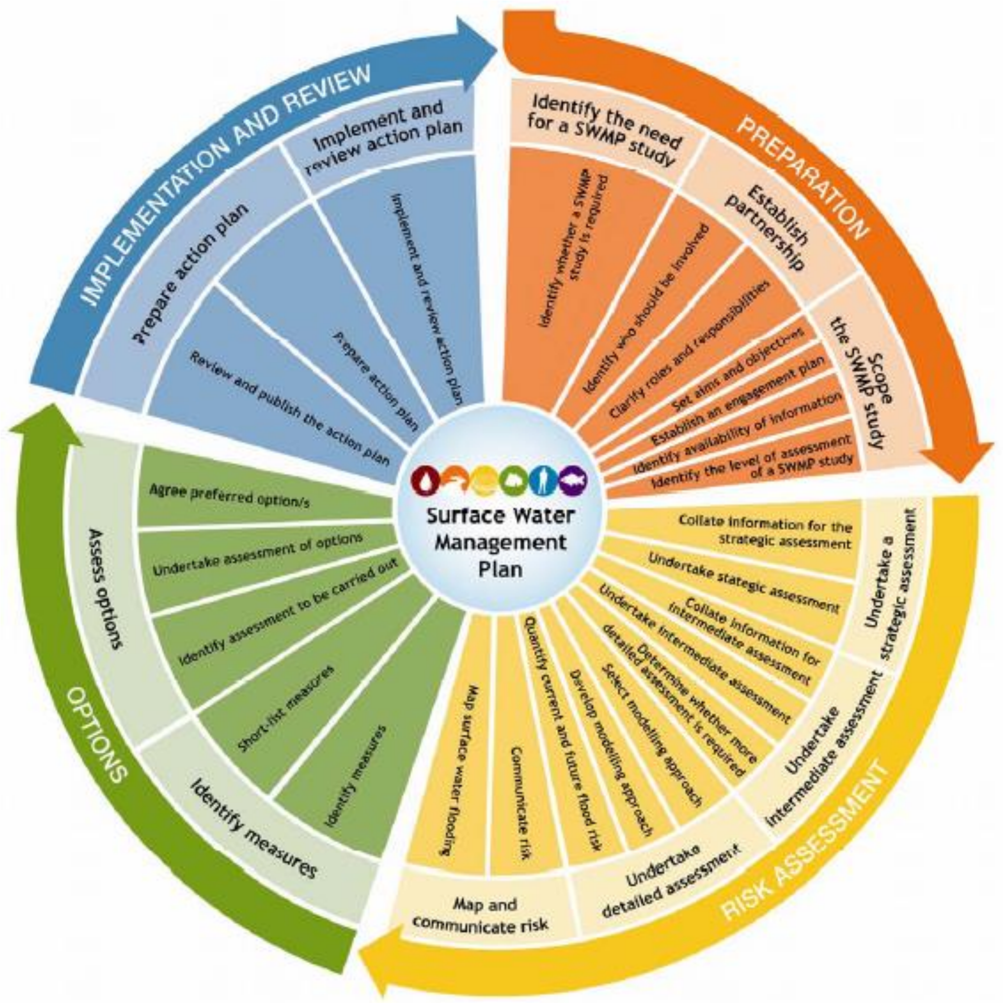
1 Introduction

1.1 What is a Surface Water Management Plan?

A Surface Water Management Plan (SWMP) is a plan that enables local communities and different organisations to gain a better understanding of flood risk and outlines the preferred surface water management strategy at a given location. In the context of the Flood and Water Management Act (HMSO, 2010) local flooding is defined as “flood risk from surface runoff, groundwater, and ordinary watercourses.

Defra (2010) has produced guidance for those undertaking Surface Water Management Plans in England. The SWMP follows a four stage process, illustrated in the guidance by the SWMP "wheel", shown in Figure 1-1 below:

Figure 1-1: The SWMP "wheel"



The preparation stage identifies the requirements for a SWMP, establishes the partnership of organisations required to co-operate, and defines the scope and level of detail required. The risk assessment stage gathers available information and may undertake further analysis in order to assess the risk at a level of detail appropriate to the scale of the study. The Options stage considers the range of flood risk management measures available, how these could be brought together as feasible options, possibly including an assessment of cost-benefit. The Action Plan sets out the responsibilities and timescales for implementation, and how these will be supported and monitored by the partnership.

1.2 What is meant by Surface Water Flooding

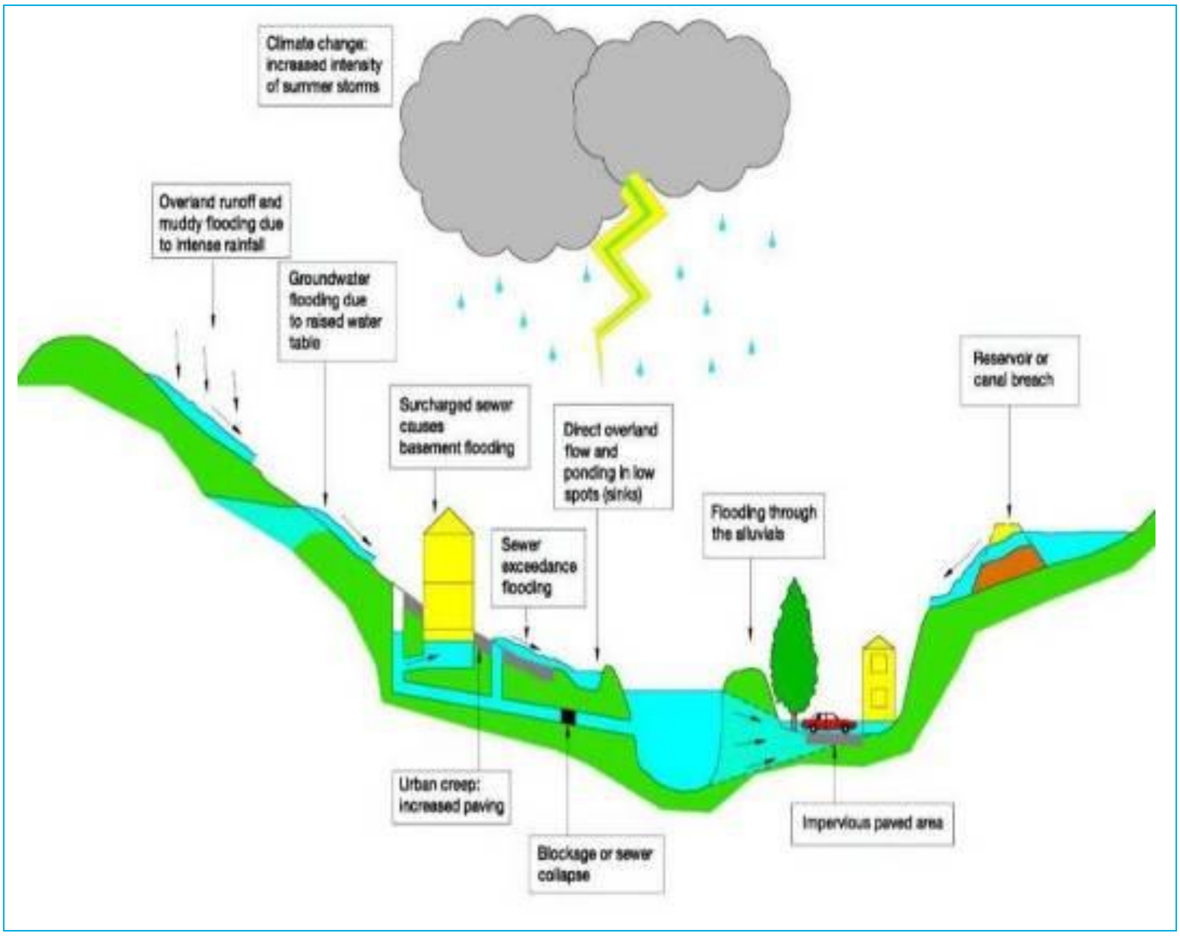
In the context of this SWMP, the definition of surface water flooding as set out in the Defra SWMP Guidance has been followed:

Surface water flooding describes flooding from sewers, drains, small water courses and ditches that occurs during heavy rainfall in urban areas. It includes:

- Pluvial flooding; flooding as a result of high intensity rainfall when water is ponding or flowing over the ground surface (surface runoff) before it enters the underground drainage network or watercourse, or cannot enter it because the network is full to capacity.
- Sewer flooding; flooding which occurs when the capacity of underground systems is exceeded, resulting in flooding inside and outside of buildings. Normal discharge of sewers and drains through outfalls may be impeded by high water levels in receiving waters.
- Flooding from small open-channel and culverted urban watercourses which receive most of their flow from inside the urban area
- Overland flows from the urban/rural fringe entering the built-up area, including overland flows from groundwater springs.

Flow interactions between surface water and larger main rivers and tidal waters can be important mechanisms that significantly influence the extent and frequency of surface water flooding. In the Brentwood Borough there are no tidal watercourses, therefore tidal interaction is not examined.

Figure 1-2: Sources of flooding



1.3 Background to the Brentwood SWMP

JBA Consulting was commissioned by Essex County Council to complete a SWMP. The preparation of a SWMP for Brentwood is driven in response to the following primary considerations:

- The need to manage local flood risk as a consequence of assessments performed under the Flood Risk Regulations, 2009 and the Flood and Water Management Act 2010
- The need to inform spatial planning and development control, develop a strategy for flood risk management, and provide evidence that future new development can be implemented and local flood risk safely managed

The Level 1 Strategic Flood Risk Assessment (SFRA) for Brentwood Borough Council (2011) states that settlements such as Brentwood and Ingatestone may all contain areas which are potentially vulnerable to surface water flooding. The SFRA mapped areas where surface water was a historical issue. The purpose of this SWMP is to provide a more detailed assessment of the risk from surface water flooding.

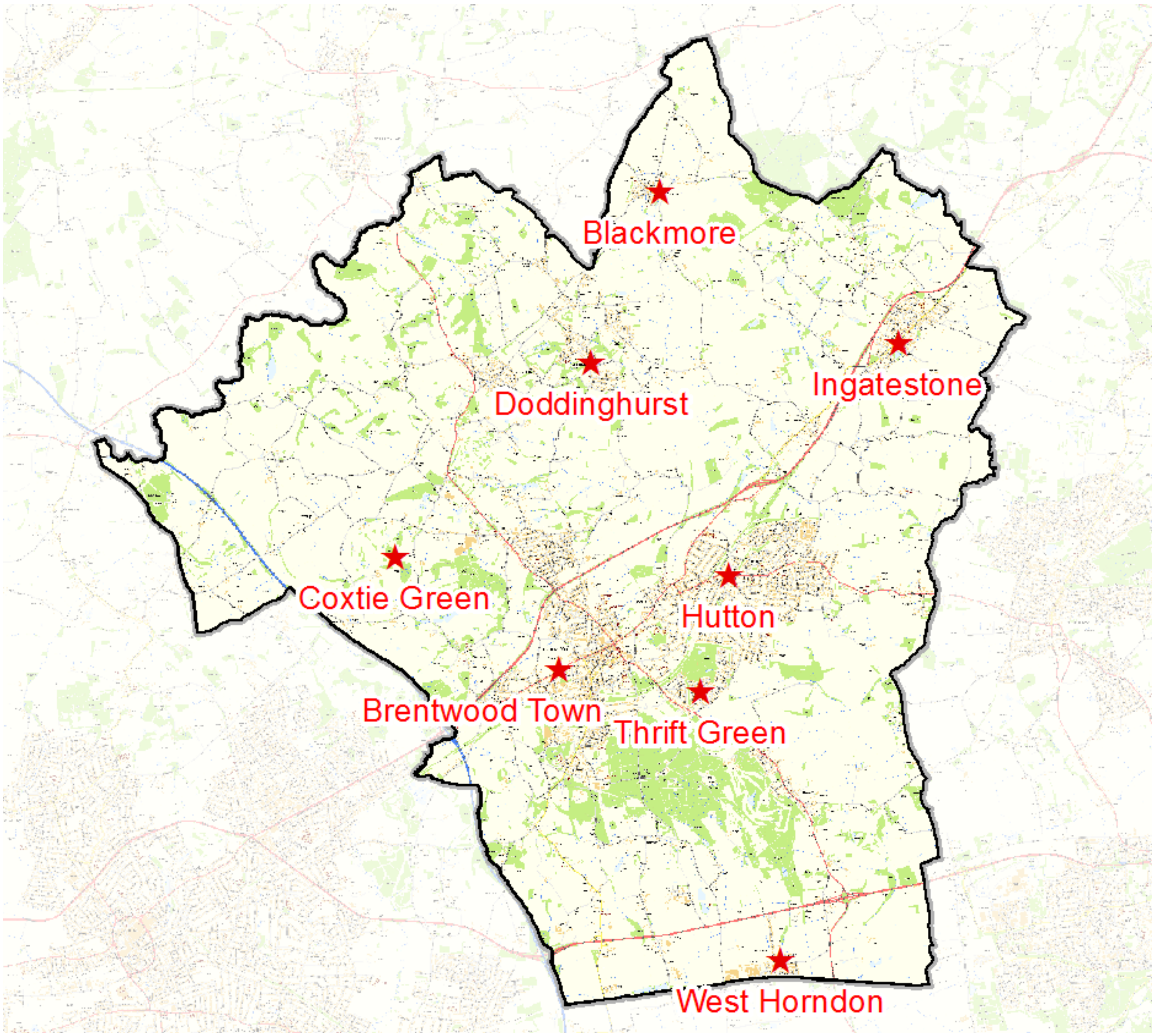
This SWMP study has been undertaken in consultation with key local partners who are responsible for and involved with surface water management and drainage in the Brentwood Borough. This included Brentwood Borough Council, Essex County Council, Essex Highways, the Environment Agency and Anglian Water. The Partners have worked together to understand the causes and effects of surface water flooding and identify the most cost effective way of managing surface water flood risk for the long term.

This document also establishes a long-term action plan to manage surface water and will influence future capital investment, maintenance, public engagement and understanding, land-use planning, emergency planning and future developments.

1.4 Study Area

Figure 1-3 shows Brentwood Borough Council's boundary, which makes up the study area for the Brentwood SWMP.

Figure 1-3: Brentwood SWMP Study Area



The topography of the area ranges from approximately 100mAOD in the north and central regions to approximately 10mAOD in the south of the Borough. The Borough forms the headwaters of four key watercourses which drain the area: the River Wid, the River Ingrebounre, the River Roding and the River Mardyke.

The River Wid is the main catchment in the Borough and is located on the eastern boundary of the Borough. It flows in a north to south direction, north of Hutton. The river eventually joins the River Can in Chelmsford. The River Ingrebourne drains the south western part of the Borough and is located west of Brentwood. The river flows south joining the River Thames at Rainham. The River Roding is located on the north-western boundary of the Borough and flows in a south-westerly direction joining the River Thames via Barking Creek. Finally the River Mardyke drains the south of the Borough via numerous small tributaries.

Other watercourses of interest include the Ingatestone Hall Brook in the north-east, the Stondon Hall Brook in the north-west and the Ingrebourne Brook in the west. In the course of developing the SWMP it is anticipated that the assessment will focus on those locations with known flood problems and areas identified for future development, namely:

- Ingatestone
- the A12 north of Brentwood
- Central Brentwood area

The sewer network in this area is owned and maintained by Anglian Water. Through Brentwood the network consists of a separate foul and storm (surface water) system.

The land use within the Borough is predominantly Greenfield and farmland with the main urban expanses of Brentwood and Hutton being located in the centre of the Borough. Other notable towns include Ingatestone, Doddinghurst and Blackmore. These urban areas include both commercial and residential properties. Other than properties a number of other significant structures exist within the Brentwood Borough including:

- The M25 located approximately 1km to the west of Brentwood
- The A12 which crosses the Borough in a south-west to north-east direction, north of Brentwood
- A railway line that runs through the Borough in a south-west to north-east direction through Brentwood, Hatton and to the east of Ingatestone.

1.5 Policy Context and Links with Other Plans

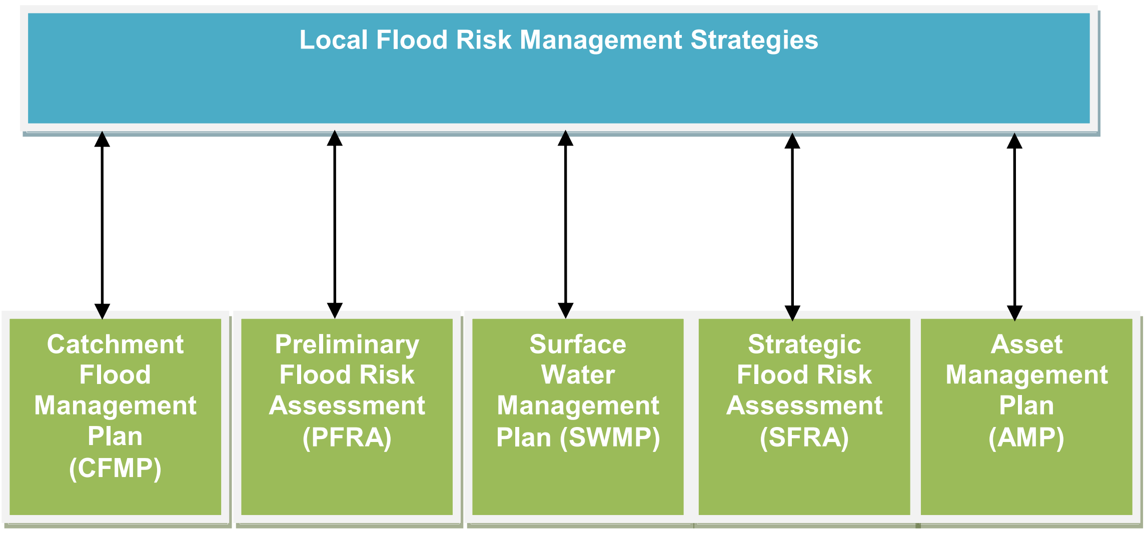
The Brentwood SWMP will link to and inform the existing network of plans and policy. The policies and strategies specific to Essex and Brentwood are summarised in the following paragraphs:

1.5.1 Local Flood Risk Management Strategies

The Flood and Water Management Act 2010 (FWMA) requires each Lead Local Flood Authority (LLFA) to produce a Local Flood Risk Management Strategy (LFRMS) although it is understood that there is no strict deadline for this to be issued. The SWMPs, PFRAs and their associated risk maps will provide the necessary evidence base to support the development of LFRMS.

The schematic diagram below illustrates how the Catchment Flood Management Plan (CFMP), Preliminary Flood Risk Assessment (PFRA), SWMP, SFRA and Asset Management Plan (AMP) link to and underpin the development of a Local Flood Risk Management Strategy.

Figure 1-4: Links between existing plans and the LFRM Strategy



Although Essex County Council have already completed the Local Flood Risk Strategy the findings of this study may feedback into this document to inform any future updates.

1.5.2 Brentwood Strategic Flood Risk Assessment (SFRA)

Each local planning authority is required to produce a SFRA under the National Planning Policy Framework (NPPF). This provides an important tool to guide planning policies and land use decisions. The current SFRA for Brentwood Borough Council was completed in 2011 by Entec. It highlighted that surface water flooding is likely to be the most significant cause of flooding within the Brentwood Borough with previous records of flooding from December 2009, February 2010 and March 2010 near Ingatestone.

The some of the main recommendations from the SFRA relevant to this study are shown below:

- Aim to reserve land in Flood Zone 1 for essential infrastructure and where possible highly vulnerable / more vulnerable land uses
- Manage flood risk through avoidance of risk where possible
- Ensure all developments should attempt to reduce surface runoff by sustainably managing runoff on site and not increasing flood risk elsewhere.

Due to the localised nature of urban development's it is recommended that a surface water management plan is used to assess the risk of surface water flooding in the area as well as identifying potential solutions. This would inform the SFRA level 2 which would relate to the development site allocation.

1.5.3 Brentwood Local Development Plan

Brentwood Borough Council is currently preparing a new Local Plan for the borough which, once adopted, will supersede saved policies in the current Replacement Local Plan (2005).

The new Local Plane will cover a 15-year period between 2015 and 2030. The Plan sets out polices, proposals and site allocations to guide future development in the Borough. It will enable the Council to manage growth while protecting key areas. Among other things, the Plan will include policies to deliver climate change mitigation, adoption, protection and enhancement of the natural environment.

The Local Plan Preferred Options consultation document was published in July 2013, and identified strategic growth locations within the Borough. Further consultation on the Local Plan is proposed during 2014 to further consider key policies and options for the distribution of growth across the borough. The SWMP will form part of the evidence base for the Local Plan, to inform and guide production of the Plan.

1.5.4 River Thames Catchment Flood Management Plan

CFMPs have been developed by the Environment Agency for 77 catchments in England and Wales. They set out the Environment Agency's flood risk management policies for inland waters. They address current and future risk (due to climate change) and seek to direct investment where risk is greatest.

The Brentwood Borough is covered by sub-area 9 of the River Thames CFMP conducted by the Environment Agency in 2009. The policy for this area is policy option 4 which states that there are "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 CFMP sets out the following actions to implement the preferred approach:

- Continue to make sure the recommendations in SFRA and Local Development Framework policies create potential to reduce flood risk through regeneration.
- Adopt a strategic approach to planning so that the wider community objectives as well as flood risk objectives can be met.
- Continue to develop emergency response planning to deal with extreme floods.
- Continue to maintain existing flood defences and when redevelopment takes place, replace and improve them so they are more effective against the image of climate change. There will be focus on removing structures such as culverts that cause significant conveyance problems.
- Explore the opportunities to reduce flood risk by recreating river corridors in urban areas.

1.5.5 Essex County Council Preliminary Flood Risk Assessment (PFRA)

The PFRA is required as part of the Flood Risk Regulations which implement the requirements of the European Floods Directive. Essex County Council, as the LLFA prepared a PFRA that gives an overview of all the local sources of flooding in the County. The PFRA is a county-scale assessment and the flood risk identified by this study in Brentwood is not of a scale which could lead to the area being identified as an indicative Flood Risk Area.

The PFRA highlighted that there is a lack of local data available on surface water flood risk within Essex. As part of the PFRA process settlements have been ranked using DEFRAs National Rank Order of Settlements Susceptible to Surface Water Flooding document. Essex is shown to be highly susceptible to surface water flood risk with nearly all of the settlements assessed being ranked in the top 1000 including Brentwood and Ingatestone. SWMPs such as this study aim to fill in the void in information and inform a second cycle of the PFRA process and assist in the production of flood hazard / flood risk maps for this area.

1.5.6 Brentwood Scoping and Outline Water Cycle Study (2011)

The Brentwood Water Cycle Study assesses the capacities of water bodies and water related infrastructure to accommodate future development and growth in Brentwood Borough intended to form part of the evidence base for the local development plan. The study covers the Brentwood Borough and comprised a steering group formed from key partners in the areas.

In regards to surface water flood risk as part of the Water Cycle Study examines flood risk and sustainable drainage highlighting that the greatest flood risk potentially risks from surface water flooding in urban areas. The SWMP can further inform the locations at risk from surface water flooding within borough highlighting any relating issues.

1.5.7 National Planning Policy Framework

The National Planning Policy Framework (NPPF) was introduced by the Department for Communities and Local Government in March 2012 and supersedes the Planning Policy Statements. Similar to PPS25 (Development and Flood Risk) the NPPF considers flood risk to developments using a sequential characterisation of risk, based on planning zones and the Environment Agency Flood Map. Using classifications for flood zones and a vulnerability classification of different types of properties considerations can be made to apply a sequential test and if necessary the exception test. Sequential tests are used to steer new developments area from areas of highest flood risk. The SFRA gives the basis for applying a sequential test. The SWMP can give further input into the areas at risk from surface water flooding and therefore how any development is steered in regards to NPPF away from flood risk.

1.6 Summary of Aims and Objectives

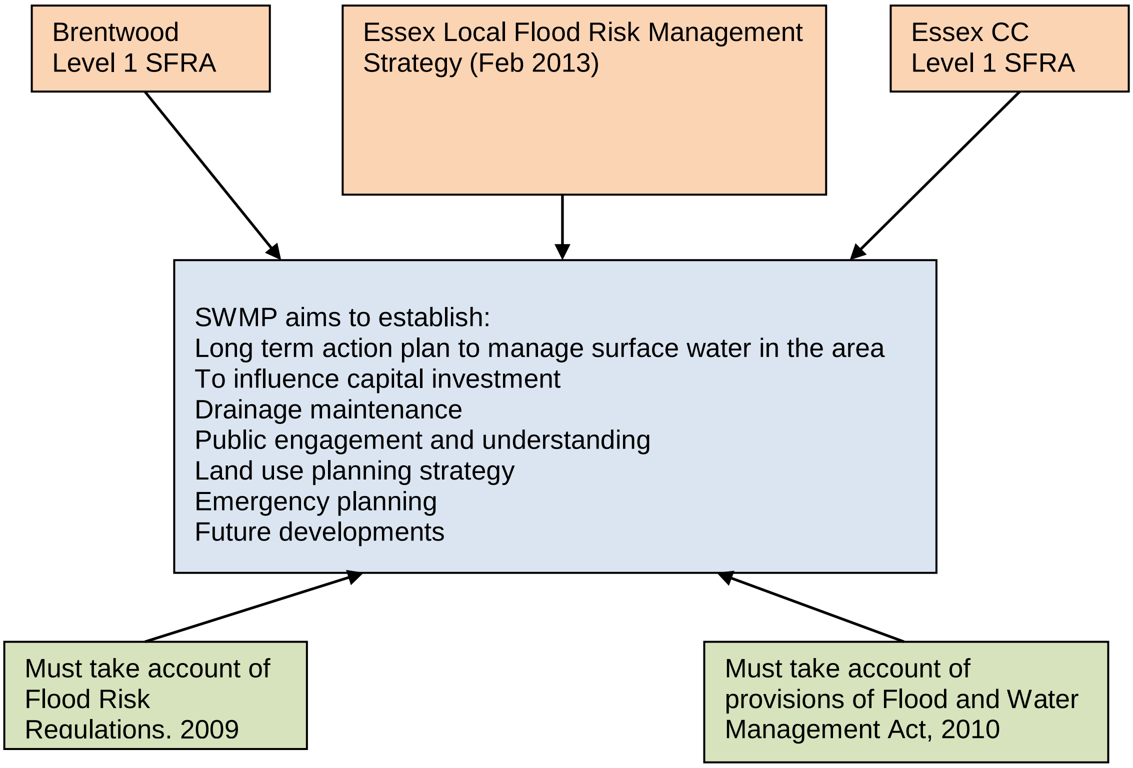
The objectives of the study as defined in the project brief are set out below in Table 1-1:

Table 1-1: Study objectives

Task	Approach
1. To determine the extent and direction of flow of floodwater in Brentwood arising from the problem points identified in the Tier 1 areas as described in the Essex Flood Risk Management Strategy.	An InfoWorks 2D model was prepared for the study area represented on Figure A1 of the Brentwood Level 1 SFRA where LIDAR data is available. This model was extended to include locations where surface runoff from rural areas contributes to existing and proposed development areas. Brentwood has a predominantly separate public sewerage system; The model included the surface water sewer network for the specific areas where new development is proposed and allow for the discharge from sewers at other locations. Volumes and flows were derived using JFlush, a tool combining several hydrological techniques aiming to estimate design flood hydrographs where there is a significant cross-boundary transfer of water via the sewer systems.
2. To identify the impacts of flooding on the areas highlighted in the Essex Flood Risk Management Strategy.	A detailed InfoWorks model was prepared to replicate the interaction between surface and sewer flows for the specific allocations.
3. Identify what range of mitigation measures could be incorporated into new and existing developments. Also make positive recommendations for approach to flood risk at windfall sites.	Results from modelling have been used to understand influential flood mechanisms and thus the scope of measures that could be used to mitigate potential adverse effects and to reduce existing flood risk. We have also prepared assessment of wider flooding mechanisms
4. Identify feasible options for mitigation, based on indicative cost and timescales.	We have prepared a selection process for options and identify preferred options. We have also prepared budget costings for preferred options.
5. Engage with Brentwood Borough Council, The Environment Agency, Essex County Council and Anglian Water.	We will attend engagement and consultation events to keep parties informed and where necessary provide input to decision making process.

The aims and influences on the SWMP are summarised in Figure 1-5:

Figure 1-5: Brentwood Wood SWMP aims and influences



1.7 Using this report

Having set the scene in this chapter, **Chapter 2** discusses the preparation stage of the SWMP. **Chapter 3** then assesses the risk of surface water flooding to the Brentwood Borough, and **Chapter 4** provides a detailed assessment of risk of surface water flooding to key areas. **Chapter 5** considers options to manage this risk and finally **Chapter 6** outlines the study recommendations brought together as an Action Plan.

This page was left intentionally blank.

2 Preparation

2.1 Identify Need for SWMP

In accordance with the Defra (2010) guidance, the Brentwood Borough has been prioritised as an area considered to be at significant risk of surface water flooding and an area where partnership working is considered essential to both understand and address surface water flooding concerns.

Surface water flooding can cause damage to properties and disrupt road, rail and pedestrian movements in affected areas. In addition, the sudden onset of surface water flooding can create road safety hazards and risk to pedestrians. Consequently it is an issue that must be understood and addressed within all future development plans.

Brentwood Borough Council (2011) undertook a Level 1 SFRA which provided an outline understanding of flood risk and where it is located. The SFRA recommended that surface water flooding is likely to be the most significant cause of flooding and therefore would benefit from a SWMP to assess the risk and identify potential solutions.

This Surface Water Management Plan for the Brentwood Borough adds greater detail to the assessment of flood risk than previously available in the SFRA, and explores initial approaches to tackling this flood risk, with an emphasis on sustainability, cost effectiveness and viability.

2.2 Establish Partnership

Surface water cannot be managed by a single authority, organisation or partner; all the key organisations and decision-makers must work together to plan and act to manage surface water within Brentwood Borough, as many organisations have rights and responsibilities for management of surface water. Although Essex County Council has commissioned this project, the key partners have been consulted throughout the SWMP process. Working in partnership encourages co-operation between different agencies and enables all parties to make informed decisions and agree the most cost effective way of managing surface water flood risk in Brentwood Borough for the long term. The partnership process is also designed to encourage the development of innovative solutions and practices; and improve public engagement and understanding of surface water flooding.

2.2.1 Who is involved

Partners are defined as organisations with responsibility for the decision or actions that need to be taken to manage surface water flooding. The key partners involved in this project are:

- Environment Agency
- Essex County Council
- Essex Highways
- Brentwood Borough Council
- Anglian Water

2.2.2 Roles & Responsibilities

Partnership roles and responsibilities were discussed throughout the development of this SWMP. Table 2-1 highlights the roles and responsibilities of key partners. Other groups also have notable roles and responsibilities in the Brentwood Borough:

- Riparian Owners/Large landowners - have a responsibility for channel maintenance along their reaches.
- Public - have responsibilities with respect to drainage of their properties, and, since 2008, to adhere to legislation with regards to permeable paving of driveways.

Table 2-1 Formal Roles, Duties and Powers

Organisation	Role	Duties and Powers
Brentwood Borough Council	Local Planning Authority Riparian Owner	Input to National and Local Statutory Strategies. Ordinary watercourse management. Any other responsibilities delegated from LLFA.
Environment Agency	National supervisory role for flood risk management.	Management of main rivers, sea, and reservoirs. National Statutory Strategy Reporting and general supervision. Permissive powers
Essex County Council	Lead Local Flood Authority	Management of surface water, groundwater and other sources of flooding. Input to national strategy. Formulate and implement local flood risk management strategy Monitor flooding within their area and investigate the causes and map the hazard associated with the source of flooding. Under the FWMA, LLFAs are the designated SUDS Approval Body (SAB) for any new drainage system, and therefore must approve, adopt and maintain any new sustainable drainage systems (SUDS) within their area. This aspect of the FWMA is yet to be formally enacted.
Anglian Water	Sewerage Undertaker	Operational and regulatory powers along sewer network. Co-operate with LLFA with regards to surface water.

2.3 Available Information

The following is a summary of the information available for this study:

- OS MasterMap topographic mapping was used in the modelling process to distinguish between land uses across the Borough. It was also used to better define the model grid so key flow paths around buildings, along roads and water course are appropriately represented.
- LIDAR data in the form of 0.5m, 1m and 2m resolution. This was obtained from the Environment Agency via Essex County Council. The LIDAR covered key areas of the Brentwood Borough. LIDAR data was used to model the terrain.
- Post code location polygons which were used for mapping purposes.
- The Flood Estimation Handbook (FEH) CD-ROM was used to obtain the rainfall parameters needed to define the hydrological inputs into the InfoWorks ICM model.
- Records of historic flooding.
- Flood Risk Registers from Anglian Water to derive flooding hot spots and verify results.
- Asset information provided from a variety of sources, were used to define pipes structures with the InfoWorks ICM model. They provide details of pipe/culvert dimensions which enable 1D elements to be modelled with greater accuracy. These were provided by Anglian Water. Thames Water had no relevant data in areas of interest.
- Watercourse walkover reports from the Environment Agency to allow greater accuracy in modelling and determining flood risk.
- Detailed Asset data and gully information which is provided by various partners to assist in the modelling process.
- Various local plan mapping layers such as watercourse chemical / biological data reports. This will be used for the option appraisal section of the SWMP.

A full listing of all data supplied by each of the partner organisations is provided in Appendix A.

2.4 Overview of Flood History

Previous studies of the Brentwood Borough highlight the limited amount of data available outlining historical flood events. The Brentwood Level 1 SFRA (2011) states that previous flooding is largely a result of rapid surface runoff, where water ponds in low lying areas. There is a note of instances where cars have been trapped due to floodwater in areas such as Ingatestone and on the A12, north of Brentwood.

The SFRA shows mapping that highlights the locations of some historic events. They show that Ingatestone has cases of flooding caused by land drainage issues as well as one instance where flooding was caused by a sewer system. Elsewhere Blackmore is shown to have instances where flooding is caused by land drainage issues. There are few other instances recorded in the Borough.

As part of the available data numerous records of flooding were provided by Essex County Council and Brentwood Borough Council. These records were often sporadic with the cause of the flooding not always being clear. Appendix B shows the location of the historical flood records. Table 2-2 shows a list of the more detailed historic flood records that were compiled. These records have been compiled where there have been more than one incident on the same day, therefore giving more certainty that the records were related to natural causes. Where possible the cause has been attributed to the event. However, some of the events have been defined as "natural" where they appear to be from natural causes but there is not enough evidence to make an accurate assumption.

Table 2-2: Historic Flood Events

Source of Flooding	Location / Consequence	Year	Data Source
Surface Water	There have been causes of flooding in properties and on roads within Hutton.	2000	Essex Fire & Rescue
Fluvial	Flooding in multiple locations in Ingatestone.	2001	Essex Fire & Rescue
Surface Water	Several properties have been flooded on the High Street, Brentwood. Water is described as flooding into shops and therefore is likely to be attributed to surface water.	2004	Essex Fire & Rescue
Natural	Several cases were reported in the Brentwood Borough of flooding within residential gardens which affected properties.	2007	Essex Fire & Rescue
Natural	There were reports in Doddinghurst, Hutton and Thrift Green of flooding caused by natural causes. Based on the information it is unknown whether this was caused by surface water or fluvial interaction.	2010	Essex Fire & Rescue
Surface Water	There is a report of at least one vehicle being stuck in approximately 2ft of water at Stock Lane in Ingatestone. Also there was a similar instance at Hay Green Lane in Blackmore.	2010	Essex Fire & Rescue
Surface Water	North areas of the Borough and one instance in Coxtie Green experienced flooding of properties.	2011	Essex Fire & Rescue

2.5 Conclusions

The outputs of the preparation stage included a SWMP partnership being formed, data being shared under a protocol agreed by all partners, and a better overview of historic flooding from all sources across the Brentwood Borough. The need for and scope of the SWMP were confirmed, enabling the project to move on to the risk assessment stage. At this stage the initial areas which appear to be at risk from surface water flooding are Brentwood, Hutton and Ingatestone.

This page was left intentionally blank.

3 Intermediate Assessment

3.1 Definition of Flood Risk

The Brentwood Level 1 SFRA highlighted the Brentwood Borough as an area prone to surface water flooding. DEFRA Guidance (2010) defines the potential levels of assessment within an SWMP.

Table 3-1 shows the various levels of an assessment for a SWMP. This SWMP has been prepared at the 'Borough' scale to provide an initial assessment of flood risk. This intermediate assessment is applicable across a large town, city or Borough. This will allow for flooding hotspots to be informed for more detailed assessment.

Table 3-1: SWMP Study Levels of Assessment (DEFRA 2010)

Level of Assessment	Appropriate Scale	Outputs
Strategic Assessment	County wide	Broad understanding of locations that are more vulnerable to surface water flooding. Prioritised list for further assessment. Outline maps to inform spatial and emergency planning.
Intermediate Assessment	Borough wide	Identify flood hotspots which might require further analysis through detailed assessment Identify immediate mitigation measures which can be implemented. Inform spatial and emergency planning.
Detailed Assessment	Known flooding hotspots	Detailed assessment of cause and consequences of flooding. Use to understand the mechanisms and test mitigation measures, through modelling of surface and sub surface drainage systems.

3.2 Intermediate Assessment

The intermediate assessment was focussed on collation of data and information on flooding into a format that would allow criteria for further analysis to be generated. This section outlines the steps taken to inform the flooding hotspots which would be mapped in more detail.

3.2.1 Location of Historical Events

The intermediate assessment firstly incorporates historical records of flooding provided by Essex County Council and other SWMP partners. These were geo-referenced to give an indication of any areas of the Brentwood Borough which regularly suffer from flooding and categorised based on the possible source of the flood event. The events were broken into the following categories:

- Domestic
- Fluvial
- Groundwater
- Sewer
- Surface Water
- Natural
- Unknown

The category "natural" was based on events where evidence or the events location determined it be caused naturally but there was not enough information to determine its true source. The category "unknown" refer to events where no or insufficient information was provided and therefore the event could not be categorised accurately. The locations of the historical events can be found in Appendix B.

3.2.2 Flood Risk Metrics

Frism is a JBA Consulting tool which has been developed to rapidly assess the impacts of flooding at any scale. These can range from national-scale studies down to detailed SWMPs such as the Brentwood SWMP. The software allows the user to assess the economic, social and environmental impacts using flood risk metrics considers the impact on all forms of receptors (e.g. households, businesses, infrastructure etc). The software can be used to summarise key statistics such as the number of properties flooded, and if detailed information is available a detailed assessment can indicate the likely financial cost of flooding.

The following data sets were used within Frism to estimate the number of properties affected by surface water flooding across the Borough.

- National Receptor Database (NRD)
- Mastermap Data
- Flood outlines (ASTSWF - Areas Susceptible to Surface Water Flooding)

The NRD and Mastermap data were used to represent the location and footprint of buildings. The NRD was split into two separate formats, one containing the residential data and one containing non-residential data. A number of records were removed based on the operational guidance given by the Environment Agency for using NRD data for property counts. Mastermap data was used to represent the footprint of structures in the NRD data, to allow the detailed count method to be implemented. The Environment Agency's Areas Susceptible to Surface Water Flooding (ASTSWF) maps for Brentwood Borough were used to identify properties at risk of flooding. These are broken into three classifications with maximum indicative depths for each threshold. These categories are the following:

- Less: 0.1-0.3m
- Intermediate: 0.3-1.0m
- More: >1.0m

Analysis was only conducted on the "Less" and "More" categories for the Brentwood Borough in order to give an indication of where flooding hotspots were likely to be located.

Frism produces summary statistics and highlights the number of properties flooded within regular 250m grid cells, easily highlighting locations at risk of flooding across the Borough. In addition, statistics were also compiled for Brentwood Borough as a whole.

3.2.3 Frism for Brentwood

Table 3-2 shows the number of properties shown to be at flood risk based on the ASTSWF maps for whole of Brentwood Borough.

Table 3-2: Frism Outputs for Brentwood Borough

Outline	Total Area (m^2)	Flooded Area (m^2)	Number of Properties Flooded	
			NRD Residential	NRD-Non-Residential
ASTSWF Less (0.1-0.3m)	153124061	17672474	3731	1012
ASTSWF More (>1.0m)	153124061	3285387	384	94

The Mastermap data suggests that there are 99,232 buildings within the Brentwood Borough with only a small proportion of residential and non-residential properties flooding as a result of surface water. To refine this further the Brentwood Borough was broken into 250m grid cells. This allowed for the number of flooded residential and non-residential properties to be counted for each cell. This was again run using the ASTSWF "Less" and "More" categories. Figure 3-1 shows an example of the outputs for the residential modelling run using the ASTSWF "Less" outlines. Appendix C shows the results for all scenarios.

Figure 3-1: ASTSWF Less Frism Grid Output - Residential Properties

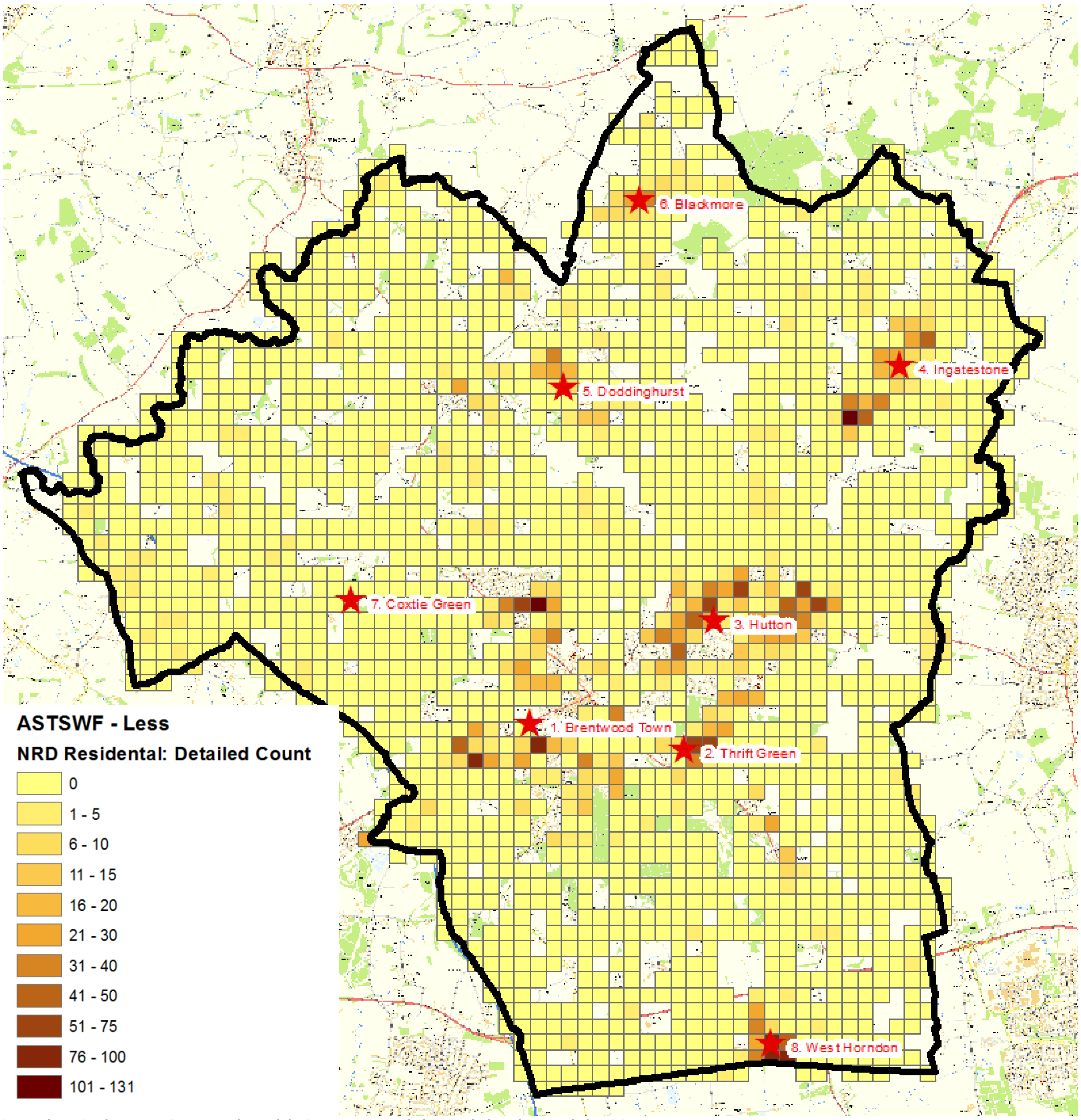


Figure 3-1 shows that in the case of residential properties the most affected areas appear to be Brentwood Town, Hutton, Thrift Green, Ingatestone and West Horndon. Doddinghurst and Blackmore also show some pockets of residential flood although this is less pronounced due to the size of the settlement. This compares well with the historic flood records particularly in Brentwood, Hutton and Ingatestone. There are few records for Blackmore, Coxtie Green and Doddinghurst in the historic records.

3.2.4 Surface Water Flooding Hotspot

Based on the historic flooding events supplied by Essex County Council and the intermediate analysis conducted using Frism, a number of flooding hotspots have been identified. Table 3-3 shows the hotspots and discusses the merits of further assessment.

Table 3-3: Brentwood Hotspots

Hotspot	Number of Historic Events	Include for Detailed Assessment?	Comments
Brentwood Town	22	Yes	The eastern portion of Brentwood is subject to urban surface water flooding where as the western portion is dominated by fluvial flooding. It is proposed to model in greater detail the eastern portion with western portion being coarsely modelled but requiring additional study outside of the SWMP.
Thrift Green	9	Yes	The urban nature of the study area could make it susceptible to sewer flooding. This area is proposed to be modelled in greater detail.
Hutton	9	Yes	The historic records for this area correlate well with ASTSWF. The urban nature of the study area could make is susceptible to sewer flooding. This area is proposed to be modelled in greater detail.
Ingatestone	8 (+3 vehicular flood incidents)	Yes	The historic records for this area correlate well with ASTSWF. The eastern portion of the area is urban and therefore susceptible to urban surface water flooding. The western portion of the area is more susceptible to fluvial flooding. This area is proposed to be modelled in greater detail.
Doddinghurst	1	No	Only one historic event was found in the vicinity of Doddinghurst. The intermediate analysis using Frism shows that few properties are within ASTSWF outlines. Furthermore no LIDAR is available for this area therefore it will not be further assessed in this study.
Blackmore	1	No	Only one historic event was found in the vicinity of Blackmore which fell outside the ASTSWF outlines. Flood risk for Blackmore generally originates from the watercourses within the village. It is proposed that an additional study is needed outside of the SWMP to construct a fluvial hydraulic model to map flood risk.
Coxtie Green	4	No	There are four historic events in the area however; these do not correlate well with the ASTSWF outlines. The driver of flooding appears to be small private ponds in the area. Further modelling is unlikely to offer more insight than ASTSWF and therefore was not further assessed. It is proposed a flood study of historic event may prove more relevant and provide an understanding of flood sources.
West Horndon	0	Yes	No historic events were recorded in this area however; Frism calculations indicated a high number of properties within ASTSWF outlines. It is proposed that this area be modelled in further detail.

The location of the proposed flooding hotspots is shown in Appendix D.

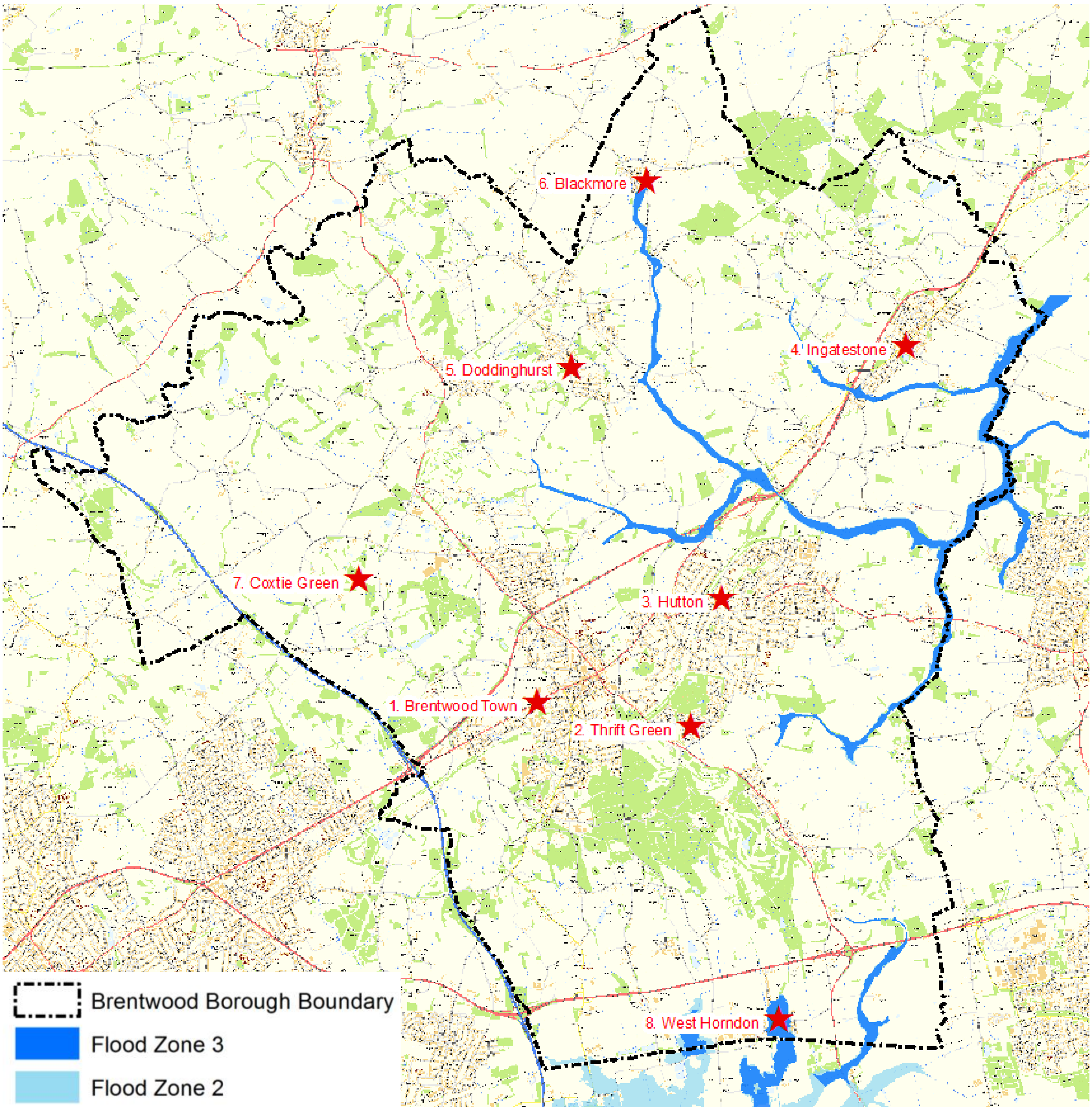
As a further part of the intermediate assessment an overview of other sources of flood risk has been complied. This follows in the next section.

3.3 Other Sources of Flood Risk

3.3.1 Fluvial

Watercourses are designated either main river or ordinary watercourses. Ordinary watercourses include small open channel and culverted watercourses. These watercourses should be maintained by the riparian owner (i.e. those who own property either side of the bank). Main rivers are larger watercourses which the Environment Agency has permissive powers to maintain. Fluvial flood risk has been considered as river levels can influence surface water flood risk. This is relevant as there are a number of watercourses which run through population centres such as Ingatestone and Brentwood. Figure 3-2 shows the Environment Agency flood maps for the Brentwood Borough. This map is a combination of detailed modelled outlines and JFlow 2D modelling for some of the ordinary watercourses. The Flood Zones are determined without consideration to the presence of flood defences, although there are no formal defences maintained by the Environment Agency in Brentwood.

Figure 3-2: Environment Agency Flood Maps



Unfortunately the outlines only exist for the River Wid and a number of its tributaries. The watercourse flows down the eastern boundary of the Borough and extends into Ingatestone as well as up towards Blackmore, north of Hutton. The other available outlines are found in the southern region of the Borough surrounding West Horndon. This area is surrounded by numerous drains one of which flows directly through West Horndon.

Other areas of Brentwood Borough have also been examined to determine the fluvial risk to population centres.

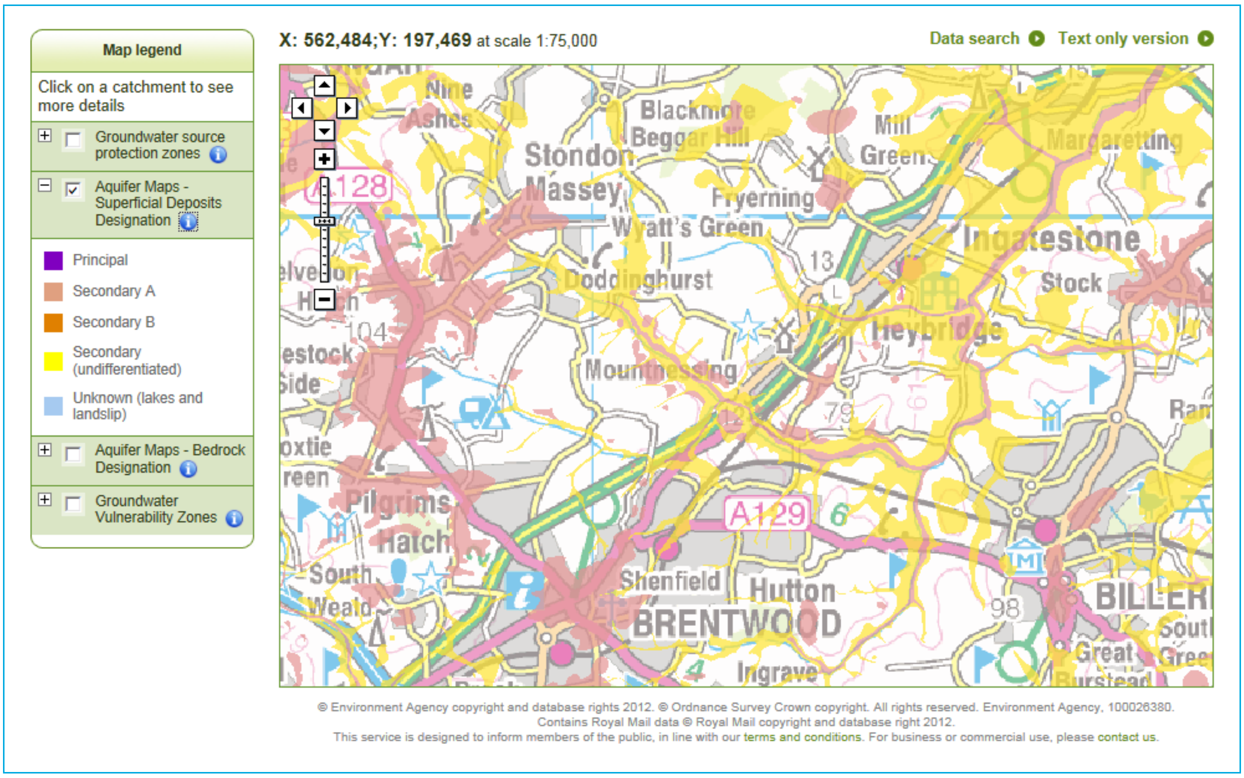
3.3.2 Groundwater

Under some circumstances groundwater levels can rise and cause flooding problems in subsurface structures or at the ground surface. There are no reported incidents of groundwater flooding in the area.

The British Geological Society's Soil Map of England and Wales (1975) shows that soils within the Brentwood Borough are predominantly slowly permeable clayey soils with areas of impeded drainage.

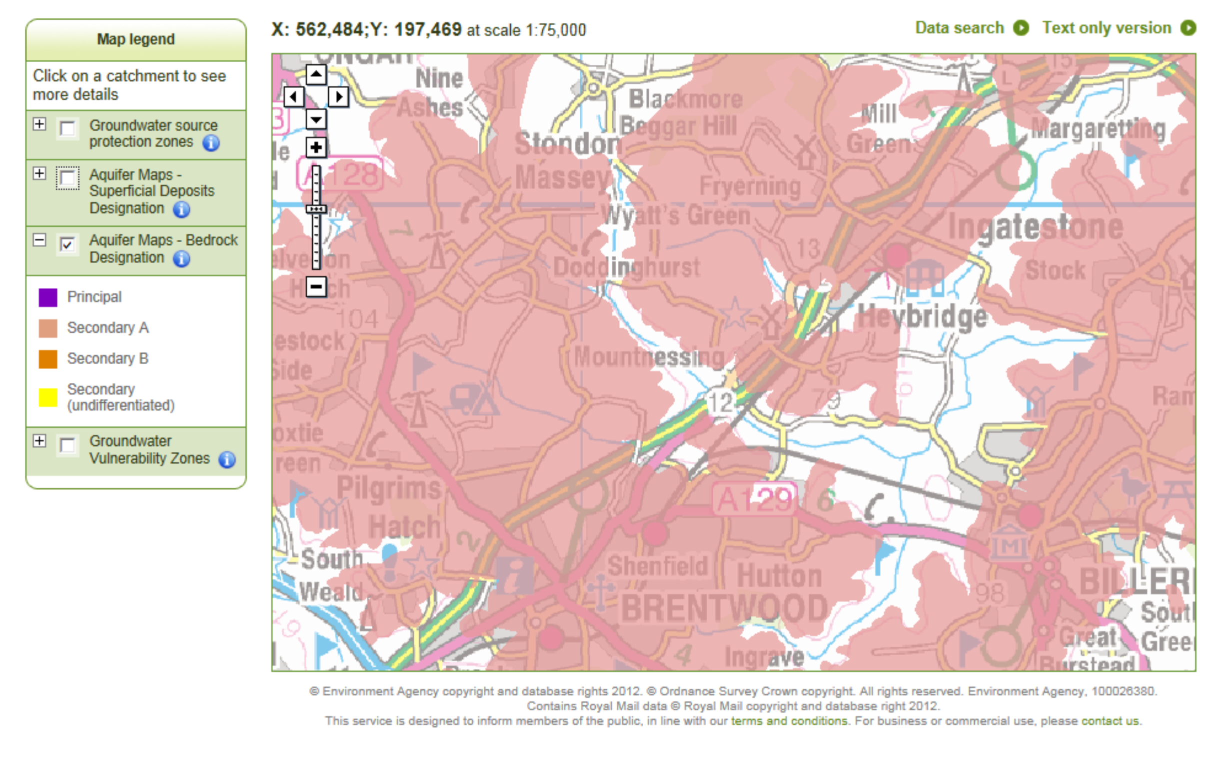
Basic information regarding the local hydrogeology has been obtained from the Environment Agency website. Brentwood Borough does not have any groundwater protection zones within its boundaries. The superficial deposits are designated as a combination of Secondary (undifferentiated) in the vicinity of Ingatestone and Secondary A in central Brentwood. A Secondary A classification states that the deposits are permeable layers capable of supporting water supplies at a local rather than regional scale and can form important sources of base flows to local watercourse. This is shown in Figure 3-3.

Figure 3-3: Superficial Deposits Designation



The underlying bedrock designation is Secondary A. Secondary A is defined on the Environment Agency website as permeable layers capable of supporting water supplies at a local rather than strategic scale, in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers. This is shown in Figure 3-4.

Figure 3-4: Bedrock Designation



3.3.3 Sewer Flooding

Sewer flooding can occur from several mechanisms, summarised below:

1. **Rainfall events exceeding the capacity of the sewer / drainage system.**

Sewer systems have been typically designed and constructed to accommodate a rainfall event with a 1 in 30-year probability of occurrence in any given year (33%) or less. Therefore rainfall events exceeding this will be expected to result in surcharging of the sewer system.

2. **Drainage systems become blocked by debris or sediment.**

Over time sewer systems can become blocked from fallen leaves and build up with sediment and debris. This will decrease the efficiency of the drainage systems and in severe rainfall events completely block system, resulting in surcharging. Only regular maintenance can minimise the impact of blockage.

3. **Drainage systems surcharging due to high water levels in receiving watercourses.**

Where sewers discharge through outfalls to rivers, high water levels can stop water discharging into the river and cause flows to back up along the sewer. Once the storage capacity within the sewer itself is exceeded, the water will overflow into streets through manholes.

Responsible Organisations

In order to identify problems and solutions it must first be outlined which organisations are responsible for maintenance of drainage infrastructure. In Brentwood the primary parties responsible for the drainage infrastructure are Essex Highways and the water utility company (Anglian Water).

Essex Highways is responsible for maintaining an effective highway drainage system including the road gullies and pipes which connect the gullies to the trunk sewers and soakaways. The utility companies, in this case Anglian Water are responsible for maintaining the trunk sewers. It is their responsibility under the Water Industry Act 1991 to provide, maintain and operate systems of public sewers and works for the purpose of effective drainage of the area.

Riparian owners are responsible for private drainage networks where they are small open channels and culverted urban watercourses.

Available Data

Anglian Water have provided details of their infrastructure such as sewers and outfalls. This information has been used within the further modelling stage to provide an accurate representation of how the local sewer networks deals with surface water and areas where it may be causing surface water flooding. This information will allow flood risk issues to be analysed and mitigated where possible.

3.4 Conclusion

The intermediate assessment has provided an overview of flood risk from a variety of sources across the Brentwood Borough. Analysis of the ASTSWF maps using Frism highlighted eight flooding hotspots of which a five will be put forward for more detailed modelling. The aim of the detailed assessment would be to understand the cause and consequences of flooding as well as explore the mechanisms that lead to flooding. The detailed assessment is conducted in the next chapter.

4 Detailed Assessment

4.1 Assessment Approach

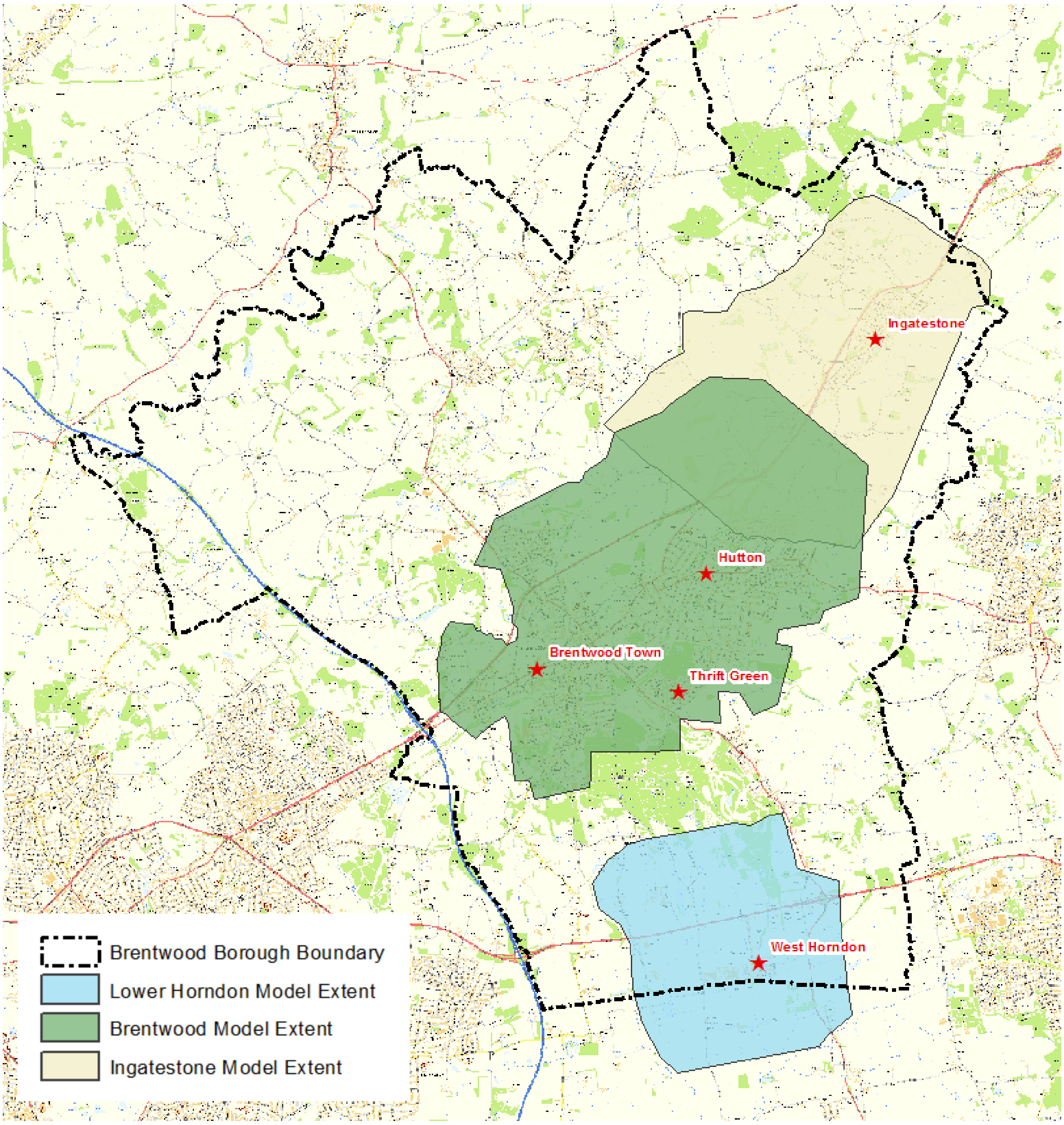
The intermediate assessment was used to identify areas where the flood risk is considered to be most severe. These areas are known as surface water flooding hotspots. These areas have been identified as areas which would benefit from an integrated modelling approach. As detailed in Table 3-1 the next stage is to use modelling to understand the mechanisms and test mitigation measures.

To perform the modelling, InfoWorks ICM was chosen as the modelling platform. This package allowed the modelling of surface water and the sewer networks. The 1D sewer networks can be informed by Anglian Water network data, linked to a 2D model domain based on LIDAR data. . The following points briefly describe the modelling:

- InfoWorks ICM was selected principally for its ability to model sewer networks and surface water flow routes in one software package.
- Sewer networks are included in this model using data provided by Anglian Water. Surface water flow routes are represented using LIDAR data and mapping data to define a 2D model.
- The model of the catchment surface includes representation of features which play an important role in directing, diverting and storing surface water including buildings, roads, railway embankments and small ditches.
- The inputs to the model are rainfall events appropriate for Brentwood Borough that were generated using FEH catchment descriptors to derive the 30-year, 100-year, 100-year plus climate change and 200-year events for storms of 1 hour, 3 hours and 6 hour durations.
- Outputs of depth, velocity and hazard were produced by combining the results of all the durations for each return period and displaying the maximum values. For depth results, flooding less than 0.025m has been removed as this was not deemed to present a flood risk. Hazard and velocity results were only displayed for areas where the depth of surface water was greater than 0.025m.
- JBA Frism tool was used to further analysis in further detail based on model outputs to increase understanding of flood risk and prioritise areas for schemes.
- Flooding from the sewer system, caused by a blockage in a sewer or urban drainage system was not modelled in detail.
- Fluvial networks entering the modelling domains had inflows generated from FEH catchment descriptors. This was a generalised approach designed to allow the interaction between watercourses and sewer outfalls as well as areas where culverts have insufficient capacity and generate surface water flooding.

In total three InfoWorks ICM models have been developed that covered Ingatestone, West Horndon and a centralised model which included Brentwood Town, Hutton and Thrift Green. The extents of the InfoWorks ICM models are shown in Figure 4-1.

Figure 4-1: Hotspot Modelling Extents



4.1.1 Calculation of Damages using Frism

As stated in the previous section, Frism was used to further analyse the flood risk based on the model results. The Frism calculations were run on all return periods (30, 100, 100 plus climate change and 200 year) using depth grids of flooding greater than 0.025m.

Each flooded property point is attributed minimum, maximum and mean damage values corresponding to the damage value for the within the property footprint (taken from OS Mastermap data). For the purposes of this study the mean damage values were used.

The damage value is presented in pounds and is estimated by obtaining a unit damage value (£/m2) using the depth-damage curves from the Multi Coloured Manual (Flood Hazards Research Centre 2010). The unit damage value depends on the flood depth at the property and the property type. This damage value is then multiplied by the value in the floor area field of the NRD to obtain an absolute damage value.

To display the damage costs the results with the sum of the mean damages to both residential and non-residential properties within each 100m grid cell was displayed as a thematic map.

The following definitions are useful to understand the results of the risk assessments.

- **Damages:** The value of negative social, economic and environmental impacts caused by flooding or erosion.
- **Annualised Average Damages (AAD):** - average damage in pounds (£) per year that would occur in a designated area from flooding over a very long period of time. In many years there may be no flood damage, in some years there will be minor damage and, in a few years, there will be major flood damage

4.1.2 Hazard to People Rating

The flood hazard to people rating gives a visual indication of the areas where there is greater hazard posed to people from flooding. Flood hazard is a function of the flood depth, flow velocity and a debris factor (determined by the flood depth). The following equation (Defra/Environment Agency FD2320/TR1 report, 2005) is used to calculate the hazard to people:

Hazard Rating = (D * (v+0.5) + DF)

Where

D = *depth of flood water (m)*

V = *velocity of flood water (m/s)*

DF = *Debris Factor (either 0, 0.5 or 1 depending on the probability that debris will lead to a hazard)*

Guidance within the FD2320 report recommends the use of a Debris Factor (DF) to account for the presence of debris during a flood event in the urban environment. The Debris Factor is dependent on the depth of flooding; for depths less than 0.25m a Debris Factor of 0.5 was used and for depths greater than 0.25m a Debris Factor of 1.0 was used.

The result of the hazard rating equation related to the hazard to people classification below in Table 4-1.

Table 4-1: Hazard to People Classification

Degree of Flood Hazard	Hazard Rating		Description
	<0.75	Caution	Flood zone with shallow flowing water or deep standing water.
	0.75 – 1.25	Dangerous for some (i.e. children)	Danger: Flood zone with deep or fast flowing water.
	125 – 2.5	Dangerous for most people	Danger: Flood zone with deep fast flowing water.
	>2.5	Dangerous for all	Extreme danger: Flood Zone with deep fast flowing water.

For the overview of flood risk within the hotspots Hazard to People has only been discussed where there is a significant risk to populated area.

4.2 Overview of Flood Risk within Hotspots

This section discusses the hotspot modelling results and analysis. The section has been broken in to sub-catchments defined by the three modelling domains. For each sub-catchment the modelling results will be discussed and analysed to assess the receptors at risk from flooding in different return periods. This involved both a simple count of properties, but also assessment of the damage costs, based on the Multi-Coloured Manual (2010) methodology.

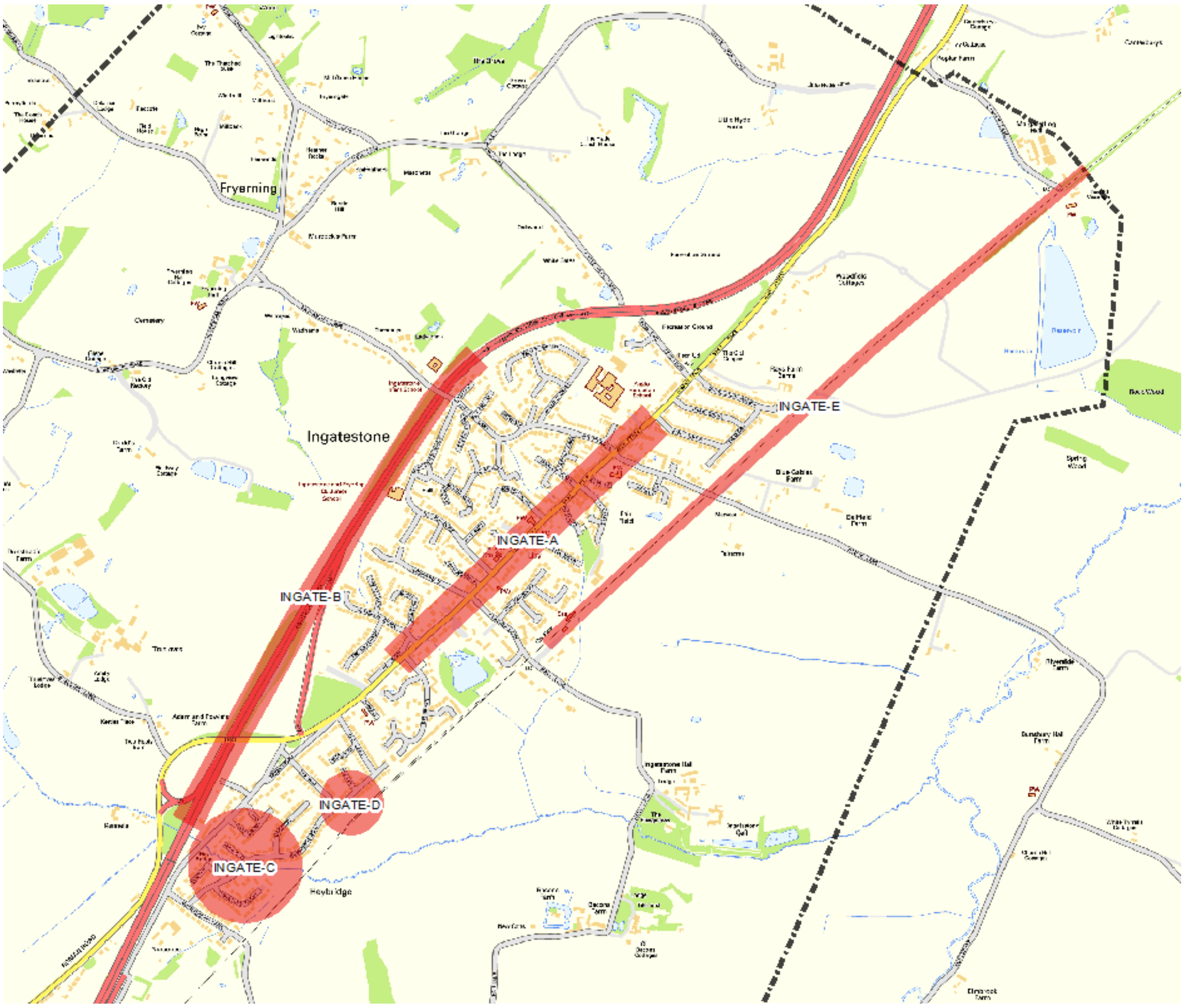
4.2.1 Ingatestone

Overview of Flood Risk

The modelling results for Ingatestone showing flood depths and hazard to people are shown in Appendix E.

To give an overview of flood risk in Ingatestone a number of areas were identified. These are shown in Figure 4-2.

Figure 4-2: Key Areas within Ingatestone



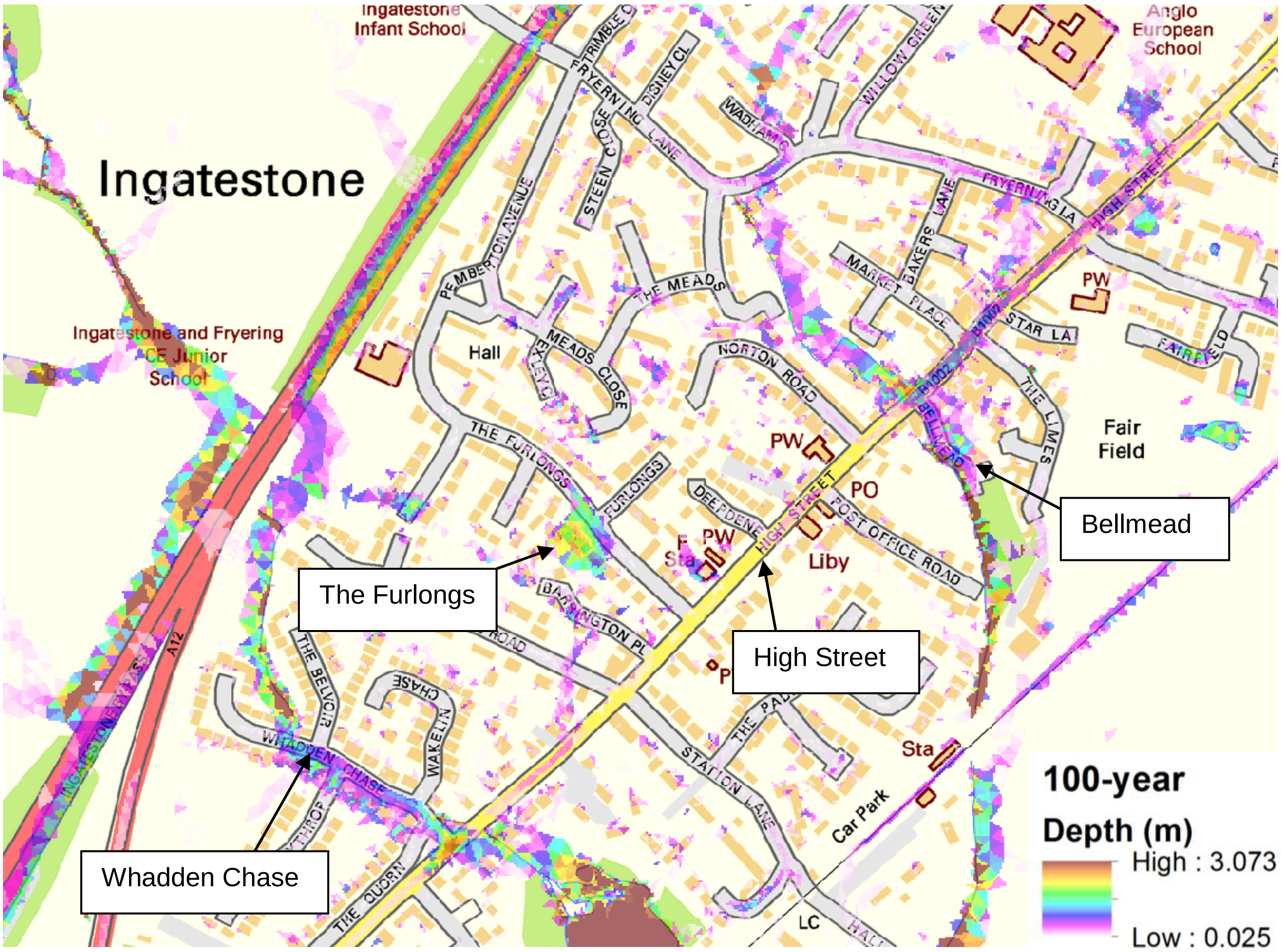
Contains Ordnance Survey data (c) Crown copyright and database right 2014

A summary of flood risk in these locations within Ingatestone is presented overleaf:

Area INGATE-A: Ingatestone High Street

Figure 4-3 shows the flood depths for the 100-year return period in the vicinity of the High Street.

Figure 4-3: Flood Depth in the vicinity of Ingatestone High Street for the 100-year Return Period



Contains Ordnance Survey data (c) Crown copyright and database right 2014

Ingatestone High Street floods at three main locations, Whadden Chases, Bellmead and The Furlongs. At Whadden Chase and Bellmead unnamed watercourses pass underneath the High Street. In the case of Whadden Chase water backs up within the sewer network both upstream and downstream, surcharging and flooding a low spot on the High Street. Maximum flood depths for all return periods are between 0.4 and 0.5m. Other surface water pathways contribute to this area of flooding from the A12 and from The Furlongs, located to the north east of Whadden Chase. With regards to flood hazard, Whadden Chase is classed as having a mixture of areas that are “Danger for Some” and “Danger for Most”. The low spot where surface water ponds at the junction, is shown to be an area classed as “Danger for Most”.

In regards to the flooding shown at Bellmead junction, a similar interaction between the watercourse and the sewer network takes place, with the surcharging sewer network generating surface water flow down the High Street. Maximum flood depths along this section of the High Street are between 0.10 and 0.15m for the 100-year return period. With regards to flood hazard, Bellmead and the surrounding area are mainly classed as “Very low hazard”. Small areas of the High Street are classed as “Danger for Some” with areas of “Danger for Most” upstream of the road culvert.

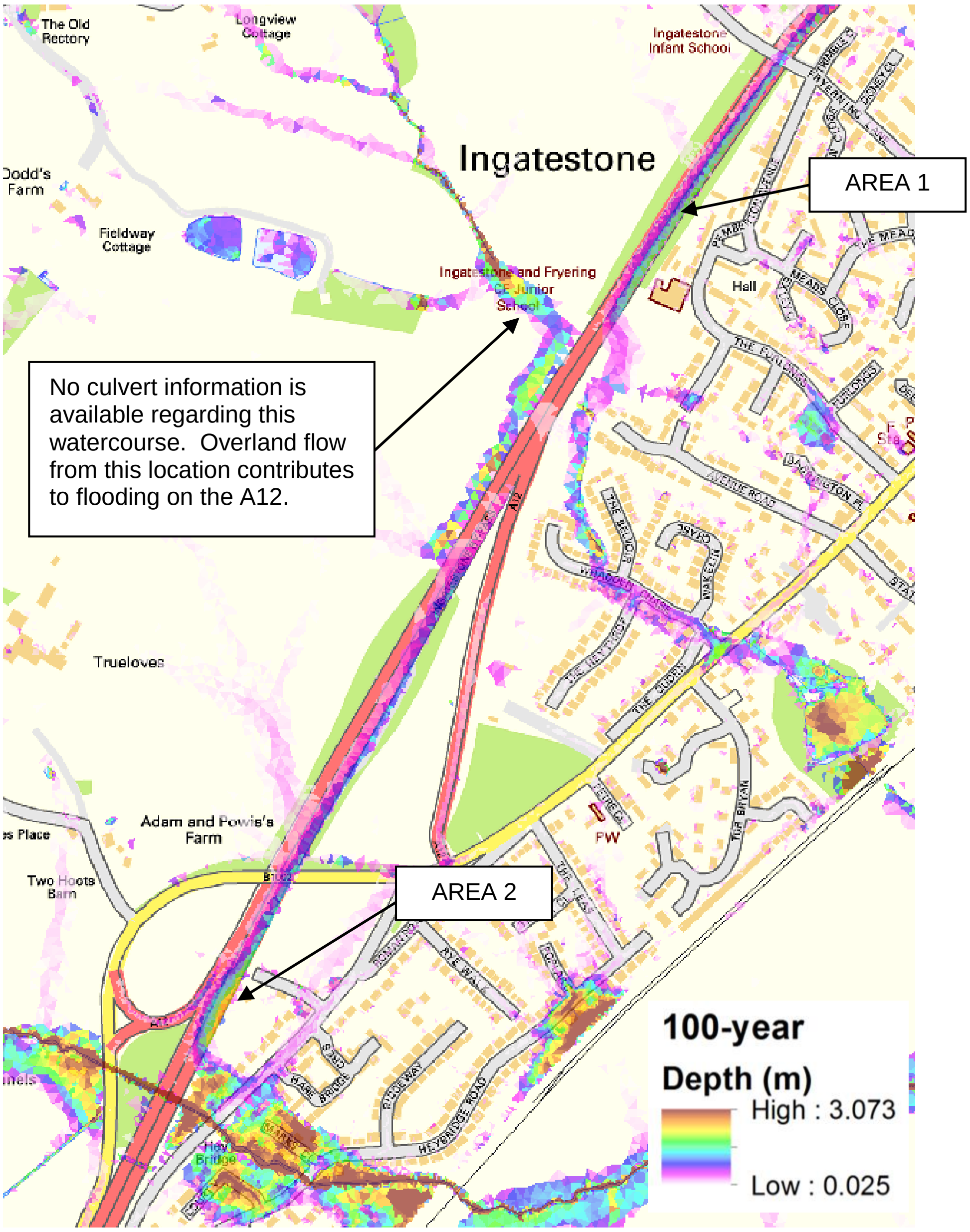
Flooding along The Furlongs relates to a mixture of undersized sewer pipes and lack of sewer network data in the area. The lack of capacity and in some places outfalls represented unrealistically by the provided sewer data causes flooding to poor in area of low ground. Further survey could be used to improve the sewer data in this area which may result in a reduced flood extent.

Results along the High Street appear to correlate with historic flood records (shown in Appendix B) which show a number of historic flood events relating to sewer and fluvial flooding.

Area INGATE-B: A12 Ingatestone By-Pass

Figure 4-4 shows the flood depths for the 100-year return period in the vicinity of the A12 By-Pass

Figure 4-4: Flood Depth in the vicinity of A12 By-Pass for the 100-year Return Period



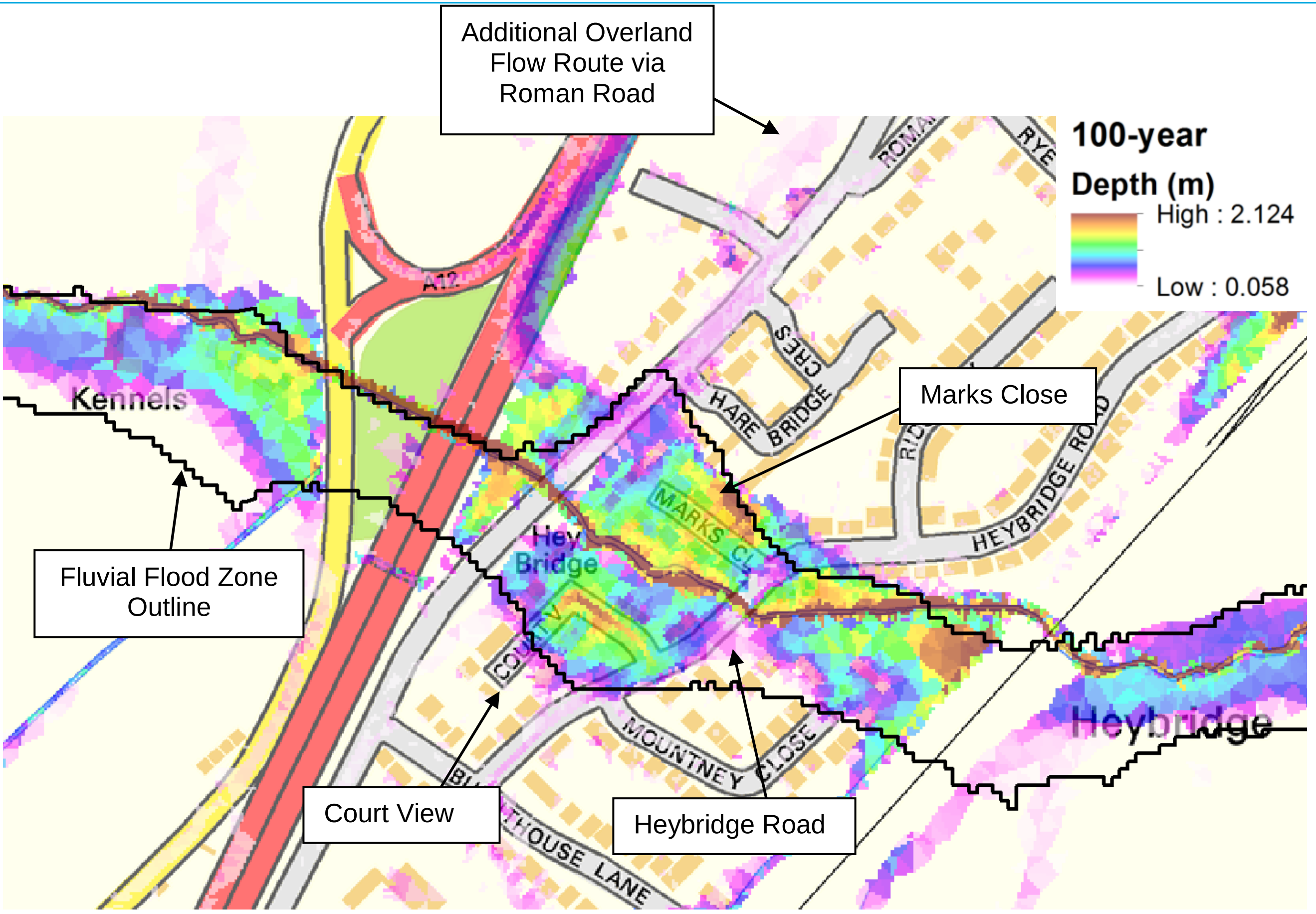
The A12 is shown to flood in all modelled returns periods. Flooding along the by-pass is most significant in Area 1 and 2 as shown on Figure 4-4. Flooding in Area 1 has depths of approximately 0.25-0.4m for all return periods. Maximum flood depths in Area 2 are approximately 0.50-0.70m for all return periods. The southern carriageway is the primary route of flow with the northern carriageway only becoming shallowly submerged in higher return period events. In regards to hazard, the majority of southern carriageway is classed “Danger for Most” with the shallow flooded areas classed as “Very low hazard”.

Although the modelling results have shown the highway to flood and be a surface water pathway it is important to note that no detailed information was available regarding the highway drainage of the by-pass. To improve the accuracy of the modelling in future, detailed drainage information could be added to better represent the flooding likely to be experienced on the by-pass. Also no culvert data was provided regarding the unnamed watercourse located adjacent to the Ingatestone Junior School (See Figure 4-4). Overland flow generated from this channel significantly contributes to flooding on the A12. Further survey would be required to determine the location of the culvert and its dimensions.

Area INGATE-C: Area surrounding Heybridge

Figure 4-5 shows the flood depths for the 100-year return period in the vicinity of the Heybridge.

Figure 4-5: Flood Depth in the Vicinity of Heybridge for the 100-year Return Period

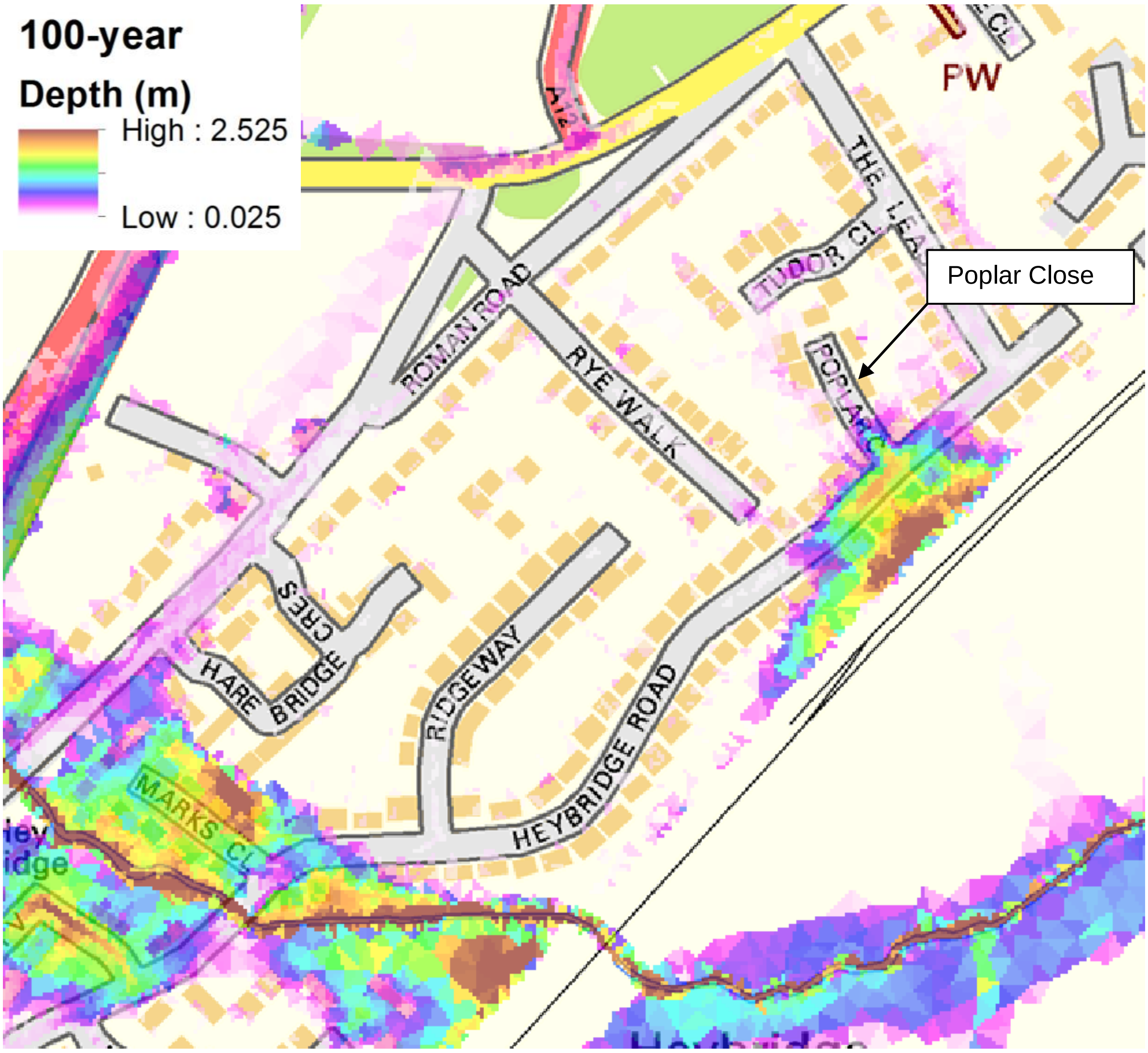


Flooding in this area is shown to be mainly fluvial in nature with current flood zones covering the most affected roads (notably Marks Closes, Court View and Heybridge Road). This correlates with historic flood records shown in Appendix B. Flooding in this area relates to the sewer network which discharges at various locations along the watercourse, backing up due to high water levels at the outfalls. There are also a number of surface water pathways which originate from the A12 by-pass and along Roman Road which contribute surface water to the area. Flood hazard in the area is generally classed as “Danger for Most” with areas close to the watercourse classed as “Danger for All”.

Area INGATE-D: Poplar Close

Figure 4-6 shows the flood depths for the 100-year return period in the vicinity of Poplar Close.

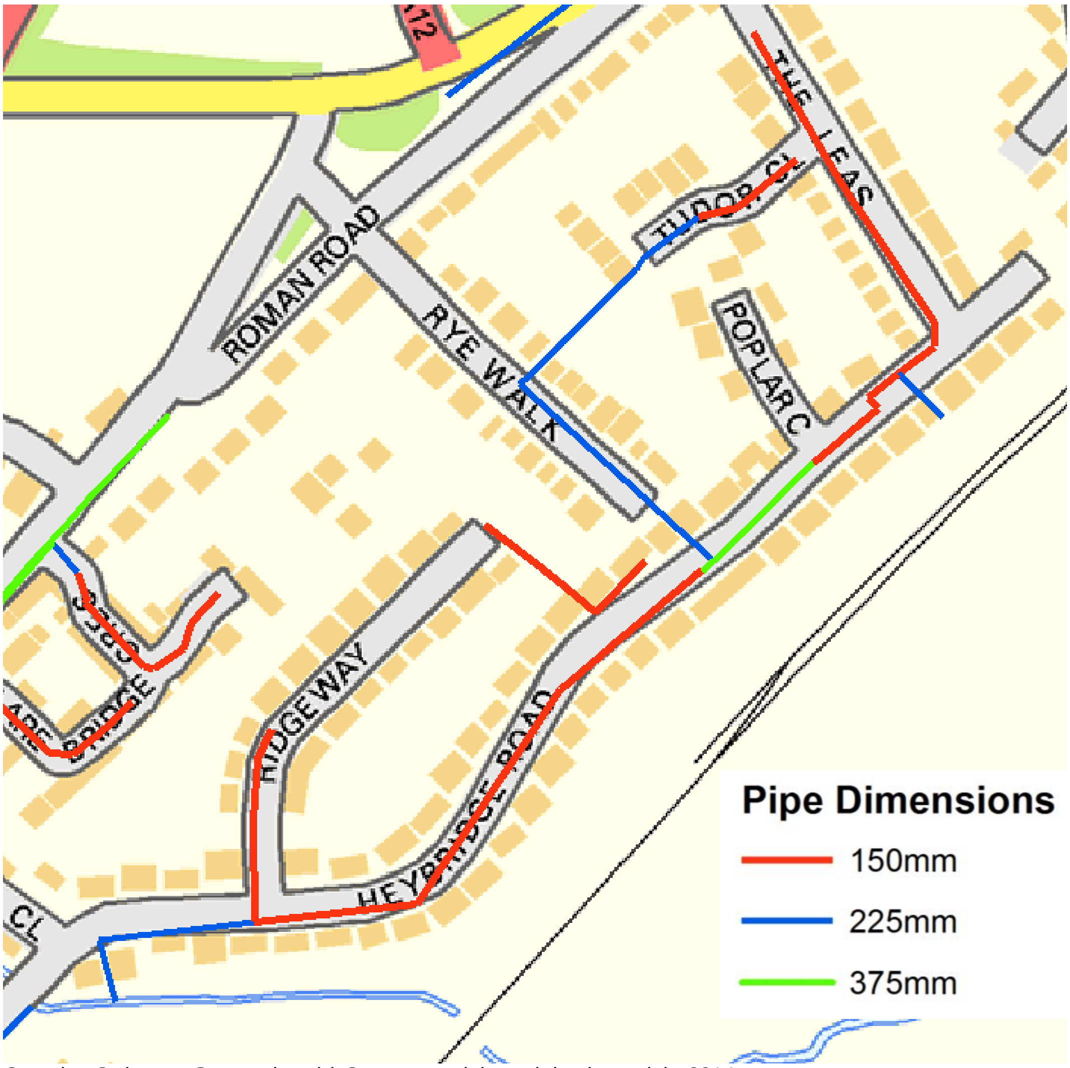
Figure 4-6: Flood Depth in the vicinity of Poplar Close for the 100-year Return Period



Flooding in this location relates to surcharging of the sewer network. This is caused by high water levels at the outfall of the sewer backing up into the system. The pipe diameter at this location is 150mm with a small section of piping having a diameter of 375mm (see Figure 4-7). With a number of sewers being linked to the sewer network surrounding Poplar Close the current pipe network is too small to support the volumes required. Surcharging water spills and fills low spots against the railway embankment that prevents flow from moving away from the area. As there are uncertainties in the sewer network it is recommended that further investigations are conducted in this area.

In regards to hazard, the areas of deeper flood water which cover a number of residential properties is classed as "Danger for Most".

Figure 4-7: Approximate Location of Surface Water Sewer Pipe Dimensions



Area INGATE-E: Railway Line

The north-east section of railway line is shown to flood for all return periods. Flooding extends from the railway station, (in vicinity of Halls Lane) in a north-easterly direction, reaching the edge of the model domain. Maximum flood depths are between 0.35m and 0.65m for all return periods. Flooding around the railway station itself is shallow being approximately 0.10-0.15m in depth for all return periods. Unfortunately no drainage network information is available in the vicinity of the railway; if in future more information becomes available the modelling should be revisited to reassess flood risk.

With regards to flood hazard, the railway is shown to be classed as “Danger for Most” or “Danger for Some” for all but the 200-year return period. The 200-year return period shows some areas classed as “Danger for All” which relate to areas where flood water is significantly deep.

Overview of Existing Properties

To represent the number of properties flooded in each return period Frism was run using 100m grid cells. Appendix H displays the number of properties flooded for each given return period as well as a graphical representation of the mean sum of damage within each flooded 100m grid cell for each return period. Table 4-2 shows a summary of the number of properties that are at risk across the sub-catchment for the modelled return periods. Table 4-3 shows the annualised average damages within the Ingatestone model extent.

Table 4-2: Number of properties at risk of surface water flooding in Ingatestone

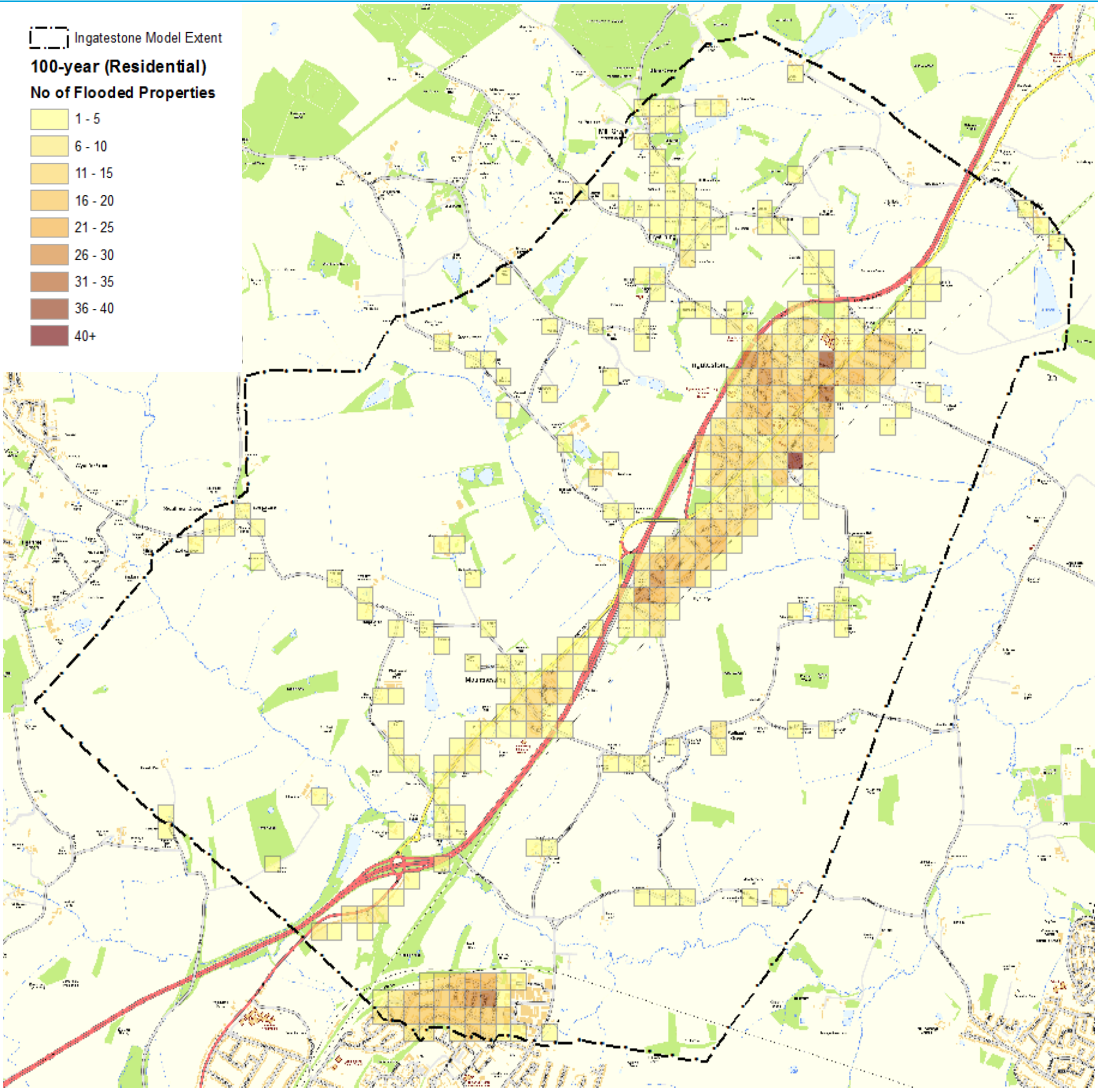
Return Period	Total number of Properties	Residential Properties at Risk	Non-Residential Properties at Risk	Number of People at Risk	Total Damage £M (Residential)	Total Damage £M (Non Residential)
30-year	4,504 (3,283 Residential & 1,221 Non Residential)	2,162	768	5,081	£18.09M	£4.48M
100-year	4,504 (3,283 Residential & 1,221 Non Residential)	2,426	867	5,701	£25.74M	£5.32M
100-year (plus Climate Change)	4,504 (3,283 Residential & 1,221 Non Residential)	2,466	879	5,795	£26.52M	£5.52M
200-year	4,504 (3,283 Residential & 1,221 Non Residential)	2,578	912	6,058	£28.28	£5.90M
NOTE:the number of people at risk was based onthe asusmption that the average number of people per residential property is 2.35.						

Table 4-3: Annualised Average Damage for Ingatestone

Annualised Average Damage (£)	
Residential	**Non- Residential**
£5,849,232	£1,217,331

Number of Flooded Residential/Non-Residential Properties

Figure 4-8: Number of Flooded Residential Properties for the 100-year Return Period



Contains Ordnance Survey data (c) Crown copyright and database right 2014

Number of Flooded Residential/Non-Residential Properties

Figure 4-8 shows that the number of flooded residential properties is centralised around Ingatestone, which is the location of the majority of the residential properties within the modelling extent. There are numerous isolated cells that show a small number of properties in the surrounding Greenfield land. The residential areas surrounding watercourses running through Ingatestone (at Heybridge and in the vicinity of Fryerning Lane) record the highest number of flooded properties per 100m grid cell. In these locations numerous cells having more than 20 flooded properties. Two cells in North-East Ingatestone are shown to have more than 40 flooded properties however, this relates to indivudial blocks of flats becoming flooded rather than 40 separate dwellings.

Figure 4-9: Number of Flooded Non-Residential Properties for the 100-year Return Period

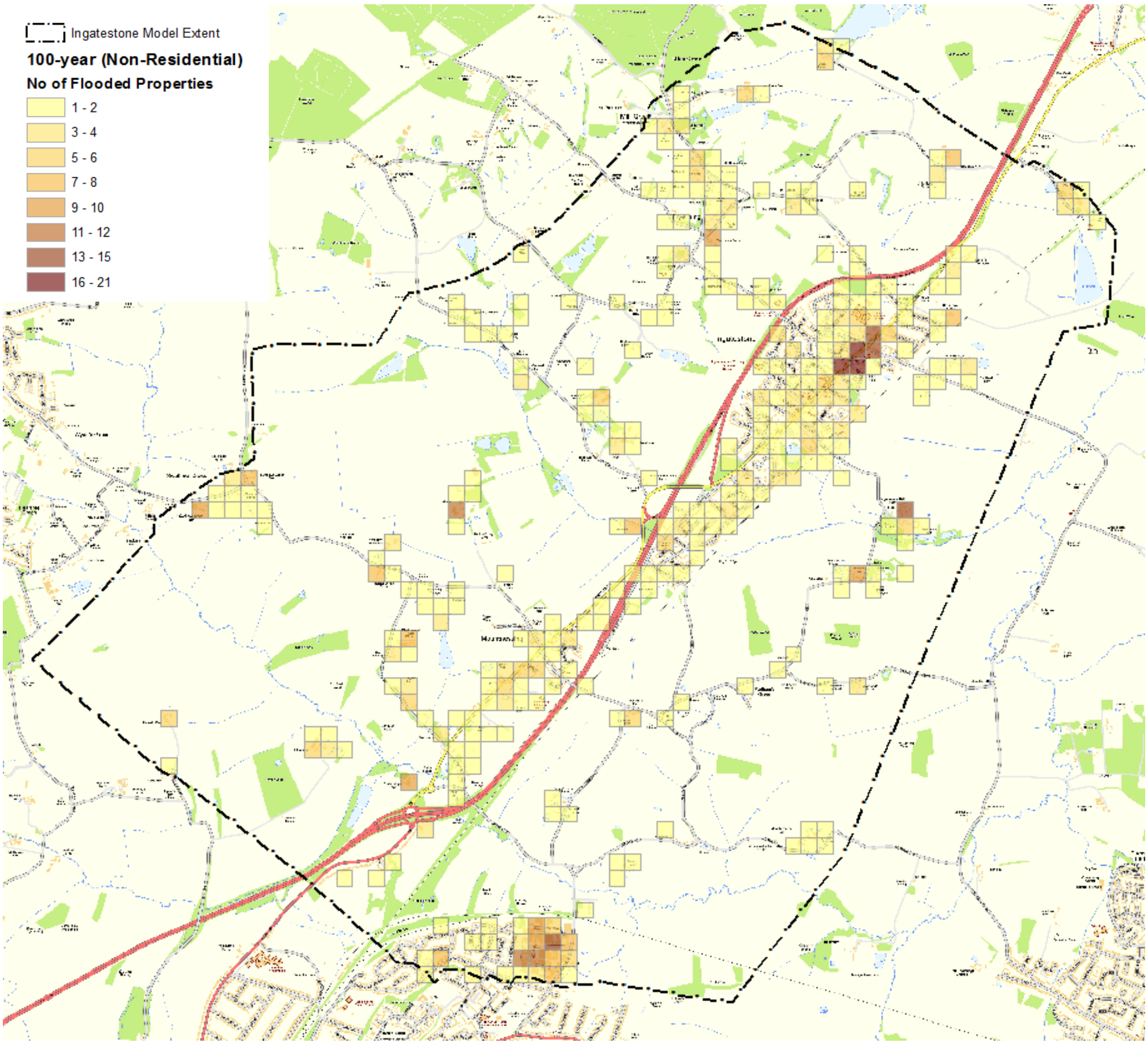


Figure 4-9 shows the number of flooded non-residential properties within Ingatestone. The majority of grid cells which show non-residential flooding within Ingatestone have less than 5 flooded properties. Although these areas are mainly residential in nature they do contain non-residential infrastructure such as schools and community halls. The largest area of non-residential flooding is found in North-East Ingatestone along the High Street. At this location there are a number of cells which record 13-21 flooded non-residential properties. This correlates with a high density of commercial properties along the High Street.

Mean Flood Damage for Residential/Non-Residential Properties

Figure 4-10 and Figure 4-11 show the distribution of flood damage costs within the Ingatestone model extent for the 100-year event. Appendix H contains all mapping illustrating the distribution of mean damage costs for the other return periods in the Ingatestone model extent for all return periods.

Figure 4-10: Mean Aggregated Flood Damage (£K) for Residential Properties in the 100-year Return Period

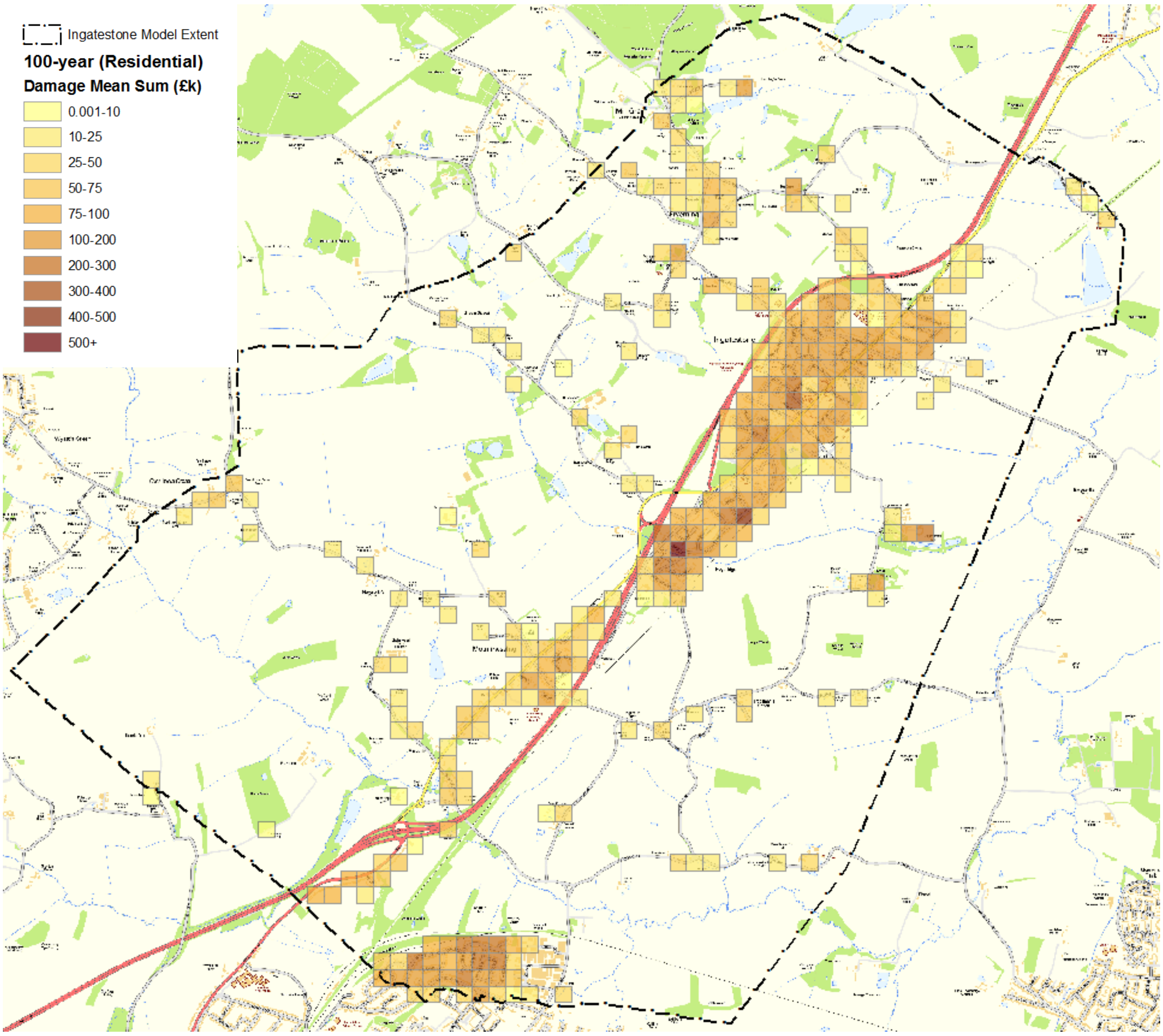


Figure 4-10 shows the mean aggregated flood damage (£K) for residential properties for the 100-year return period. The highest recorded cost is found in the vicinity of Heybridge having mean damages of £677,000. This area has been shown to experience widespread flooding from both the local watercourse running through the area and surface water. Other areas that experience high flood damage values are areas surrounding the watercourse running through northern Ingatestone and at Poplar Close. Both these areas have been highlighted in the overview of flood risk. Overall the mean flood damages per 100m cell is £66,000 - £83,000 for all return periods

Figure 4-11: Mean Aggregated Flood Damage (£K) for Non-Residential Properties in the 100-year Return Period

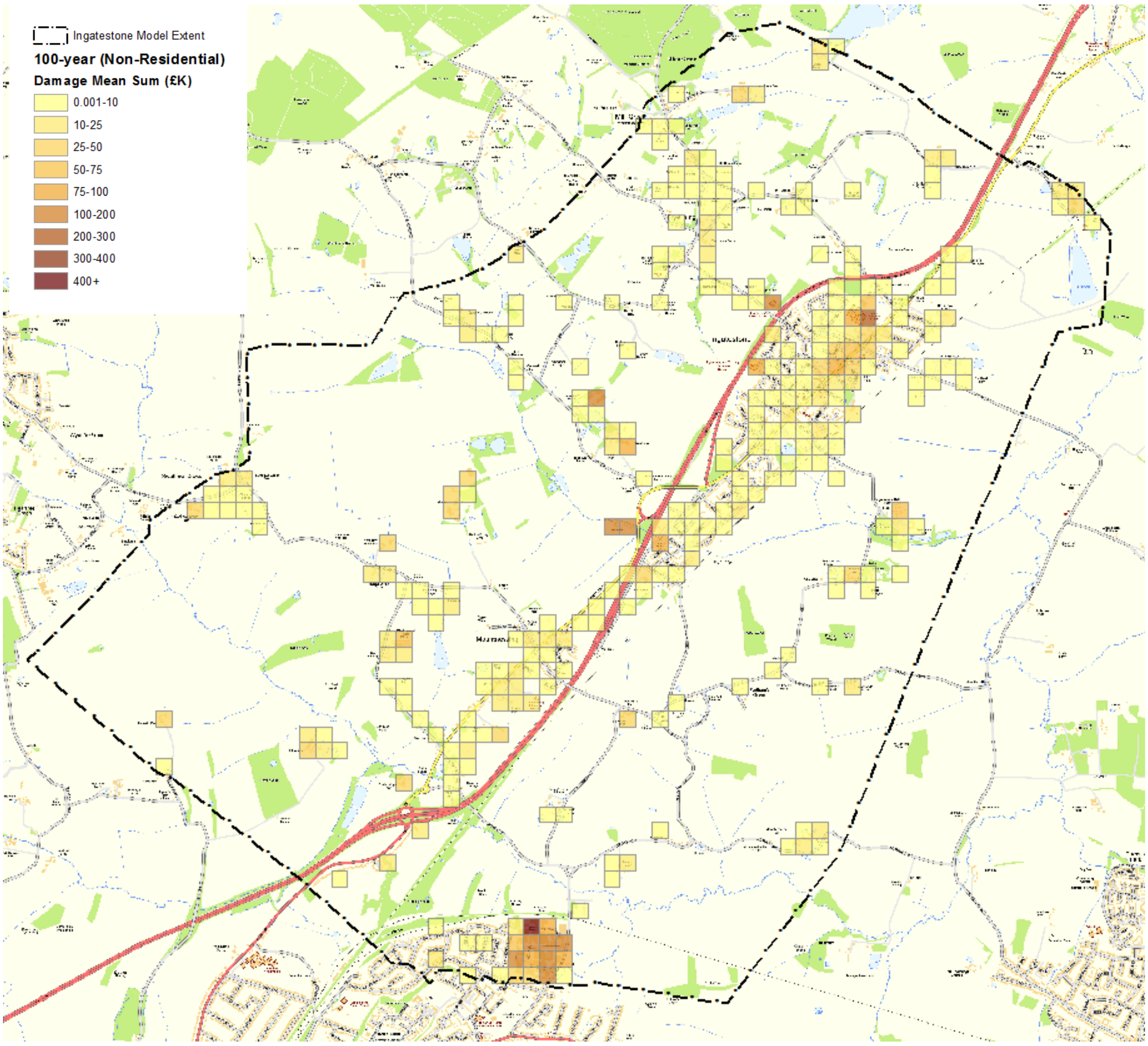


Figure 4-11 shows the mean aggregated flood damage (£K) for residential properties in the 100-year return period. The highest recorded costs for all return periods are found in North-East Ingatestone along the High Street. Cells in this location show an aggregated mean flood damage of £50,000 - £100,000. This appears consistent with the high concentration of commercial properties in the area. Overall the mean aggregated flood damage per cell is £16,000-£18,400 for all return periods.

Recommendations for Ingatestone

The results of the detailed modelling show a number of areas to flood to a significant level in all modelled return periods. These are shown in Figure 4-2 are discussed below.

Area INGATE-A includes the High Street which shows flooding in three main locations; Whadden Chase, Bellmead and The Furlongs. The representation of the watercourse at Whadden Chase and Bellmead may be improved with additional survey of the watercourse and this may refine the flood outline in this area. Flooding is shown to originate from an incomplete sewer dataset, this causes water to back up through the sewer system, the flood extent could also be improved in this area if improved sewer data were available from new survey.

Area INGATE-B represents the A12 where there was no data on the road drainage system of the by-pass. Also a watercourse near Ingatestone Primary School has estimated culvert geometry as survey information was not available. Both of these factors may contribute to an over estimation of flood risk in this location. It is recommended that details of the road drainage are collected as well as the culvert linked to the unnamed watercourse to allow the flood extents to be refined.

Area INGATE-C shows significant flooding originating from both fluvial and surface water sources. It is proposed that investigations should be conducted in to whether the land in and around the A12 could be used to locate Sustainable Drainage Systems (SUDS). SUDS could reduce the flow of water within the watercourse during flood events and reduce flood damage in the area. Implementation of SUDS could be explored to the North of this area with the aim of intercepting surface water flows that contribute to flooding.

Flooding at Poplar Close (Area INGATE-D) relates to a lack of capacity in the sewer network to deal with surface water. The sewer pipes downstream of Poplar Close are shown to have a diameter of 150mm with surrounding Poplar Close having a mixture of diameters ranging from 150 - 375mm. It is possible that due to the mixture of pipe diameters that the sewer data supplied is not representative of the true conditions. It is therefore recommended that further investigations are conducted to verify the pipe dimensions around this site. This information will allow flood risk to be assessed more accurately. If the dimensions do prove to be correct then it is recommended that the sewer network in this area is upsized to provide sufficient capacity.

The railway line (Area INGATE-E) is another area that is shown to flood and would therefore affect the transport infrastructure through Ingatestone. The current model results give an indication of the likely flooding if the current drainage system servicing the railway were to become blocked. It is recommended that until detailed information regarding the drainage of the railway can be provided the best course of action would be ensure the current drainage system remains effective with a program of regular maintenance and cleaning.

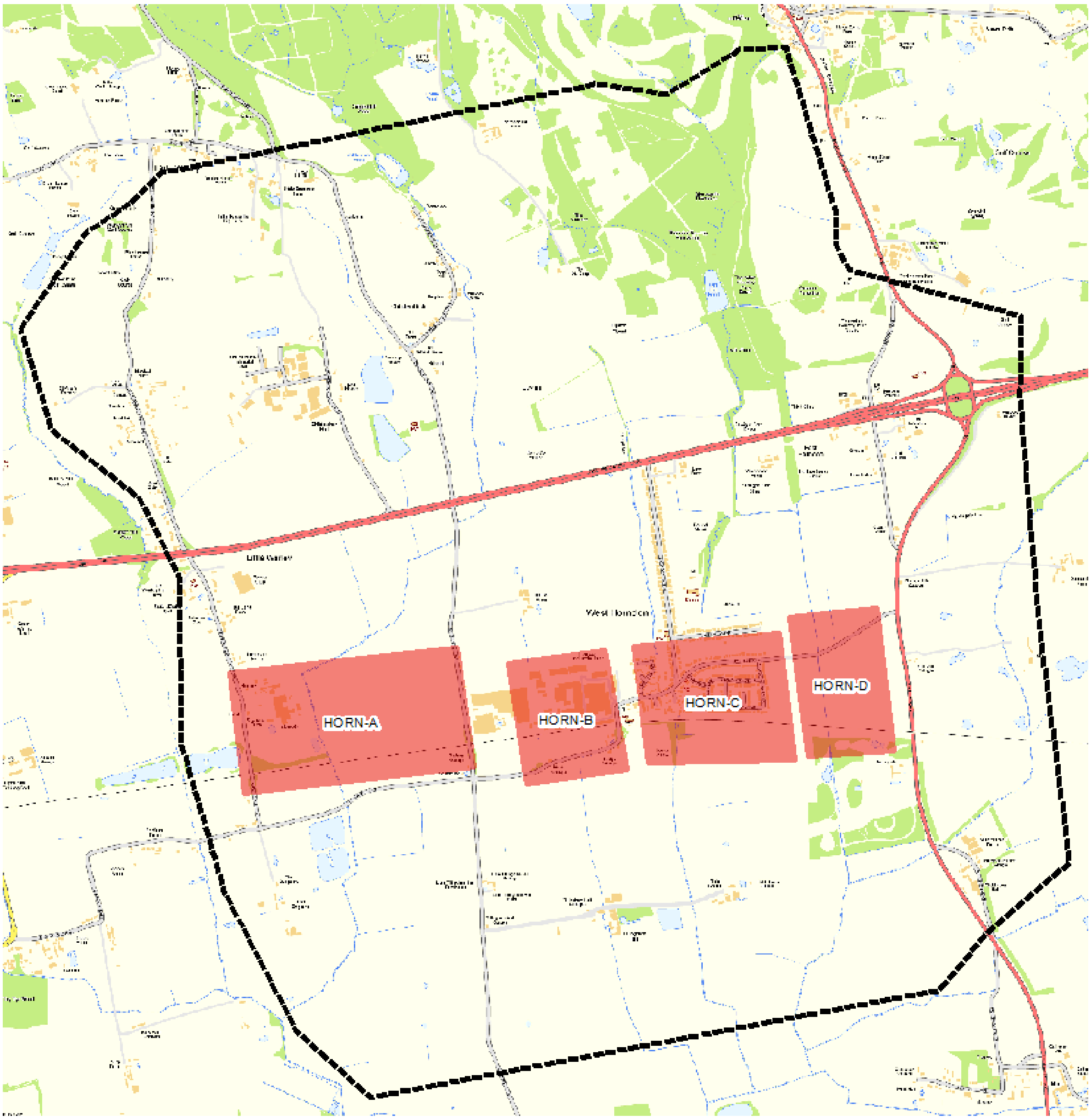
4.2.2 West Horndon

Overview of Flood Risk

The modelling results for West Horndon showing the predicted flood depths and hazard to people can be found in Appendix F.

To give an overview of flood risk a number of key flooding areas were identified. These are shown in Figure 4-12.

Figure 4-12: Key Areas within West Horndon

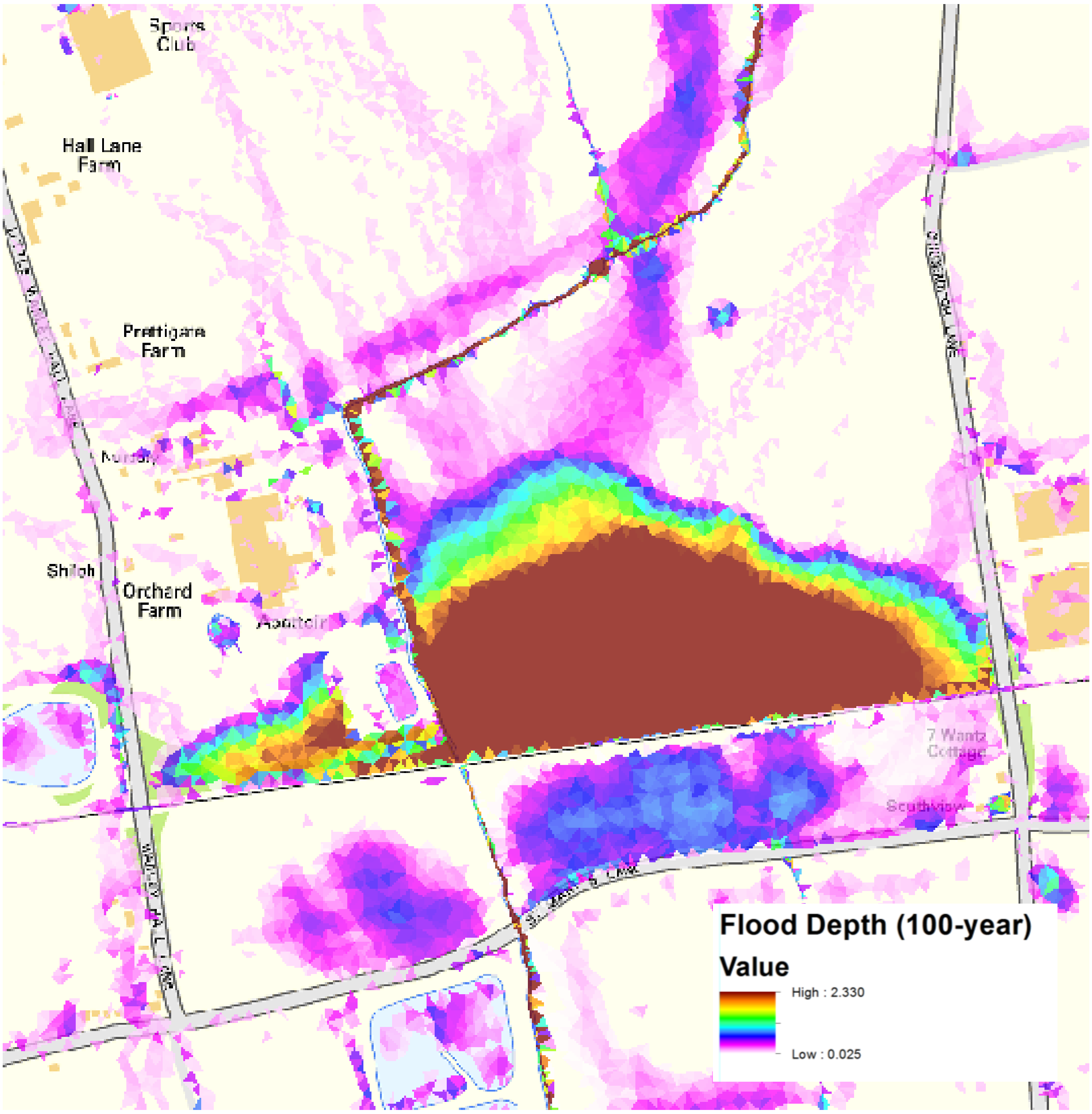


Contains Ordnance Survey data (c) Crown copyright and database right 2014

Area HORN-A

Figure 4-13 shows the flood depths for the 100-year return period in the vicinity of the HORN-A.

Figure 4-13: Flood Depth with HORN-A for the 100-year Return Period



Contains Ordnance Survey data (c) Crown copyright and database right 2014

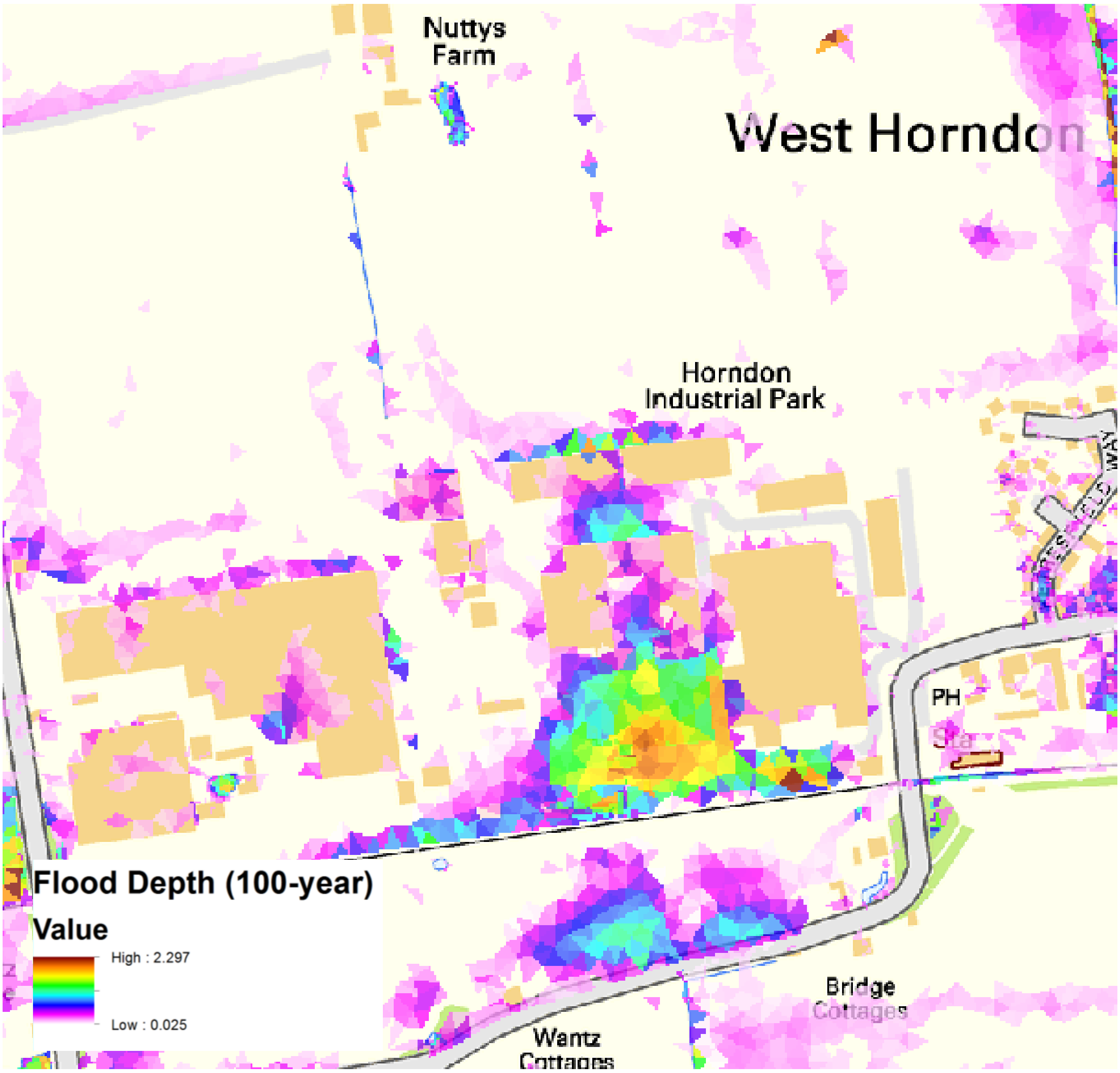
Flooding at this location originates from surface water pooling in an area of lower topography, with the railway embankment restricting flow. Flood depths at this location can be greater than 1m for all return periods where the water is ponding against the railway embankment. The culvert running through the railway embankment has significant capacity and does not surcharge. The cause of flooding relates to the broad scale nature in which the watercourses are represented within the model. Surface water originates from the unnamed watercourse to the north.

With regards to flood hazard to people, the areas of deep water are classed as “Danger for Most / Some” with the majority of contributing flow routes classed as “very low hazard”.

Area HORN-B

Figure 4-14 shows the flood depths for the 100-year return period in the vicinity of the HORN-B.

Figure 4-14: Flood Depth within HORN-B for the 100-year Return Period



Contains Ordnance Survey data (c) Crown copyright and database right 2014

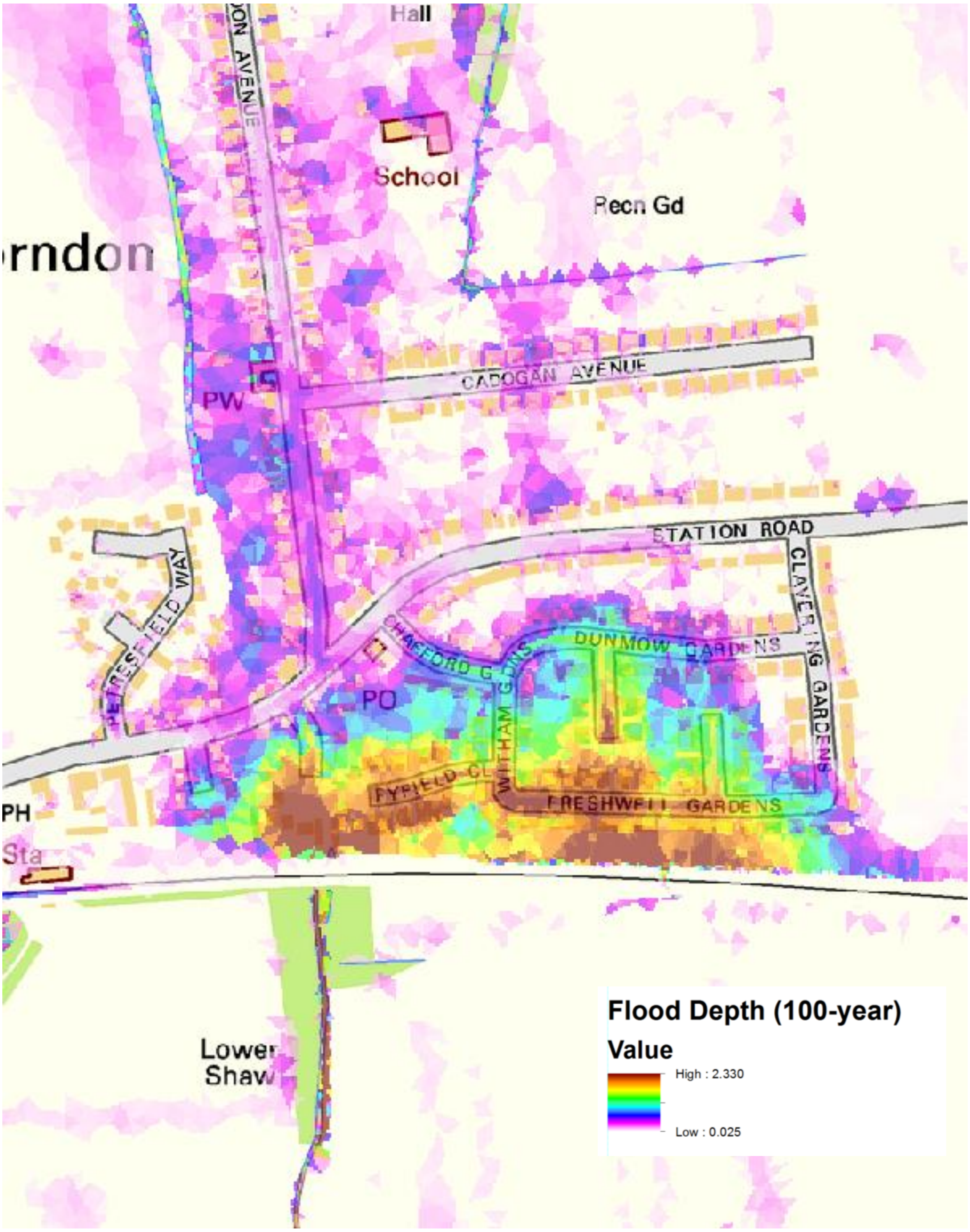
HORN-B consists mainly of industrial properties which form the Horndon Industrial Park. Maximum flood depths at this location are approximately 0.6m for all return periods and are found as water ponds against the railway embankment along the south of the industrial park. Flooding of this location is caused by surface water flows generated on farmland to the north following the natural topography.

In regards to hazard to people, the areas of deep water are classed as “Danger for Most / Some” with the majority of contributing flow routes classed as “very low hazard”.

Area HORN-C

Figure 4-15 shows the flood depths for the 100-year return period in the vicinity of the HORN-C.

Figure 4-15: Flood Depth within HORN-C for the 100-year Return Period

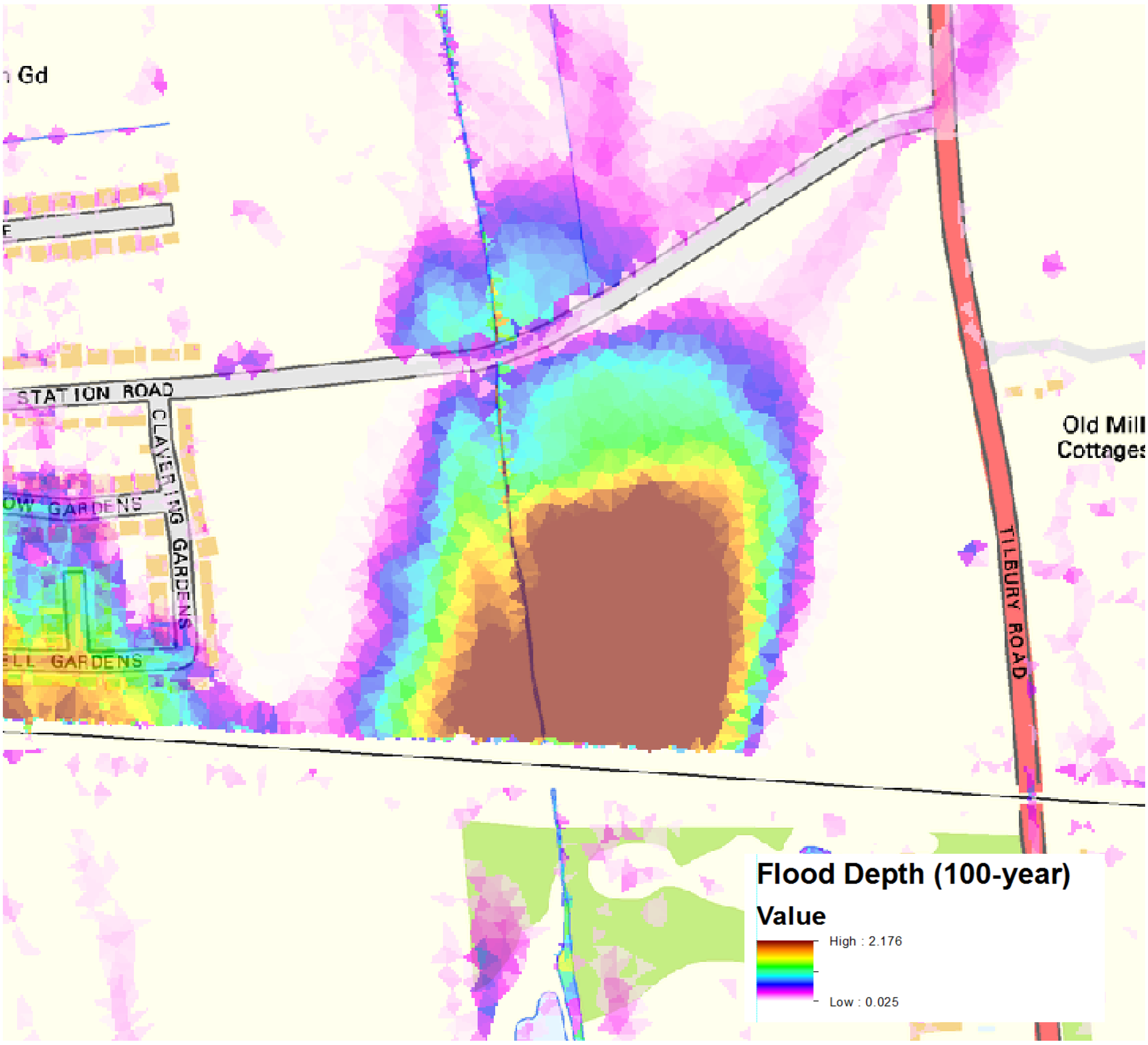


Flooding within West Horndon represents the main flood hotspot in the modelling extent due to the concentration of residential housing. Closer inspection of the model results show that within West Horndon the sewer network, which outfalls into an unnamed watercourse on the southern side of the railway embankment is surcharging. The outfall is an 825mm pipe however, the water within it is backing up and surcharging upstream with the sewer network. This is caused by the raised water level at the outfall which does not allow the water within the sewer to drain. Flooding is also contributed to by a watercourse that runs adjacent to Thorndon Avenue which overtops as it becomes culverted and generates surface flows towards West Horndon. The deepest flooding is located in the vicinity of Freshwell Gardens where water ponds against the railway embankment. At this location, flood depths range from 0.75 - 1.0m for all return periods. In regards to hazard to people, the areas of deep water in the vicinity of Freshwell Gardens are classed as "Danger for Most / Some" with the majority of contributing flow routes classed as "very low hazard".

Area HORN-D

Figure 4-16 shows the flood depths for the 100-year return period in the vicinity of the HORN-D.

Figure 4-16: Flood Depth within HORN-D for the 100-year Return Period



Deep flooding located within HORN-D is not related to either the culvert running through the railway embankment or under Station Road. Both culverts are sufficiently large to allow flow through them and do not reach capacity for any of the return periods. The flooding is caused by surface water generated north of Station Road, overtopping the road and flowing south. The board scale nature of the modelling in this case means that with additional survey data the watercourse could be represented more accurately, which will improve confidence in the flood outlines. Runoff follows the local topography falling towards the railway bank and ponding against it.

In regards to hazard to people, the areas of deep water are classed as "Danger for Most / Some" with the surrounding areas classed as "very low hazard".

Validation of Results

To validate the flood results comparisons have been made with the historic flood records (shown in Appendix B). In West Horndon there have been 5 historic flood events recorded; 3 relating to domestically caused incidents and 2 surface water related. The surface water related events were located in the vicinity of the A127 and A128 junction. These areas have experienced surface water flooding within the model. Validation of the modelling records is difficult based on the lack of accurate information and complicated interactions between surface water, the sewer network and local watercourses.

Overview of Existing Properties

To represent the number of properties flooded with each modelled return period Frism was run using 100m grid cells. Appendix I shows the number of properties flooded for each given return period. Appendix I also contains a graphical representation of the mean aggregated flood damages within each flooded 100m grid cell for each return period. Table 4-4 shows a summary of the number of properties that are at risk across the area for the modelled return periods. Table 4-5 shows the annualised average damages within the West Horndon model extent.

Table 4-4: Number of properties at risk of surface water flooding in West Horndon

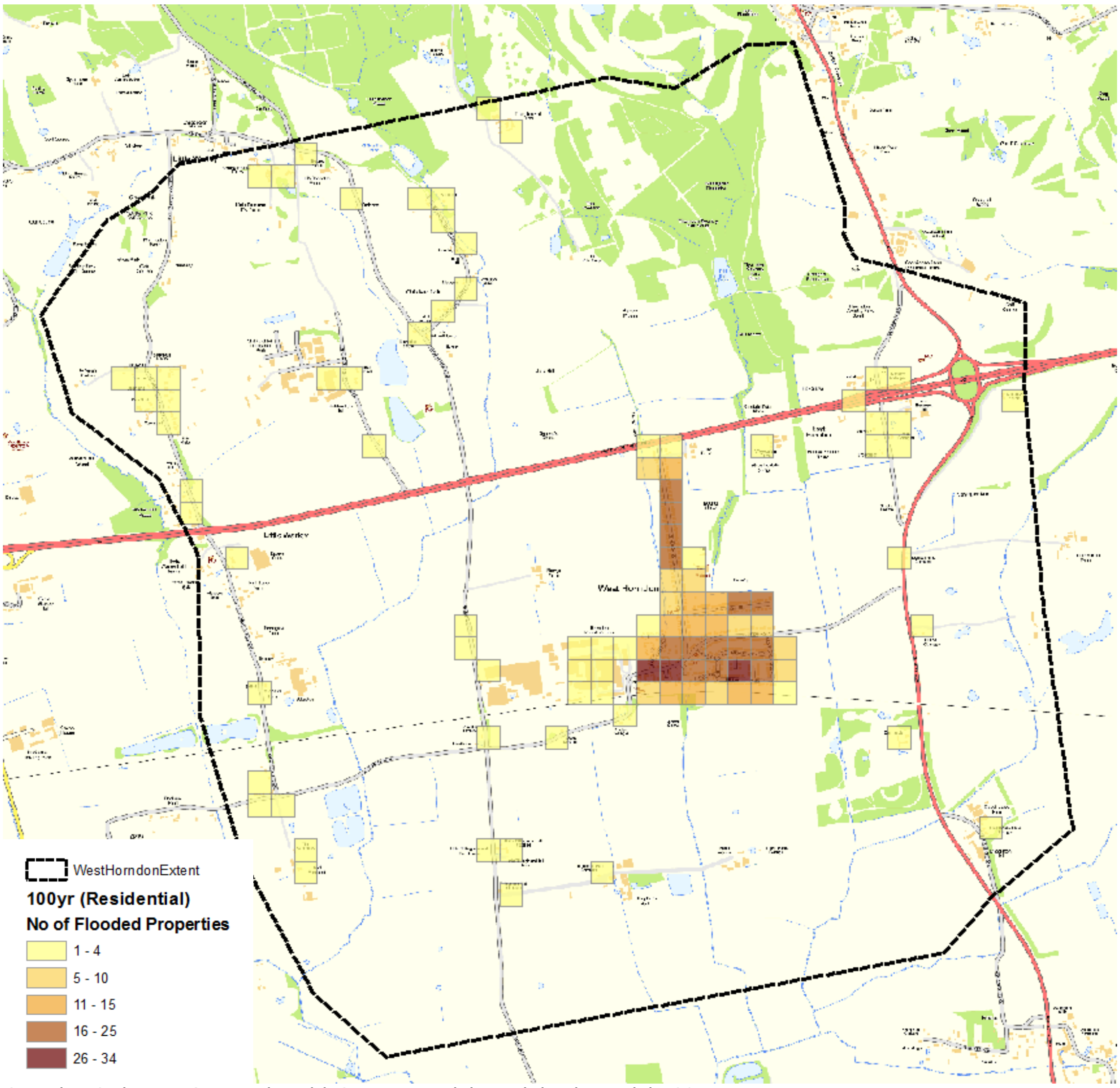
Return Period	Total number of Properties	Residential Properties at Risk	Non-Residential Properties at Risk	Number of People at Risk	Total Damage £M (Residential)	Total Damage £M (Non Residential)
30-year	1,416 (792 Residential & 624 Non Residential)	650	408	1,528	£11.78M	£6.84M
100-year	1,416 (792 Residential & 624 Non Residential)	721	448	1,694	£13.68M	£7.70M
100-year (plus Climate Change)	1,416 (792 Residential & 624 Non Residential)	723	450	1,699	£13.97M	£7.93M
200-year	1,416 (792 Residential & 624 Non Residential)	733	463	1,723	£14.62M	£8.53M
NOTE:the number of people at risk was based on the asusmption that the average number of people per residential property is 2.35.						

Table 4-5: Annualised Average Damage for West Horndon

Annualised Average Damage (£)	
Residential	**Non- Residential**
£3,190,061	£1,849,498

Number of Flooded Residential/Non-Residential Properties

Figure 4-17: Number of Flooded Residential Properties for the 100-year Event



Number of Flooded Residential/Non-Residential Properties

Figure 4-17 shows the number of flooded residential properties for the 100-year event. The largest concentration of flooded properties is centralised around West Horndon, in particular along the railway embankment which is where surface water appears to pond. The cells with the highest number of flooded properties coincide with the areas of deepest flood water (See Appendix F).

Figure 4-18: Number of Flooded Non-Residential Properties for the 100-year Event

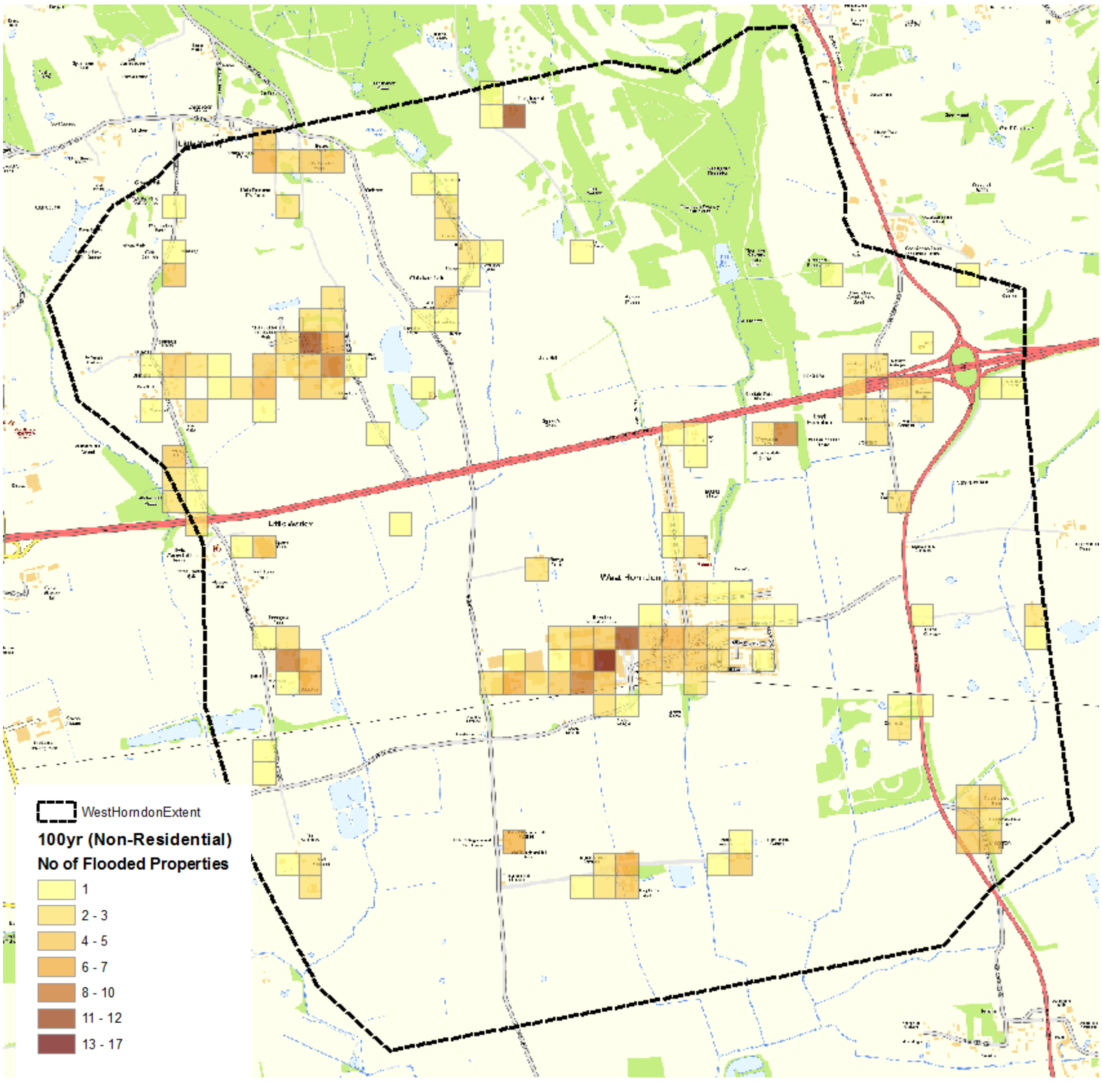


Figure 4-18 shows the number of flooded non residential properties for the 100-year event. The largest concentration of properties appears to be located at West Horndon (in particular the Horndon Industrial Park) and Childerditch Industrial Park (located in the north-west of the model extent). Other areas of flooded non-residential properties coincide mainly with the location of farms and other agricultural buildings.

Mean Flood Damage for Residential/Non-Residential Properties

With regards to the cost of flood damage Figure 4-19 and Figure 4-20 show the distribution of flooding damage costs within the West Horndon model for the 100-year event. Appendix I contains all mapping illustrating the distribution of mean flood damages for other modelled return periods in the West Horndon area.

Figure 4-19 shows the majority of the flood damage for residential properties which occurred in the 100-year event are centralised around West Horndon. The worst affected areas in West Horndon are in the vicinity of Freshwell Gardens where a residential development coincides with the deeper flood waters. The mean aggregated flood damages at this location are approximately £500,000 - £1,000,000. One 100m cell situated over Freshwell Gardens shows mean flood damages of approximately £1,300,000. For residential properties elsewhere mean flood costs are low (generally below £50,000 per 100m grid cell) due to the shallow nature of flooding and less densely packed settlements.

Figure 4-19: Mean Aggregated Flood Damage (£K) for Residential Properties with the 100-year Event

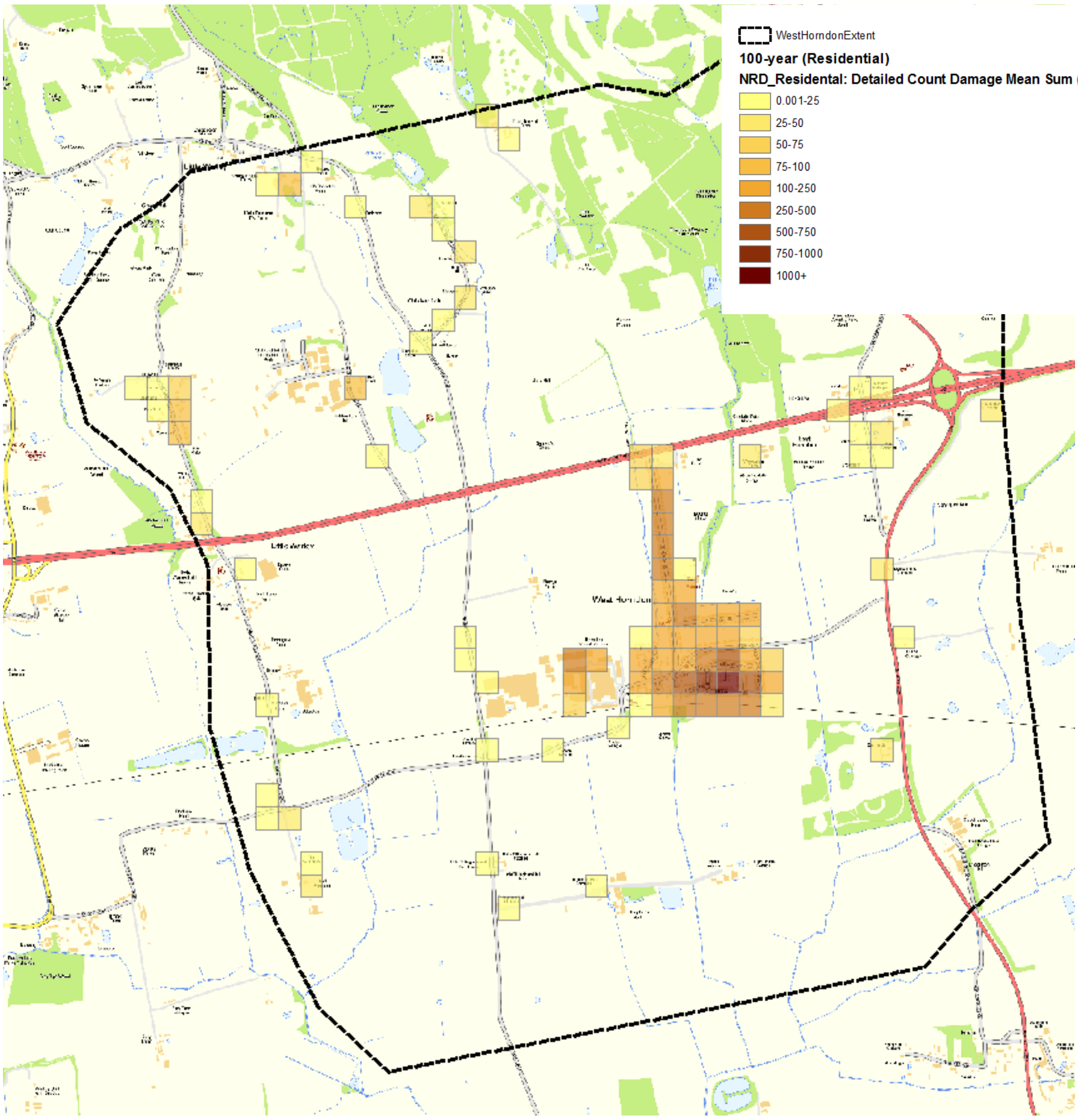
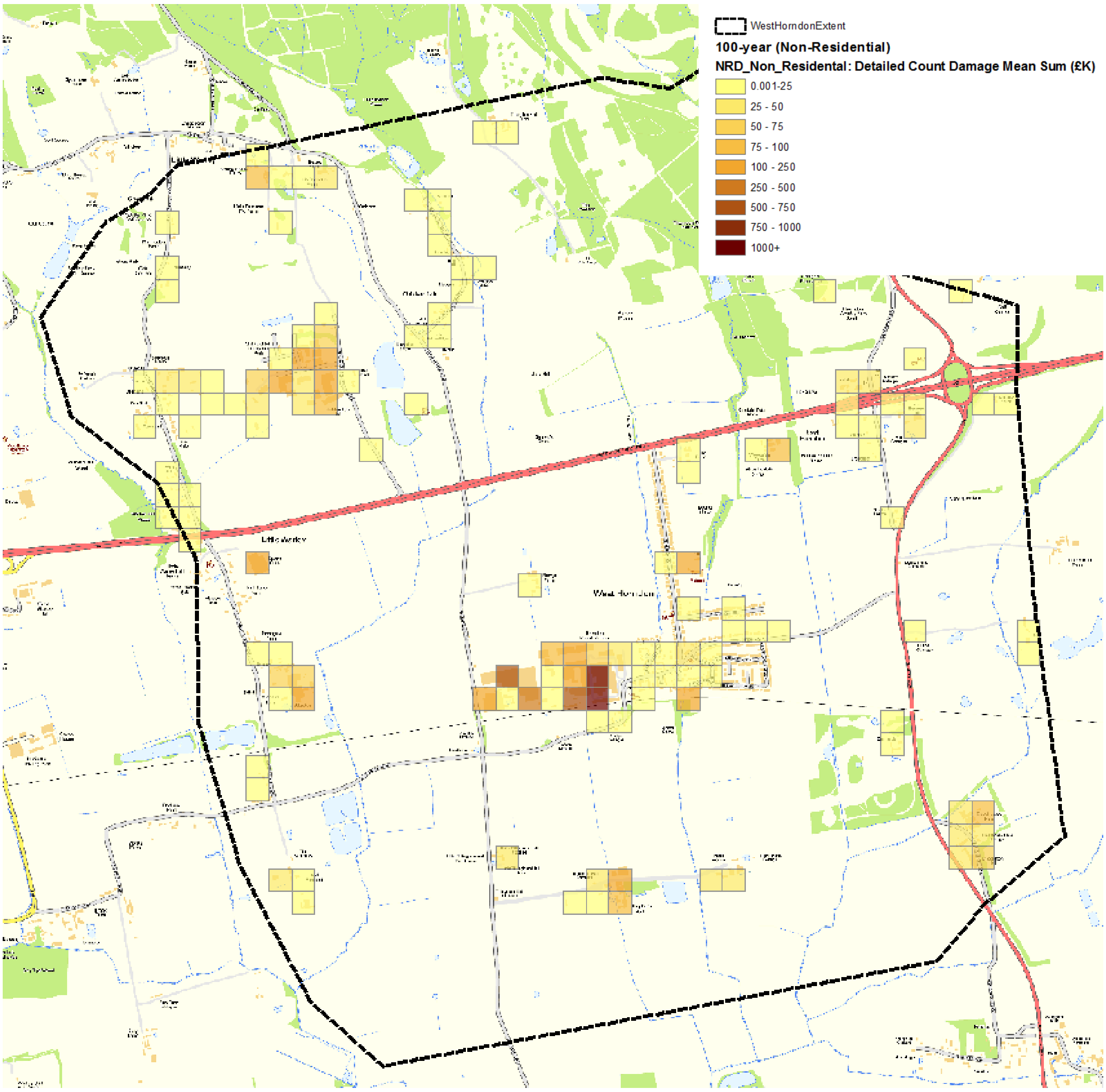


Figure 4-20 shows that the majority of the flood damages for non-residential properties which occur in the 100-year event are centralised around West Horndon. The highest mean damage costs are found in the vicinity of Horndon Industrial Park and Childerditch Industrial Park. These are the only two major concentrations of industrial buildings within the model area with other non-residential properties consisting of small concentrations of agricultural or leisure facilities. The highest average flood damages are located at Horndon Industrial Park with two cells having mean damage costs greater than £1,000,000 for the 100-year event. This coincides with high flood depths relating to surface water ponding against the railway embankment. Mean damage costs at Childerditch Industrial Park are significantly lower (approximately £140,000 per cell) due to the shallower flood depths.

Figure 4-20: Mean Aggregated Flood Damage (£K) for Non-Residential Properties with the 100-year Event



Recommendations for West Horndon

Based on the results of the modelling four areas are shown to flood to a significant depth in all return periods. These areas are highlighted in Figure 4-12. HORN-A represents an area that is mainly Greenfield; flooding may be exacerbated in this area as the watercourses are coarsely modelled using 2D techniques. It is not proposed to provide optioneering for this location, rather it is recommended that survey of the watercourse is commissioned and included in the existing model to improve understanding of flood risk in this area.

HORN-B represents an area which, similar to HORN A, suffers from a lack of detailed survey data, in this case no data was available for the sewer network at the industrial estate, allowing water to build up in this area. However, there are a number of possible optioneering options available including the creation of a channel to intercept surface water from fields to the north and improving conveyance by creating a culvert through the railway embankment discharging to a local watercourse as a means of removing water from the area.

HORN-C represents where flooding has the largest impact on residential properties. Analysis of model results showed that the sewer network was surcharging due to water backing up within the system caused by water levels in the watercourse to which the sewer discharges. Watercourses have been modelled using 2D modelling techniques within the InfoWorks model and therefore do not provide a detailed representation of channel capacity. It is recommended that following this study more detailed modelling is undertaken to assess the interactions with the watercourse and sewer network before recommending suitable mitigation options. Possible optioneering could involve improving conveyance by the upsizing of the sewer network and providing better interaction between outfalls and the receiving watercourses.

HORN-D represents an area that is predominantly rural. Site visits have shown that the culvert at Station Road can become significantly blocked meaning that despite there being no survey data for the watercourse the modelled results are likely to show realistic flow paths. Proposed optioneering could consider improving the conveyance of flow through the culvert at Station Road, with water allowed to pond in the fields to the south. This would aim to reduce flooding across the road allowing access to West Horndon.

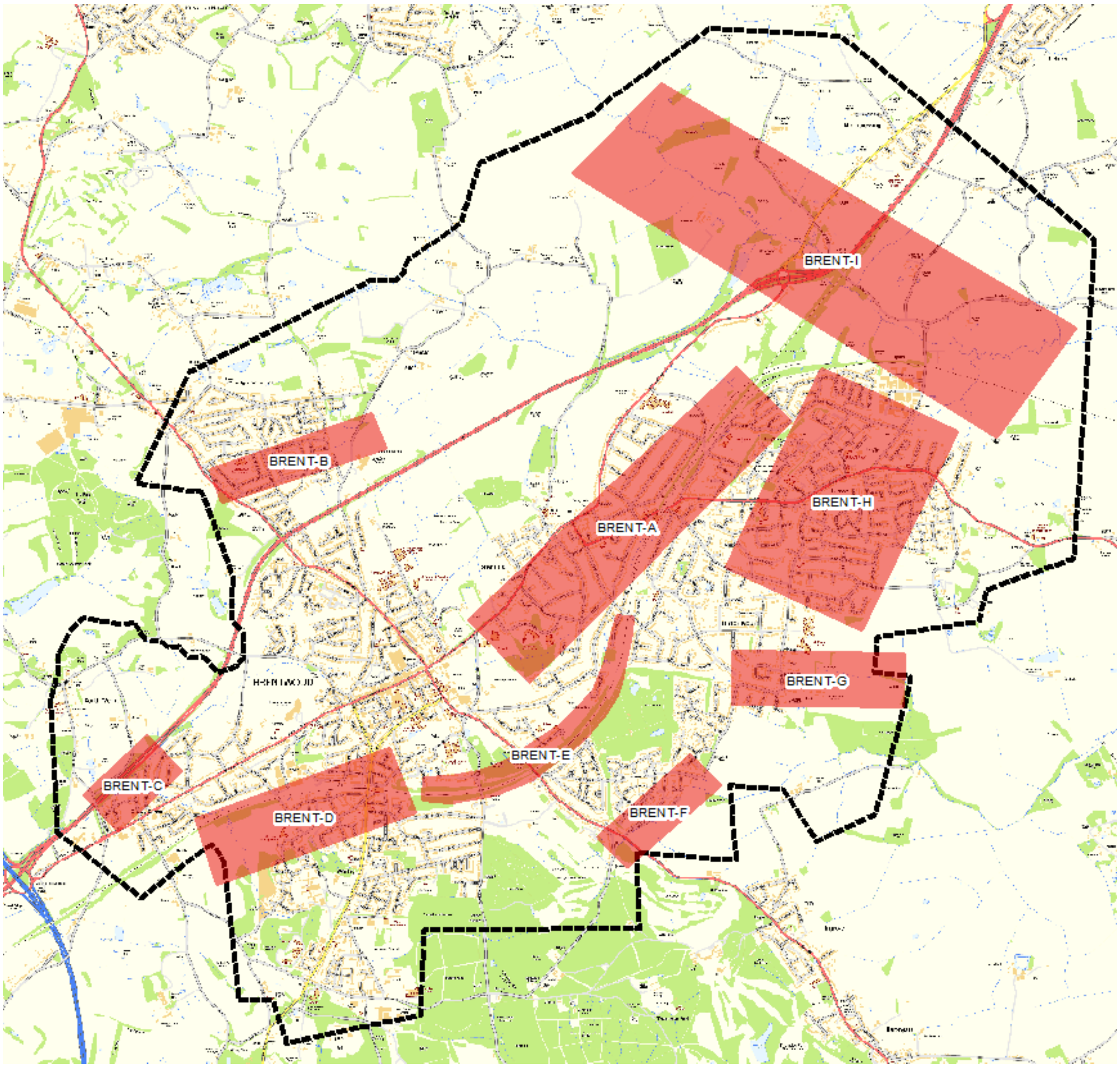
4.2.3 Brentwood Town, Hutton & Thrift Green

Overview of Flood Risk

The modelling results for Brentwood Town, Hutton and Thrift Green showing the predicted flood depths and hazard to people can be found in Appendix G.

To provide an overview flood risk, a number of key flooding areas were identified. These are shown in Figure 4-21.

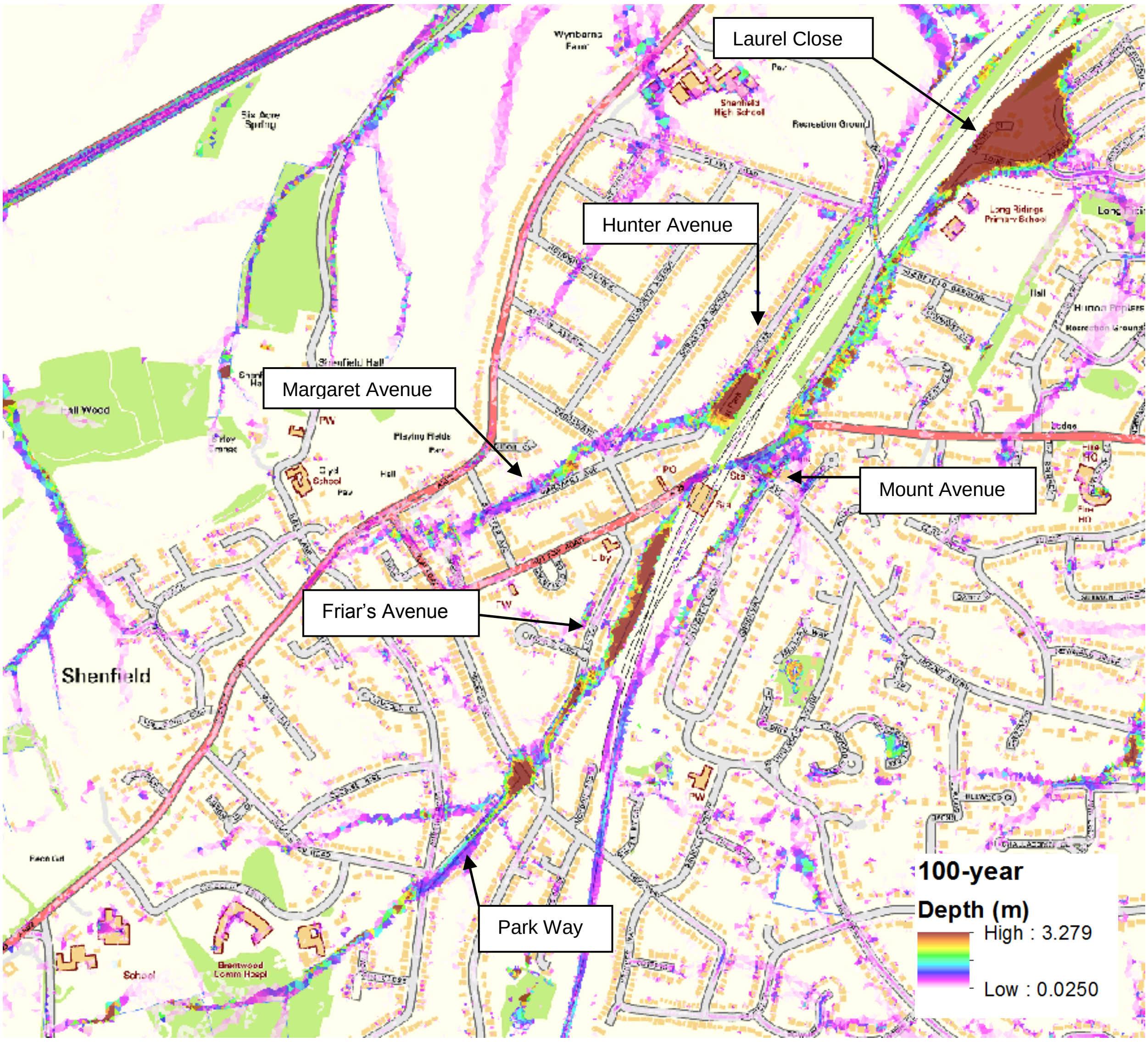
Figure 4-21: Key Areas of Flooding in Brentwood



Area BRENT-A

Figure 4-22 shows the 100-year flood depths in the vicinity of BRENT-A as shown by Figure 4-21.

Figure 4-22: 100-year Flood Depth in the Vicinity of Area A



The largest and deepest flood extent is located adjacent to Laurel Close. Surface water at this location ponds in a depression in the topography and against the railway embankment. The origins of the surface water flow can be traced approximately 2.2km south west to a watercourse flowing in a north east direction towards Park Way. At this location the watercourse overtops the culvert entrance linking it to the sewer system and proceeds to flow along Park Way. At the end of Park Way the water surcharges the sewer network with water pooling at the junction with Priest Lane. At this location the maximum flood depth is approximately 0.7-1.0m for all return periods. Water continues to surcharge the sewer network, following the topography until it rejoins the open channel watercourse opposite of Friar's Avenue. At the end of Friars Avenue water fills the culvert that flows under the railway to capacity generating further overland flow towards Mount Avenue. Further surface water is generated by inflows to sewers surcharging. The surface water follows the topography and short existing watercourses along the eastern side of the railway embankment towards Laurel Close.

The hazard for people rating for Laurel Close is mainly "Danger for Most" although return periods greater than 30-year show areas classed as "Danger for All" against the embankment. Other areas of flooding show mainly "Danger for Some/Most" although the 200-year event has areas of "Danger for All" along Park Way and Friar's Avenue.

On the western side of the railway embankment the most notable area of flooding is at Hunter Avenue, with maximum flood depths of approximately 1.0 – 1.3m for all return periods. The flooding originates from the west, along Margaret Avenue, with rainfall falling and following an overland flow route before pooling in a low spot on Hunter Avenue. Again the railway embankment prevents the water from escaping. The hazard to people rating for all return periods at this location is classed as "Danger for Most"

The key drivers of flooding in this area are culverts being overtopped by increased flow in the channels, causing the sewer network to surcharge in certain locations. In some locations such as the culvert upstream of Park Way the dimensions of culverts were uncertain and would benefit from further investigation. However, the modelling does give an insight into possible overland flow routes if the culverts were to become partially blocked. Surface water flow is dictated by the topography with the railway embankment providing areas in which surface water can become trapped and pool.

There are limited historic flood events to validate these results against however; there are records of fluvial, surface water and unknown flooding in the vicinity of Park Way and Friar's Avenue, which give confidence in the model results.

Area BRENT- B

Figure 4-23 shows the 100-year flood depths in the vicinity of BRENT-B as shown by Figure 4-21.

Figure 4-23: 100-year Flood Depth in the Vicinity of Area B

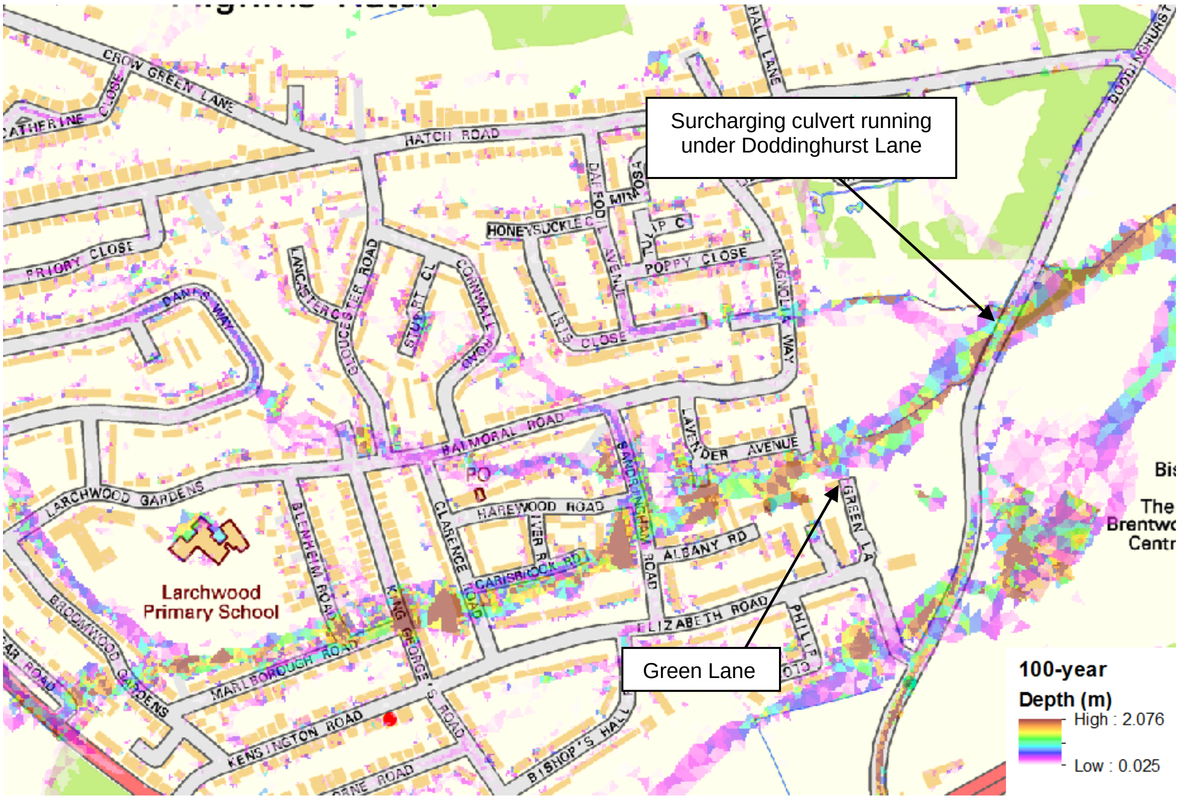
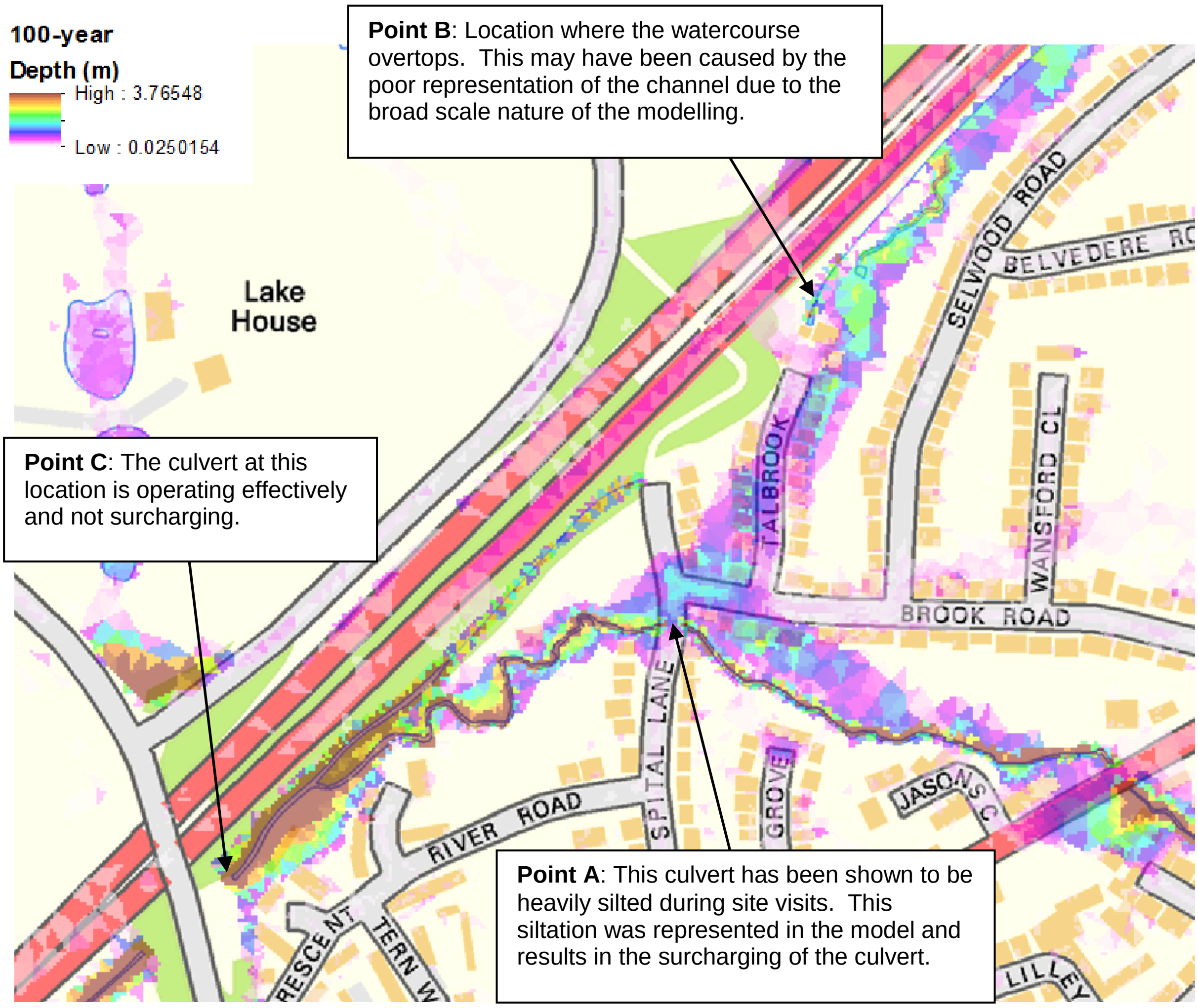


Figure 4-23 shows the flooding of the residential area south of Pilgrims Hatch, north of the A12. Maximum flood depths are approximately 0.7-1.0m for all return periods. Throughout this area the majority of the sewer network is shown not to surcharge with the likely cause of flooding being surface water following the natural topography and not entering the sewer network. This flooding may be a conservative estimate of flood risk, with the interaction between housing and the sewer network not effectively represented due to the broad scale nature of the modelling approach. This is consistent with the historic records which show only one reported flood record for this area which is of unknown cause. There are only two locations in the area where sewers surcharge. The first is on Green Lane where a number of 450mm pipes join the main 600mm sewer leading to a lack of capacity. The second location is at the culvert under Doddinghurst Lane. Both these culverts are potential candidates for upsizing. The modelling does show possible flow routes through the area which could be at risk from surface water flooding.

Area BRENT-C

Figure 4-24 shows the 100-year flood depths in the vicinity of BRENT-C as shown by Figure 4-21

Figure 4-24: 100-year Flood Depth in the Vicinity of Area C



Contains Ordnance Survey data (c) Crown copyright and database right 2014

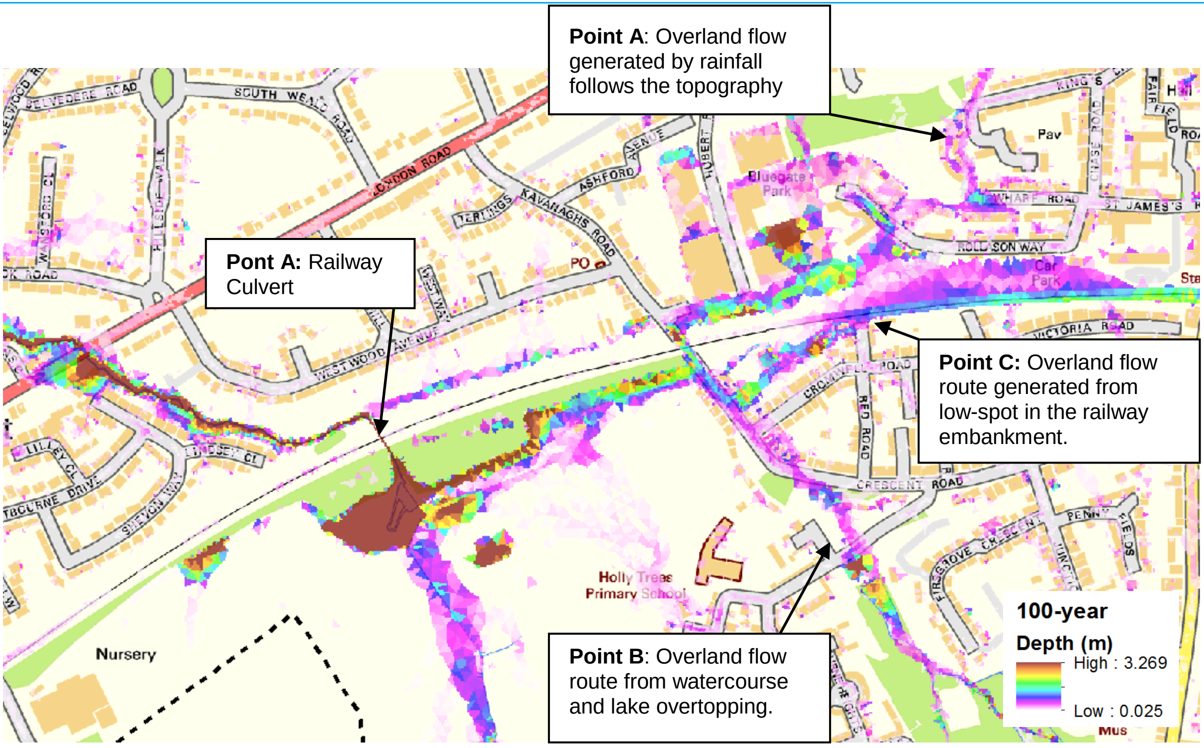
Flood water originates from two points with the BRENT-C. The first point (Point A) is from the overtopping of the Spital Lane culvert. This culvert during site visits was flagged as suffering from excessive siltation and was therefore modelled with an allowance for this. The reduction in capacity caused by siltation causes water to back up upstream of the culvert as well as overtopping of Spital Lane. The second point is located north of Talbrook (Point B) where an unnamed watercourse is poorly represented due to a lack of survey data for the watercourse. Water flows out of the channel and down Talbrook, joining the other flow route at Spital Lane. Further downstream (Point C), the Wigley Bush Avenue culvert appears to be functioning effectively and does not surcharge.

In regards to hazard to people, the overland flow routes are classed as “Danger for Most/Some” in all return periods with the watercourses been shown as areas that are classed as “Danger for All”.

Area BRENT-D

Figure 4-25 shows the 100-year flood depths in the vicinity of BRENT-D as shown by Figure 4-21.

Figure 4-25: 100-year Flood Depth in the Vicinity of Area D



Contains Ordnance Survey data (c) Crown copyright and database right 2014

Figure 4-25 highlights a build up of water behind the railway embankment (Point A). Maximum flood depths are more than 1m for all return periods. Although the culvert through the embankment was represented, no surveyed dimensions were provided. The modelling provides the best representation based on the limited data. It is likely that the culvert allows significantly more flow through the railway embankment. However, the modelling does highlight potential areas that could be affected if the culvert is blocked. It also highlights overland flow routes that contribute to this area. The first is from the overtopping of a watercourse/lake located in Warley, south east of the railway culvert (Point B). Surface water flows down Crescent Road before being diverted by the railway embankment and heading towards the railway culvert. The second overland flow route originates from the railway where a low spot in the embankment allows water to flow from the railway in a westerly direction (Point C). The third flow route is in the vicinity of Downsland Drive with water flowing south, joining the flows from the railway (Point D). This flow is related to the incomplete / poor representation of sewer data in the area which is not collecting surface water in the sewer network.

In regards to hazard to people, area of deep water south of the railway culvert and east along the embankment is classed "Danger for Most" with "Danger for All" at areas of deeper water for all return periods. Flow routes from the railway embankment and Crescent Road are mainly classed as "Very low hazard" with areas of "Danger for Some/Most".

Area BRENT-E

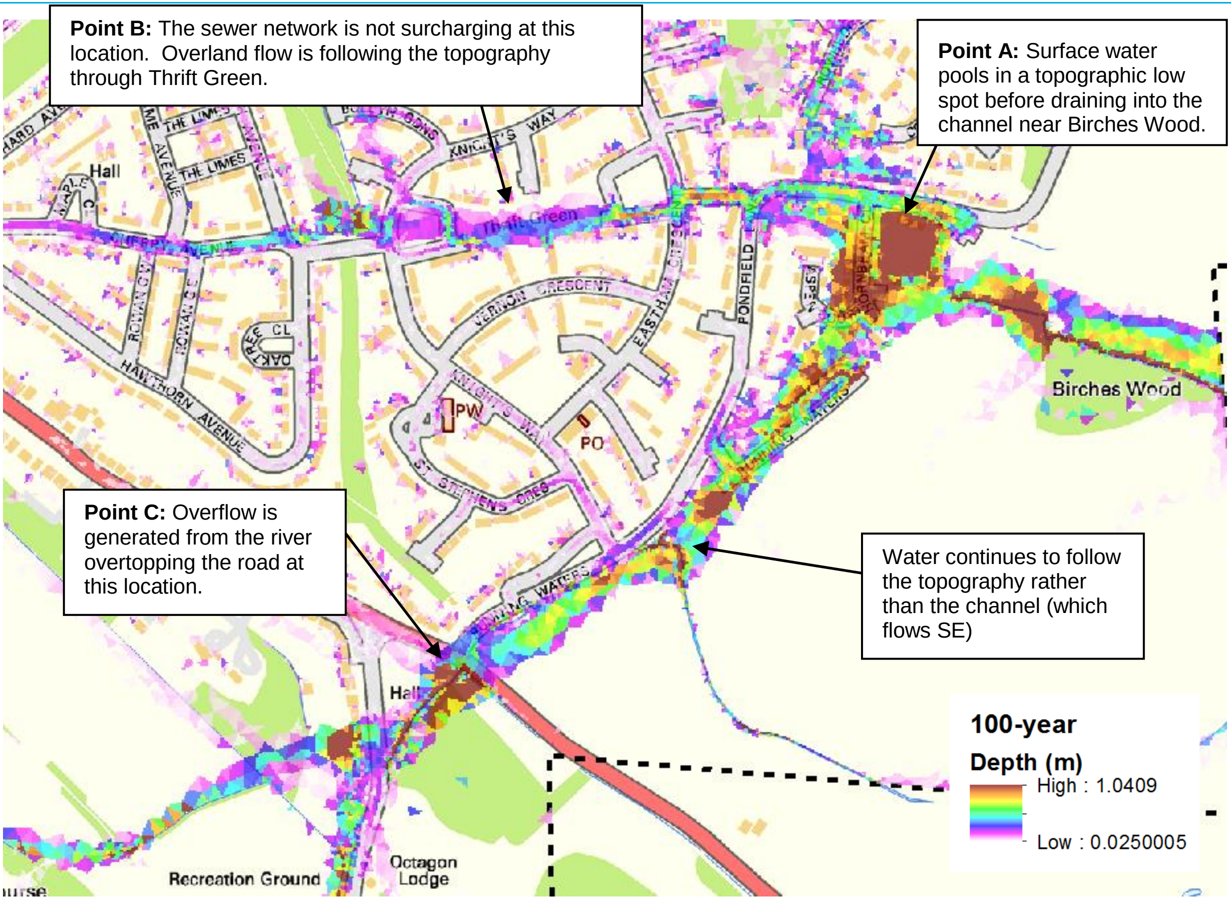
The railway line is shown to flood for all return periods. Flooding extends from Shenfield Station to Brentwood Station. Between these locations maximum flood depths are between approximately 0.1-0.2m for all return periods. Isolated areas of higher depths being found at locations were roads cross the railway causing constrictions. Surface water spills from the railway at two locations along the line, within the car parks of both stations. The surface water at both locations follows the topography joining with other surface water flows. Unfortunately no drainage network information was supplied for the railway, therefore the modelled flooding may be a conservative estimate of current flood risk. If more information becomes available in the future the modelling should be revisited to improve understanding of flood risk in the area. The modelling does however show the possible flood routes and areas at risk if the railway drainage were to become blocked.

With regards to hazard to people, the majority of the flooded railway shows the classification of "Danger for Some/Most" for all return periods. For the 100-year plus climate change and 200-year scenarios Brentwood Stations shows areas of "Danger for All" that relate to deep areas of surface water.

Area BRENT- F

Figure 4-26 shows the 100-year flood depths in the vicinity of BRENT-F as shown by Figure 4-21.

Figure 4-26: 100-year Flood Depth in the Vicinity of Area F



Contains Ordnance Survey data (c) Crown copyright and database right 2014

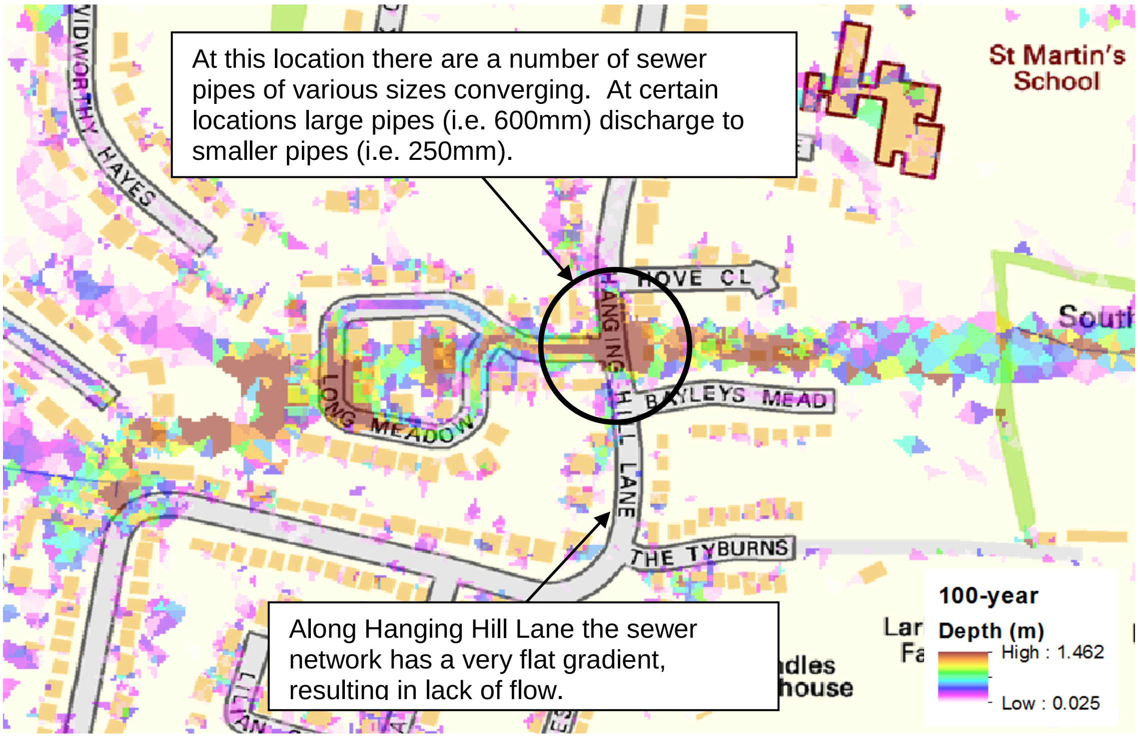
Flood water at this location pools in a low spot adjacent to Hornbeam Close (Point A). Maximum flood depths at this location are approximately 0.7-1.0m for all return periods. Surface water contributes to this area from the west along Thrift Green and south-west along Running Waters (Point B). Sewers in this location are shown not to be surcharging even though there is surface water flooding. Similarly to BRENT-B surface water is shown to follow existing topography. The flows along Running Waters originate from the high water levels in the adjacent watercourses and overtopping of the culvert under Ingrave Road (Point C). Although this shows flooding this is likely to be a conservative estimate of current flood risk due to uncertainties in data sets and model representation in this area. There are few historic flood records available for this area. If improved survey data for the sewers and watercourses becomes available the models could be re-run and understanding of flood risk in the area could be improved, however, the current modelling does show possible flow routes and areas which could be at risk from surface water flooding.

In regards to hazard to people, the discussed flow routes show the classification of "Danger for Some" with "Danger for Most" at areas of deeper water for all return periods. The area of pooling on Hornbeam Close is classed as "Danger for Most" for all return periods.

Area BRENT-G

Figure 4-27 shows the 100-year flood depths in the vicinity of BRENT-G as shown by Figure 4-21.

Figure 4-27: 100-year Flood Depth in the Vicinity of Area G



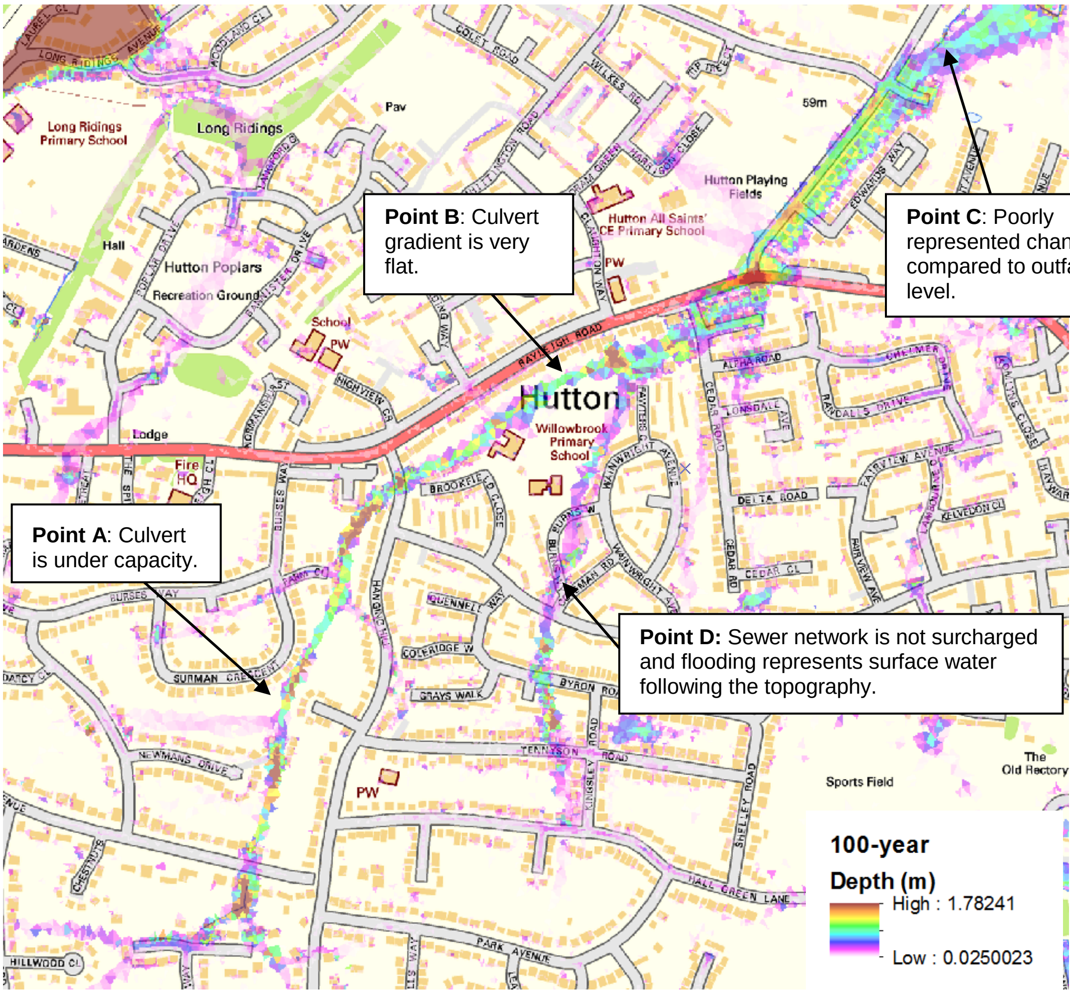
Flooding at this location originates from the lack of capacity and gradient within the sewer network. Along Hanging Hill Lane, the sewer is shown to have a very flat gradient, encouraging water to pond within the sewage network, surcharging onto Hanging Hill Lane. Also at this location there is a number of sewer pipes that appear to be undersized compared to the pipes up and downstream. This lack of capacity within the sewer causes the water to back up within the network surcharging at various points. The majority of the flooding in the area is shallow with the deepest patch being located at the junction of Long Meadow and Hanging Hill Lane. Surface water appears to follow the natural topography from this location towards the unnamed watercourse to the east.

In regards to hazard to people, the majority of the area is classed as "very low hazard" with only areas of deeper flooding (i.e. Hanging Hill Lane) being classed as "Danger for Most" for all return periods."

Area BRENT-H

Figure 4-28 shows the 100-year flood depths in the vicinity of BRENT-H as shown by Figure 4-21.

Figure 4-28:'100-year Flood Depth in the Vicinity of Area H



Contains Ordnance Survey data (c) Crown copyright and database right 2014

Figure 4-28 highlights four areas of flooding within the Hutton district. Point A is the location of a section of the sewer network (adjacent to Surman Crescent) which is under capacity and cannot convey a sufficient volume of surface water. A number of other sewer networks from the surrounding area feed into to the undersized pipe at this location, causing water to surcharge. The resulting surface water then flows north, following the natural topography. This would be a suitable location to consider upsizing the sewer network to handle larger volumes.

Point B is the location of a section of pipe which has a very shallow gradient. The lack of gradient allows water to build up and surcharge at this point. Surface water then flows north-east along Wash Road/Edwards Way. There is potential to re-grade the sewer network to provide more of a slope, promoting increased flow. Point C represents the location where the sewer network interacts with the local watercourse. Due to poor LIDAR representation the stream levels are uncertain, compromising the interaction between the sewer outfall and the receiving watercourse. This causes water to back up and surcharge in the cul-de-sac at the end of Edwards Way. Point D represents a surface water flow route starting at Kingsley Road and meeting the flow routes discussed in Points A and B to the north east of Willowbrook Primary School. The sewer network is not surcharging along the length of the flooded area and it therefore represents where rainfall is following the natural topography.

Historic flood records would normally be used to confirm the likelihood of flooding. Unfortunately there are few records available with only one record of surface water flooding along Hanging Hill, adjacent to one of the modelled flow routes was available. There is also a fluvial flood record at Wash Road/Edwards Way which ties in the flood results.

In regards to hazard to people, the discussed flow routes show the classification of "Danger for Some" with "Danger for Most" at areas of deeper water for all return periods.

Area BRENT-I

BRENT I consists of the River Wid and the A12 junction located north east of Brentwood. This area is shown to flood significantly during all return periods. The results from the modelling relate well to the Environment Agency's Flood Zone outlines with similar extents being shown from the new modelling. Although the area has few properties, the A12 is a key road link between Brentwood and Ingatestone and is shown to flood for all return periods. The likely cause of flooding is insufficient capacity within culverts passing underneath the A12. This area would be a primary candidate for optioneering to reduce flooding.

Risk to Existing Properties

To represent the number of properties flooded with each modelled return period Frism was run using 100m grid cells. Appendix J displays the number of properties flooded for each given return period as well as a graphical representation of the mean sum of damage within each flooded 100m grid cell for each return period. Table 4-6 shows a summary of the number of properties that are at risk across the sub-catchment for the modelled return periods. Table 4-7 shows the annualised average damage within the Ingatestone model extent

Table 4-6: Number of properties at risk of surface water flooding in Brentwood Town, Hutton and Thrift Green

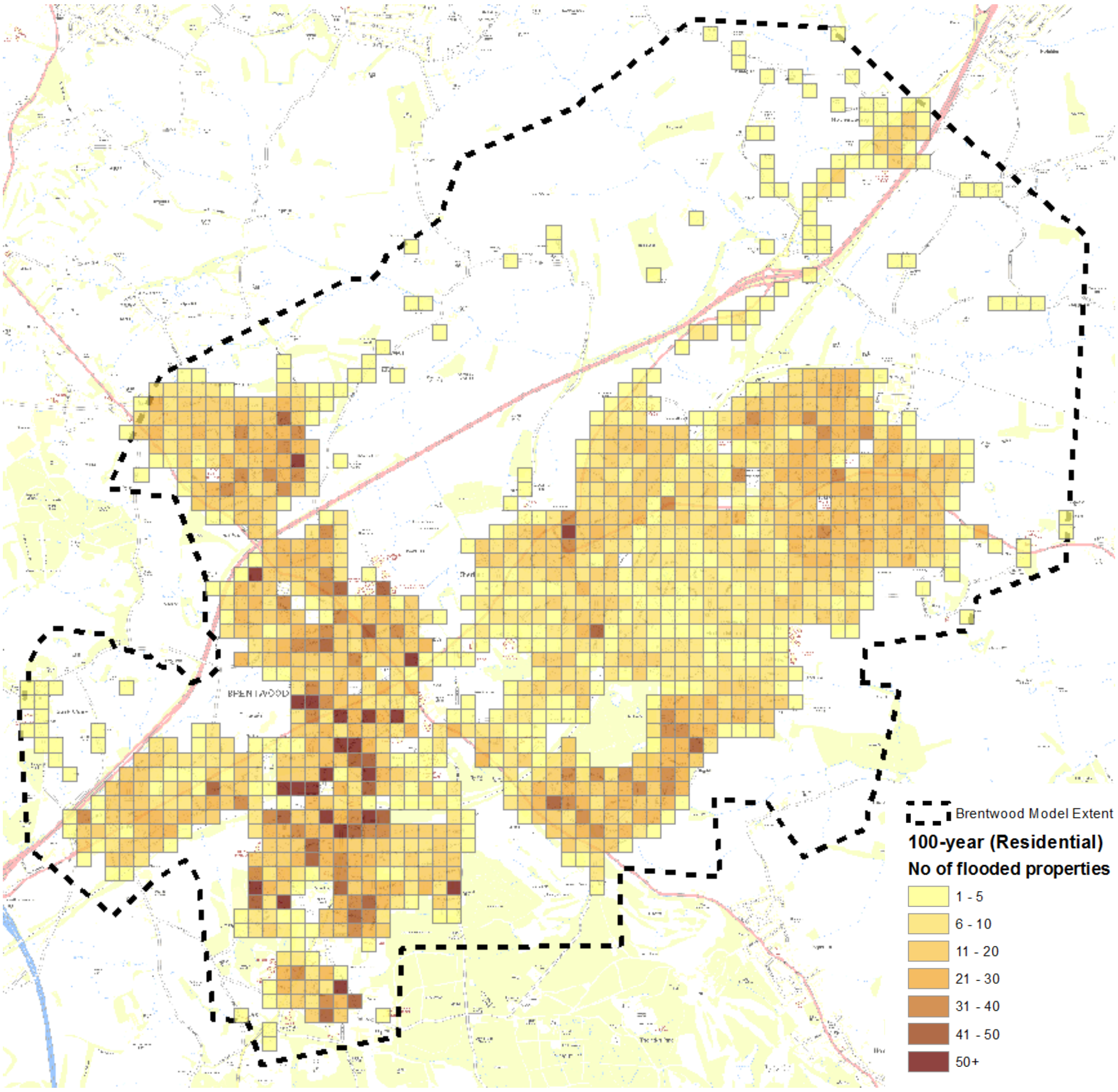
Return Period	Total number of Properties	Residential Properties at Risk	Non-Residential Properties at Risk	Number of People at Risk	Total Damage £M (Residential)	Total Damage £M (Non Residential)
30-year	27,039 (23,373 Residential & 3,666 Non Residential)	16,584	2,311	38,972	£142.68M	£21.39M
100-year	27,039 (23,373 Residential & 3,666 Non Residential)	18,564	2,650	43,625	£170.23M	£23.68M
100-year (plus Climate Change)	27,039 (23,373 Residential & 3,666 Non Residential)	18,883	2,697	44,375	£175.41M	£24.60M
200-year	27,039 (23,373 Residential & 3,666 Non Residential)	19,737	2,847	46,382	£188.75M	£26.30M
NOTE:the number of people at risk was based onthe asusmption that the average number of people per residential property is 2.35.						

Table 4-7: Annualised Average Damage for Brentwood Town, Hutton and Thrift Green

Annualised Average Damage (£)	
Residential	**Non- Residential**
£38,784,876	£5,773,720

Number of Flooded Residential/Non-Residential Properties

Figure 4-29: Number of Flooded Residential Properties for the 100-year Event in Brentwood



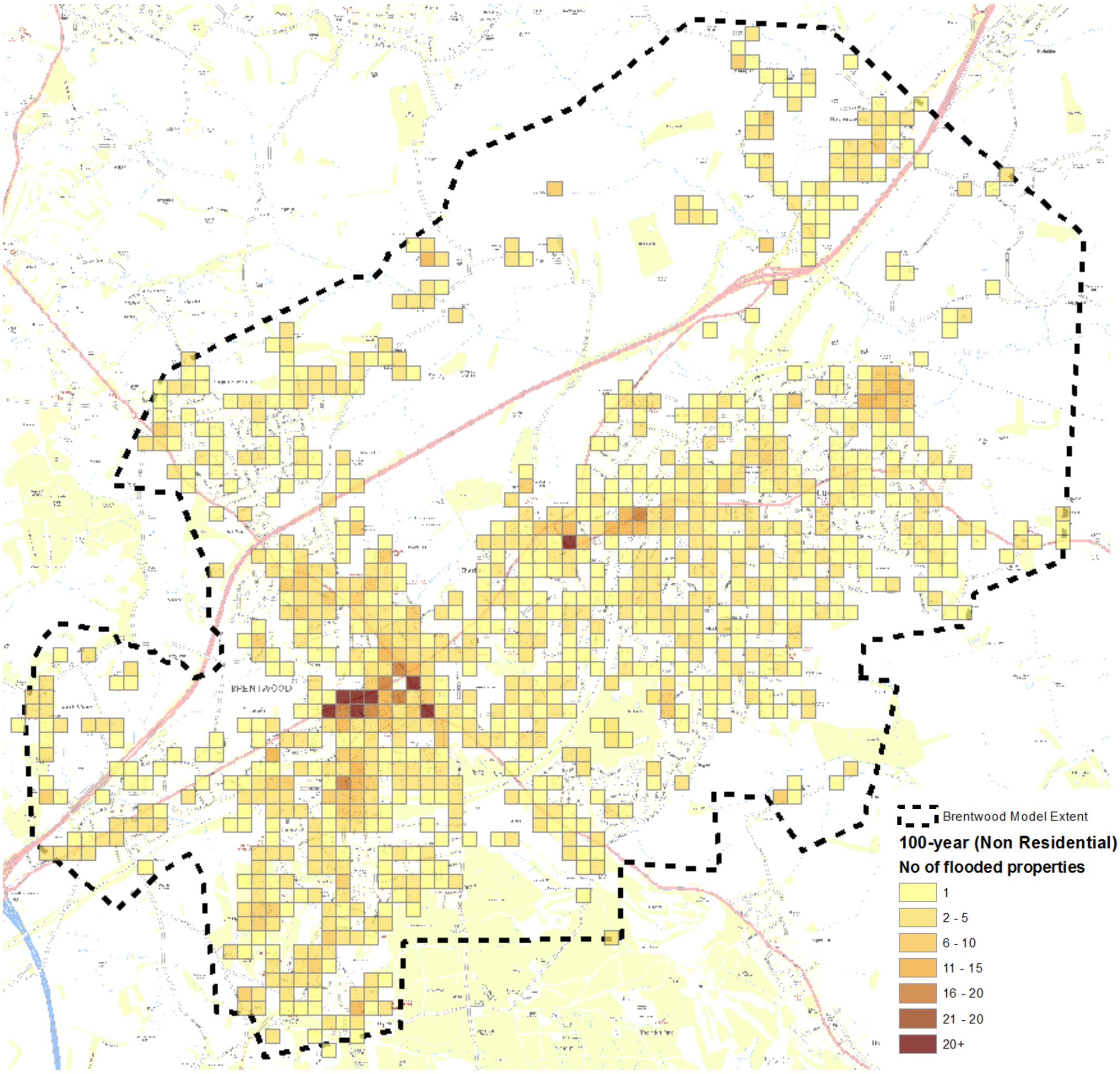
Contains Ordnance Survey data (c) Crown copyright and database right 2014

Note: Large maps can be found in Appendix J.

Number of Flooded Residential/Non-Residential Properties

Figure 4-29 shows the number of flooded residential properties for the 100-year event. The largest concentration of flood properties appears in the west, south-west area of Brentwood. This area of Brentwood has a high density of housing, as would be expected around a town centre. The majority of the buildings are comprised of either flats or terrace housing. As you move north east from Brentwood Town the number of flooded properties decreases mainly due to the decreasing housing density. In these suburbs the typical housing type is detached or semi-detached.

Figure 4-30: Number of Flooded Non-Residential Properties for the 100-year Event in Brentwood



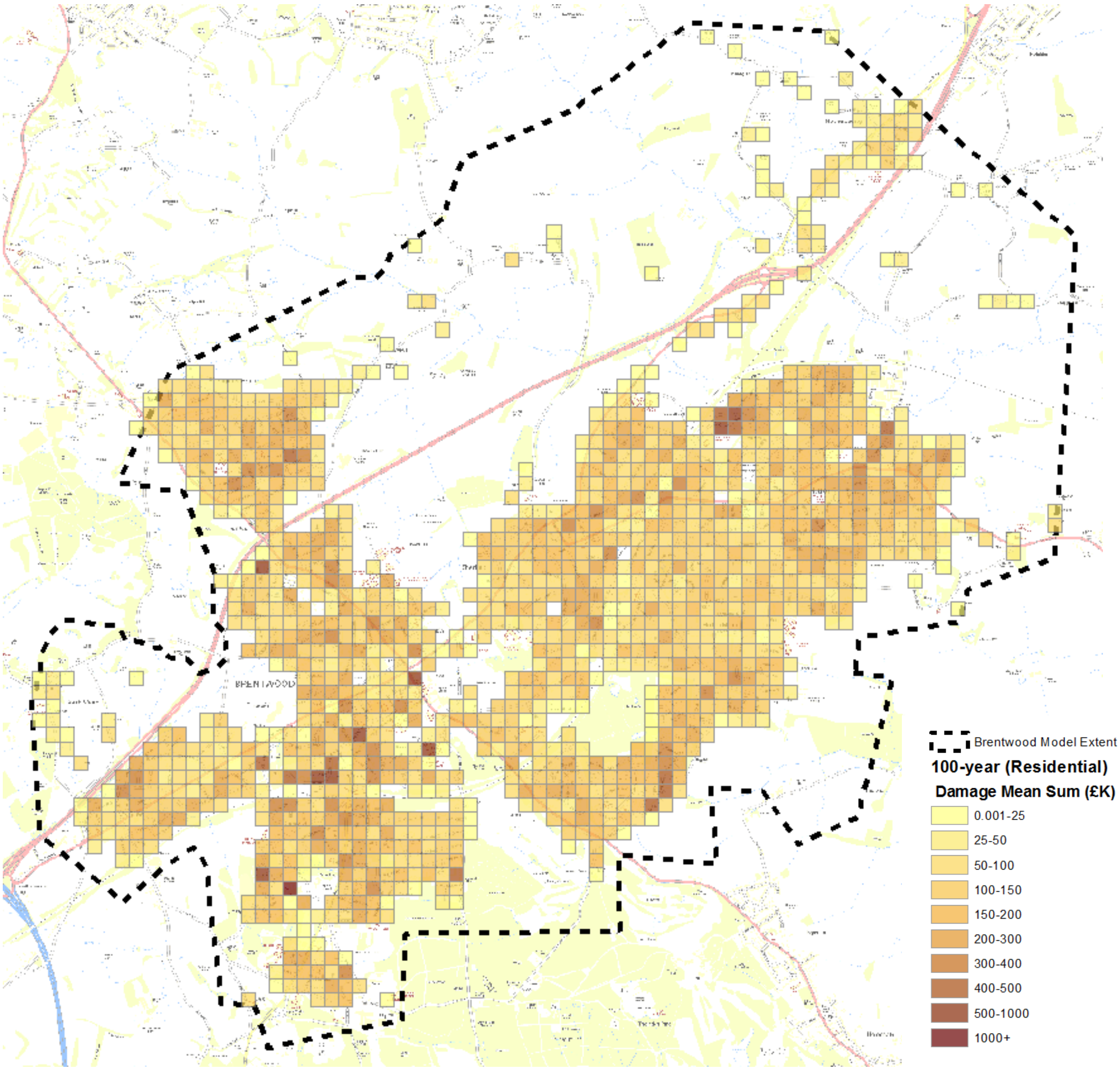
Note: Large maps can be found in Appendix J.

Figure 4-30 shows the number of flooded non residential properties for the 100-year event. The largest concentration of flooded properties is located in the vicinity of the High Street and Hart Street. At this location there are a number of 100m grid cells which have between 21-26 flooded properties. This number is understandably high with a large number of shops and other commercial buildings located in and around the High Street. Other groups of cells with more than 5 properties flooded are located around key infrastructure such as the Shenfield and Brentwood train stations. The majority of the cells that experienced flooding in Brentwood show less than 5 non-residential properties flooding.

Mean Flood Damage for Residential/Non-Residential Properties

In regards to the cost of flooding damage Figure 4-31 and Figure 4-32 show the distribution of flooding damage costs within Brentwood for the 100-year event. Appendix J contains all mapping illustrating the distribution of mean flood damage costs for all modelled return periods in the Brentwood model for all return periods.

Figure 4-31: Mean Aggregated Flood Damage (£K) for Residential Properties with the 100-year Event for Brentwood

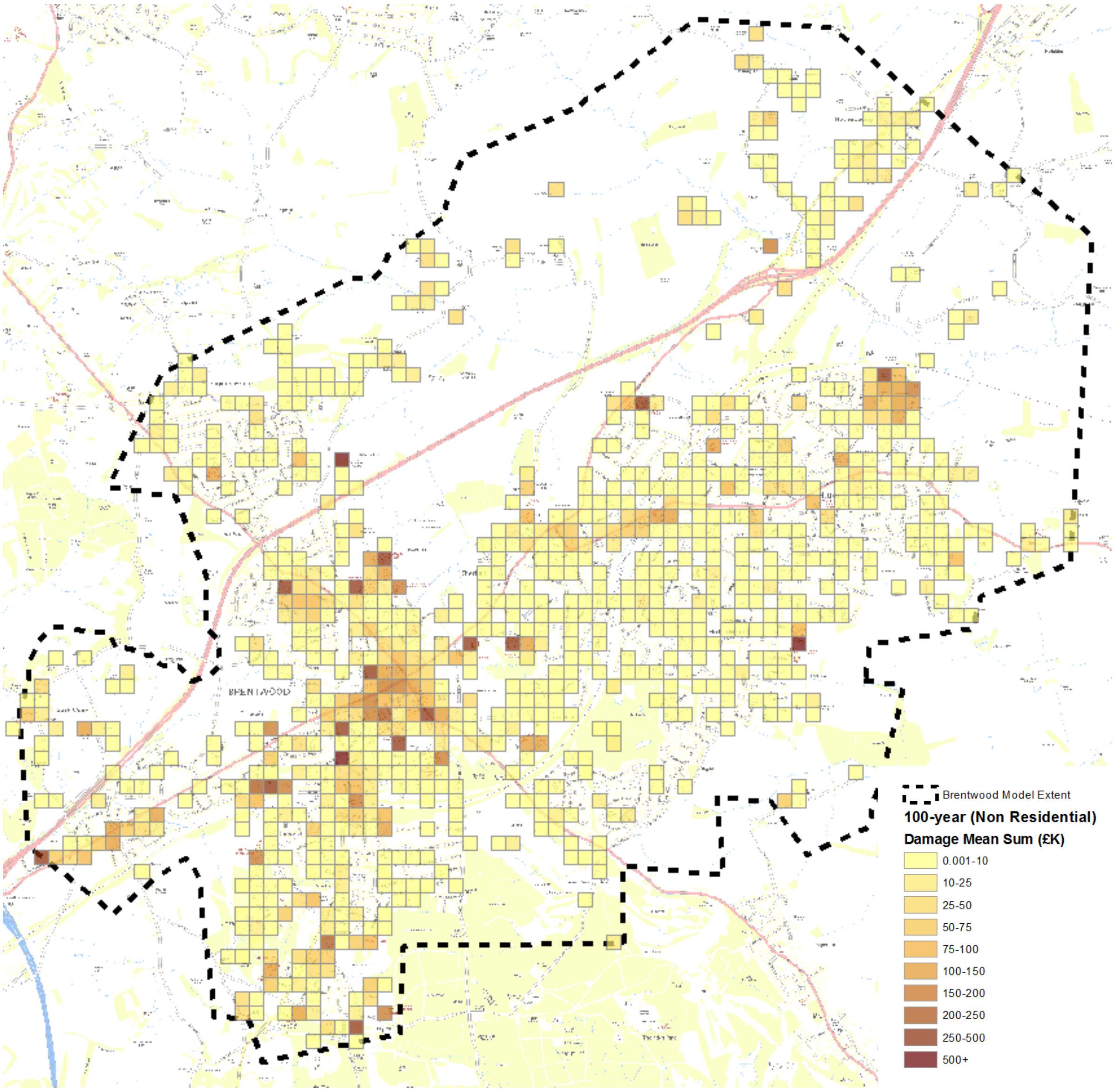


Note: Large maps can be found in Appendix J.

Figure 4-31 shows that the largest mean damage costs for residential properties in the 100-year event is centralised around the High Street, Laurel Close with isolated cells of high mean damage costs located where deep flooding coincides with high property density. The high cost experienced in the areas surrounding the High Street relates to high housing densities of the towns terrace housing. The high cost of Laurel Close relates to the deep flood water that pools at this location. The mean damage cost per cell for Brentwood is £127,000.

Figure 4-32 shows that the majority of the mean damage costs for non residential properties which occurred with the 100-year event are centralised around the High Street where there is a high concentration of shops and commercial properties. Also in the area are a number of schools and council office which are affected by flooding. Other areas of high damage costs relate to isolated schools and public infrastructure such as hospitals.

Figure 4-32: Mean Aggregated Flood Damage (£K) for Non-Residential Properties with the 100-year Event for Brentwood



Contains Ordnance Survey data (c) Crown copyright and database right 2014
Note: Large maps can be found in Appendix J.

Recommendations for Brentwood

Based on the results of the detailed modelling, a number of areas are shown to flood significantly with all return periods. These areas are shown in Figure 4-21.

BRENT-A which consists of mainly of residential areas is affected by surface water flooding originating from a number of watercourses which flow adjacent to the railway embankment. Overtopping of culverts causes overland flow and in some areas causes surcharging of the sewer network. Due to the coarse representation of the watercourses in this model it is recommended that additional surveys are commissioned and the model updated to improve the understanding of flood risk in the area. There are a number of areas where the sewer network could be improved to enhance the conveyance of flood water, particularly along Hunter Avenue and Margaret Avenue. It is recommended that this area be put forward for optioneering due to the possible benefit to residential and commercial properties.

BRENT-B highlights surface water following the local topography. There is only one historic record in this area which would suggest that there is not a significant risk of surface water flooding. The conservative flood extent may relate to the broad scale nature of modelling, however, there are a number of locations where the sewer network or culverts appear to have insufficient capacity. It is recommended that the conveyance of the flood water could be improved by up sizing pipes along Green Lane and Doddinghurst Road.

BRENT-C was the location of residential flooding in the vicinity of Spital Lane. Although one of the main causes of surface water flow would be the coarse representation of the local watercourse it has been highlighted that the Spital Lane culvert becomes heavily silted and would benefit from optioneering to improve the conveyance with the aim to stopping surcharging of the culvert.

Flooding of BRENT- D was caused by a combination of flow routes converging on a railway culvert. A number of assumptions have been made regarding the dimensions of the constricting railway culvert. Further survey of the culvert should be conducted to determine its capacity. Modelling could be re-run with this more accurate information to develop a better understanding of flood risk in the area. Additional flow routes from the railway could also be overestimated due to no drainage data supplied regarding the railway. Surface water from the watercourse/lake in Warley is also coarsely represented with it recommended that more detailed modelling be conducted to determine the flood risk. Although further data is needed to represent some features more accurately there is potential for opportunities to reduce flood risk in the areas by the railway culvert. Flood storage could be incorporated to reduce flood risk further downstream where there is a higher concentration of residential properties.

BRENT-E covers the railway flooding between Shenfield and Brentwood station. Unfortunately no drainage data was supplied for the railway and therefore this could be added at a later date to better represent flood risk. However, the current model results do give an indication of the likely flooding if the current drainage system servicing the railway were to become blocked. It is recommended that until detailed information regarding the drainage of the railway can be provided the best course of action would be ensure the current drainage system remains effective with a program of regular maintenance and cleaning.

BRENT-F represents an area where surface water is generated from overtopping of a culvert on Ingrave Road. It is recommended that further investigation of the watercourse is conducted to determine flood risk.

BRENT-G represents an area where surface water flooding appears to originate from both under sized pipes and pipes with flat gradient which do not allow sufficient flow. This is particularly apparent along Hanging Hill Lane. It is recommended that this area is a candidate for optioneering to improve the conveyance of the sewer network.

BRENT-H represents an area that suffers from sewer network related issues. At one location (adjacent to Surman Crescent) the sewer is under capacity and would benefit from up-sizing. At another location (north east of Willowbrook Primary School) the sewer network is relatively flat, hindering flow. It is proposed that this area could be re-graded to provide more flow within the sewer, preventing water from backing up.

BRENT-I represents an area where the flooding impacts upon the A12. Although this has been coarsely represented it is apparent the culverts under the by-pass have insufficient capacity to convey floodwater. Possible optioneering for this area could include improving conveyance or the creation of flood storage areas to reduce flood risk further downstream.

4.3 Localised Mechanism of Flooding

The overland flow routes associated with surface water flooding across Brentwood Borough generally follow naturally occurring drainage pathways. Some of these pathways include watercourses, some follow the historic valleys of watercourses that have been culverted or diverted. Ponding associated with these generally occurs at the low spots, or where they come up against a man made obstruction to flow, such as the railway embankment.

Culverts are pipes or other man-made channels in which a watercourse is made to flow underground. They range in length from a few metres (for example under a minor road crossing) to many kilometres. Culverts can create many new problems, including the risk of flooding due to blocking or their capacity being exceeded, impacts on water quality and therefore biodiversity (especially in long culverts), and difficult and expensive maintenance. Within Brentwood Borough there are a number of areas where culverts are under capacity or do not have a sufficient gradient to prevent flow from pooling within the system. Unfortunately due to the restrictions and limitations on available data for this study, several culverts have been modelled as a best representation of the structure, without detailed survey. Also there were a number of discrepancies with the sewer network data regarding pipe dimensions. Without detailed and up-to-date information the modelling results represent a strategic overview of flood risk within the Borough.

5 Options

5.1 Objectives

The purpose of the Options phase of the SWMP is to identify a range of structural and non-structural measures for alleviating the surface water flood risk in the identified flooding hotspots. Once a range of measures has been determined they can be assessed to eliminate those that are not feasible or cost beneficial. The remaining options are then developed and tested against their relative effectiveness, benefit and cost.

5.2 Methodology

Options identification and assessment has been undertaken in four stages as summarised below:

- Identify Potential Measures: This includes structural and non-structural measures identified for all surface water flooding hotspots irrespective of the costs or benefits.
- Short List Potential Measures: Based on the potential measures available, a shortlist is determined of the measures which will reduce flood risk to existing settlements as well as reduce future flood risk. Consideration was also made to the practicality of implementing the measures.
- Potential Options: This stage involved incorporating the short listed potential measures into a range of options which could be tested based on a range of social, environmental, technical and economic criteria.
- Determine Costs and Benefits: This stage involves determining the costs and benefits of the preferred option.

5.2.1 Potential Measures

Potential measures consist of both structural and non-structural measures which have the potential to alleviate surface water flooding in Brentwood Borough. At this stage the identification of measures pays no attention to cost or suitability to ensure that a robust assessment of the available measures can be conducted. The aim is to identify the measures available and the role they could provide in alleviating surface water flood risk.

The DEFRA SWMP Technical Guidance (2010) outlines a number of structural and non-structural measures following a source-pathway-receptor model shown in Table 5-1. Sources refer to sources of flooding which for Brentwood Borough would be pluvial, sewer and water courses. Pathways are defined as how flood water gets from a source to a receptor. This would be either overland pathways or via the sewer systems. Receptors refer to anything which can be impacted by flooding. This would include people, households, community facilities, infrastructure and land. The source-pathway-receptor model is illustrated in Figure 5-1.

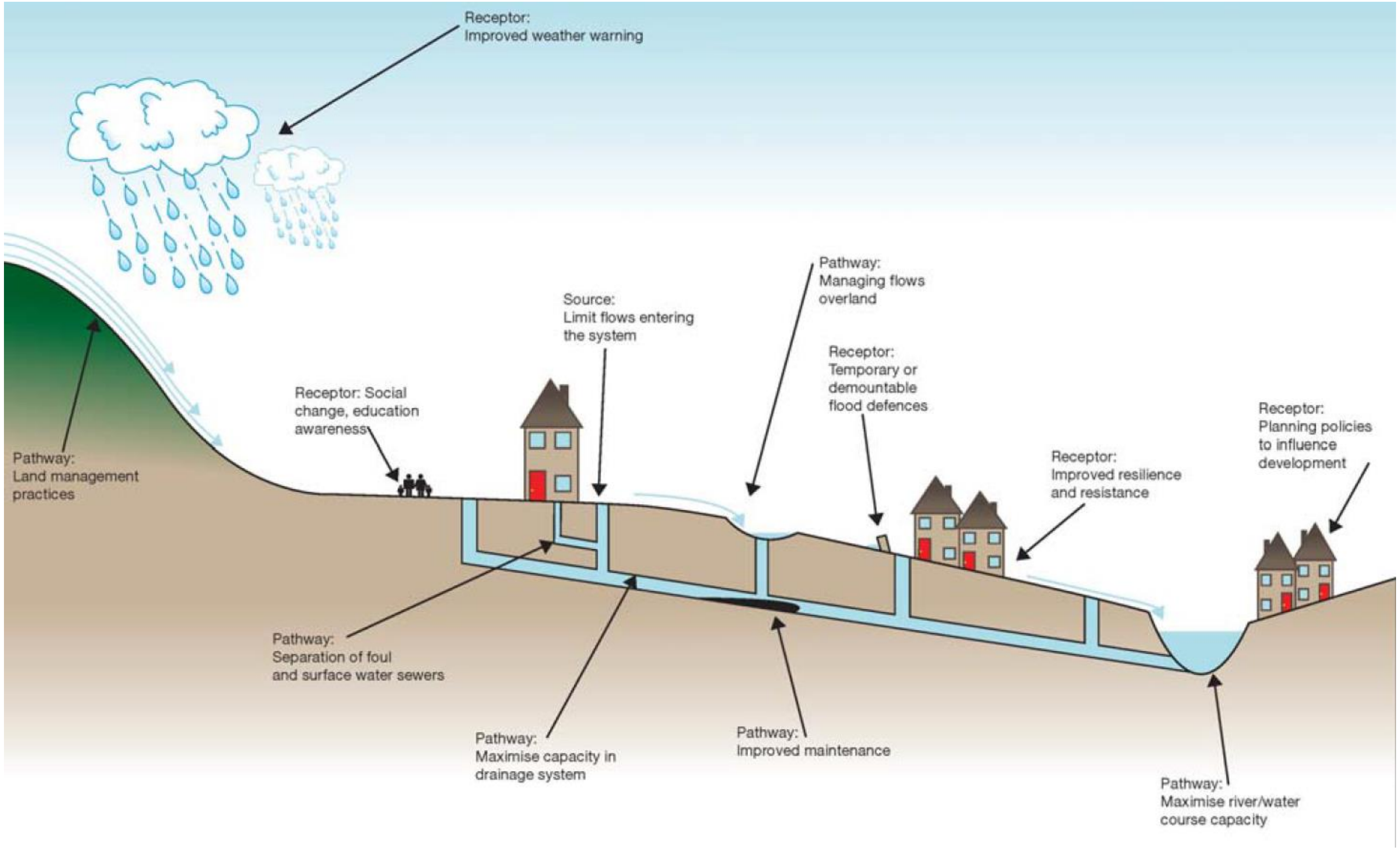
Table 5-1: Structural and Non-Structural Measures for Consideration

Source	Pathway	Receptor
Sustainable Urban Drainage Systems (SUDS)	Increase capacity of drainage systems i.e. flood storage or conveyance	Improved weather warning
Land management practices	Separation of foul and surface water sewers	Planning policies to influence development
Strategic storage	Improve maintenance regimes	Temporary or demountable flood defences
	Managing overland flows / diverting flow	Social change, education and awareness
		Improved resilience and resistance measures

Source: DEFRA SWMP Technical Guidance, 2010

This page was left intentionally blank.

Figure 5-1: Source-Pathway-Receptor Model (adapted from SWMP Technical Guidance, 2010)



Source: DEFRA SWMP Technical Guidance, 2010

This page was left intentionally blank.

In addition to the identification of measures, the first stage of options assessment also identified a number of potential actions (known as 'Quick Wins') which can be conducted at a Borough wide scale. These Quick Wins can be undertaken quickly and with low capital cost to immediately reduce the risk of surface water flooding in any given area: Examples of Quick Wins include:

- Removal of a blockage currently preventing full conveyance through a culvert or ordinary watercourse.
- Removal of debris from drains and gulley pots which can cause restriction of flow rates and causing of surface water ponding.
- Improving conveyance in watercourse by removal of excessive weed growth.
- Council wide communication of strategies designed to raise awareness of surface water flooding.

These Quick Wins have been identified based on site visits across the site area, which has identified issues.

5.3 Short-Listed Measures

Following the consideration of the long-list of measures in regards to the flooding issues within the Brentwood Borough the following shortlisted measures have been chosen to be explored in further detail.

- Sustainable Drainage Systems (SUDS) – Focus on both new developments and retrofitting SUDS into existing areas where appropriate.
- Land management to reduce run off
- Strategic storage of water outside of urban areas
- Improved maintenance regimes.
- Improving capacity of problem culverts
- Public awareness and education aimed at making the public aware what they can do to help themselves and the profound effects of individual actions on surface water flooding
- Improvements in planning policy to reduce flood risk from future developments
- Property level resilience measures
- Policy against culverting (piping) watercourses in new developments except where short culverts are required over access roads.
- Strengthening and informing planning policy and guidelines to include individual homes and driveways plus larger scale developments.

The Short-List Measures were then developed into a series of options which could be applied on a Borough scale or at key flooding hotspots. A number of the options will be more applicable on a Borough-wide scale due to the lack of detailed site specific data available. A number of options can be applied to the flooding hotspots identified in section 4.2. For these areas the options will be tested for relative effectiveness, benefits and costs.

5.4 Potential Options

Based on the short listed measures, a number of options have been proposed which were tested for their relative effectiveness, benefits and costs. Table 5-2 shows the categorised options, with each option being considered for each of the flooding hotspots.

Table 5-2: Potential Options and Measures

Options	Measures
Minimal measures	Do nothing
	Do minimum (continue maintenance at existing level)
Source control measures	Retro-fit SUDS at property level (green roofs, water butts etc)
	Retro-fit SUDS at street/area level (swales, rain gardens etc)
	SUDS on new developments at property level
	SUDS on new developments at development level
	Remove surface water misconnections from foul sewers
Strategic measures	Deculverting / daylighting stream (with additional storage capacity)
	Increased conveyance - gravity
	Increased conveyance - pumped
	Strategic storage outside urban area
	Improved maintenance regimes
	Land management to reduce runoff
	Raised defences
	Temporary defences (community scale)
Resistance and resilience	Managing overland flows (roads as rivers etc)land flows (roads as rivers etc)
	Property-level resilience - temporary (e.g. Demountable door guards)
	Property-level resilience - permanent (e.g. Raised thresholds)
Non-structural measures	Flow / level monitoring for enhanced response
	Restrict expansion
	Public awareness and education (permeable drives, fly tipping, flood preparation)

5.5 Borough Wide Options

As part of identifying short-listed options a number of options are not applicable to individual areas but should be applied on a Borough-wide scale. The inclusion of these options highlights that even if an area does not flood within a flooding hotspot it does not mean that surface water discharge from these areas are not a concern and does not need to be managed or mitigated. It simply means that the consideration of more direct options for that area is not so critical.

Borough wide options include the following:

- Retrofit of SUDS
- On-going maintenance of drainage network.
- Improving resilience to flooding (Property Level Protection).
- Public awareness education
- Planning and Development control policies

These are discussed in the following section.

5.6 Options Assessment – Borough Wide Options

5.6.1 SUDS / SUDS Retrofit

Sustainable Drainage Techniques (SUDS) aim to mimic natural drainage processes so that new developments do not increase surface water runoff and impact water quality (which is a general consequence of conventional drainage techniques). There are various SUDS techniques available, many of which are applicable in different situations. SUDS are one element of the concept of Green Infrastructure, an approach which analyses and values the services provided by green spaces, in particular within urban areas. The CIRIA SUDS manual (CIRIA, 2007) and Essex County Council guidance provides a comprehensive overview of the techniques. Examples of those thought to be applicable in the Brentwood Borough are list below:

- **Green roofs** can vary in type from Roof Gardens, Roof Terraces, Green Roofs and Green Walls. This SUDS technique utilises plants and their substrate to provide temporary storage of rainfall and minimise runoff from roof areas. They can also offer additional biodiversity benefit.
- **Rainwater harvesting** techniques, such as the installation of water butts, can aid in increasing the attenuation of rainfall and contribute to the on-site recycling of water.
- **Infiltration devices** drain water directly into the ground. They may be used at source or the runoff can be conveyed in a pipe or swale to the infiltration area. They include soakaways, infiltration trenches and infiltration basins as well as swales, filter drains and ponds. Infiltration devices can be integrated into and form part of the landscaped areas.
- **Filter strips** are vegetated areas that function by slowing runoff velocities and filtering out sediment and other pollutants, and providing some infiltration into underlying soils. This approach to SUDS also provides scope for the creation of wildlife habitats and biodiversity gain.
- **Permeable pavements** such as permeable concrete blocks, crushed stone and asphalt will allow water to infiltrate directly into the subsoil before soaking into the ground.
- **Basins and ponds and rainwater gardens** enhance flood storage capacity by providing temporary storage for storm water through the creation of landscape features within a site (which can often provide opportunities for the creation of wildlife habitats). Basins, ponds and wetlands can be fed by swales, filter drains or piped systems. In some instances, storm water runoff from a development can feed a pond which overflows into a vegetated wetland area to act as a natural soakaway. Rainwater gardens are depressions into which surface water is channelled, planted with water-loving species. They can be used in private gardens as well as on roadside verges

Although new developments can easily be designed with SUDS in mind retrofitting SUDS into currently occupied areas can help to solve some of the flooding and quality issues face in urban areas today. Such measures provide a joined up approach to managing surface water across wider areas, making urban areas more “green”. Retrofitting SUDS can be cheaper than traditional solutions and nearly always provide more additional benefits such as reducing the portable water use, reducing flood risk, improving water quality and improving biodiversity.

Key to implementing SUDS retrofit is identifying opportunities. The first opportunity relates to urban regeneration or site reconstruction. In these areas drainage improvements may not be the primary aim but retrofitting SUDS can enhance the urban areas and provide small local improvements, due to the often small scale nature of the developments. These opportunities to retrofit are not necessarily driven by surface water flood risk but to modify the drainage system to deal with water better. The second opportunity will be driven by the need the control flooding or pollution. These opportunities are often over a larger area and therefore represent a more strategic approach to retrofitting SUDS.

Feasibility in Brentwood Borough

The suitability of areas for different types of SUDS techniques is often determined by localised soil types. An initial assessment was conducted using the British Geological Society’s Infiltration Maps. These outline the constraints in a geological format based on ground conditions. Appendix K shows the feasibility of infiltration SUDS with the Brentwood Borough. These maps show that there are a significant amount of areas, particularly within Brentwood itself where infiltration based SUDS would be suitable. Implementation of retrofitted SUDS in Brentwood would allow the interception of surface water and reduce the volume which travels to constricting points such as culverts. This would be particularly useful in reducing surface water flood risk in the vicinity of Brentwood Station and areas to the west (See Areas C and D of Figure 4-21).

The application of features such as green roofs, swales and filter strips should be installed where possible review on a case by case basis. Features such as rainfall harvesting techniques and water butts can easily be installed on properties reducing the local demands on water resources.

Table 5-3 shows a number of locations where SUDS could be included to attenuate water, reducing flood risk elsewhere as informed by the modelling exercise. This is by no means an extensive list but designed to give an example of where possible opportunities can be developed. Further opportunities should be investigated throughout the Brentwood Borough in response to flood risk issues.

Table 5-3: Possible Locations of Attenuation Features

Location	Proposed Measure
Heybridge, Ingatestone	It is proposed that currently unoccupied land to the west of the A12 and within the A12 junction itself could be used as additional floodplain storage for the watercourse running through Heybridge. During extreme rainfall events additional floodplain storage would allow water to be attenuated and released at a slower rate to reducing further flooding downstream (in the vicinity of Marks Close).
Area West of Crescent Road, Brentwood	This area represents a region where water is found to back up behind a culvert passing under the railway embankment. As the surrounding area is predominately Greenfield this could be used for additional floodplain storage with features such as swales conveying surface water into a large pond. From the pond, water can be slowly released back into the watercourse.
A12, North-east of Brentwood.	This area is the location of an A12 junction which has the River Wid running underneath it. Although flooding is mainly fluvial in this location there are large areas of Greenfield land which could be utilised for additional storage. This could reduce flood depths in the area and reduce the flooding of roads in the vicinity.

With regards to new developments, it is considered that these would predominately be Greenfield developments and therefore require the use SUDS to ensure that their runoff does not exceed existing Greenfield rates. In redevelopment of existing areas within urban areas it is recommended that a reduction of at least 20% is achieved using SUDS where possible. This would help to mitigate the impact of climate change on flood risk. However, this may not always be possible and must be judged on a case by case basis.

It is important to note that the implementation of SUDS would require a concerted campaign over a number of years, involving, to greater or lesser degrees all of the project partners, along with local residents, businesses and organisations. Other opportunities will arise as a result of renovations, redevelopments, road re-surfacing, traffic calming, improvements to public open spaces etc. Taking these opportunities forward will require considerable co-operation both between and within partner organisations.

If this option were to be progressed, it is recommended that it is accompanied by an active programme of community engagement, to allow input to the design and maintenance of the retro-fit SUDS, and to use installations on public land to demonstrate SUDS in action and inspire householders and businesses to take steps to better manage their own surface water. This might involve some signage and other information to explain the purpose of the SUDS features.

Costing for SUDS

An approximate costing for SUDS within the three major urban areas of Brentwood, Hutton and Ingatestone has been provided. This was based on a number of assumptions such as:

- 70% level of impermeability per hectare to represent the existing developments
- An infiltration factor of 0.01m/hr was applied to represent the infiltration loss.

Table 5-4 shows approximate volume of attenuation required per hectare to reduce existing runoff by 25%, 50% and to Greenfield rates (approx. 75% of existing)

Table 5-4: Approximate Required Attenuation Volumes (m^3 per ha)

Area	Level of Reduction	Approx. Attenuation Volume Required (m^3 per ha)
Brentwood	25% of Existing	18-23
	50% of Existing	37-57
	To Greenfield (approx 75% of Existing)	65-114
Hutton	25%	21-22
	50%	48-55
	Greenfield (approx 75%)	84-119
Ingatestone	25%	21
	50%	47-56
	Greenfield (approx 75%)	81-116

Based on these estimates of required storage volume an approximate costing for a range of SUDS systems was devised for each area. Costs of systems were sourced from the CIRIA SUDS Manual and Stovin & Swan (2007)[1]and updated to take into account of inflation. The costs provided are indicative and do not provide a precise figure for implementing SUDS into an area. The costs do not take into account costs of pipe connections, acquisition of land or consultation fees. A more detailed assessment would be needed on a site by site basis in order to implement SUDS.

Table 5-5 shows the approximate costs for implementing a range of SUDS into Brentwood, Hutton and Ingatestone

[1] Stovin & Swan (2007) Retrofit SuDS – cost estimate and decision-support tools. *Proceedings of the Institution of Civil Engineers*. Water Management 160 (WM4)

Table 5-5: Approximate Costs for Implementing SUDS (£ per Ha)

BRENTWOOD	Approx. Cost (£ per ha)					
	25% reduction		50% Reduction		Reduction to Greenfield (approx. 75%)	
Feature	Low Cost	High Cost	Low Cost	High Cost	Low Cost	High Cost
Filter Drains	2,340	4,186	4,810	10,374	8,450	20,748
Infiltration Trenches	1,755	3,010	3,608	7,460	6,338	14,922
Soakaway	1,815	2,820	3,730	6,989	6,553	13,979
Permeable Pavement[1]	9,028	11,536	18,558	28,590	32,602	57,179
Infiltration Basin	756	1,518	1,554	3,762	2,730	7,524
Detention Basin	756	1,518	1,554	3,762	2,730	7,524
Wetland	585	897	1,203	2,223	2,112	4,446
Retention Pond	756	1,518	1,554	3,762	2,730	7,524
Swale	1,368	2,001	2,812	4,959	4,940	9,918
Filter Strip	47	120	96	296	169	593

HUTTON	Approx. Cost (£ per ha)					
	25% reduction		50% Reduction		Reduction to Greenfield (approx. 75%)	
Feature	Low Cost	High Cost	Low Cost	High Cost	Low Cost	High Cost
Filter Drains	2,730	4,004	6,240	10,010	10,920	21,658
Infiltration Trenches	2,048	2,880	46,817	7,199	8,192	15,576
Soakaway	2,117	2,698	4,839	6,744	8,469	14,592
Permeable Pavement[1]	10,533	11,035	24,076	27,586	42,132	59,687
Infiltration Basin	882	1,452	2,016	3,630	3,528	7,854
Detention Basin	882	1,452	2,016	3,630	3,528	7,854
Wetland	683	858	1,560	2,145	2,730	4,641
Retention Pond	882	1,452	2,016	3,630	3,528	7,854
Swale	1,596	1,914	3,648	4,785	6,384	10,353
Filter Strip	55	114	125	286	218	619

INGATESTONE	Approx. Cost (£ per ha)					
	25% reduction		50% Reduction		Reduction to Greenfield (approx. 75%)	
Feature	Low Cost	High Cost	Low Cost	High Cost	Low Cost	High Cost
Filter Drains	2,730	3,822	6,110	10,192	10,530	21,112
Infiltration Trenches	2,048	2,749	4,584	7,330	7,899	15,183
Soakaway	2,117	2,575	4,738	6,867	8,166	14,224
Permeable Pavement[1]	10,533	10,533	23,574	28,088	40,627	58,183
Infiltration Basin	882	1,386	1,974	3,696	3,402	7,656
Detention Basin	882	1,386	1,974	3,696	3,402	7,656
Wetland	683	819	1,528	2,184	2,633	4,524
Retention Pond	882	1,386	1,974	3,696	3,402	7,656
Swale	1,596	1,827	3,572	4,872	6,156	10,092
Filter Strip	55	109	123	291	211	603

1: Please note that although permeable paving has been included it is not a system that is suitable for large amount of storage. Permeable paving is a source control technique which should be used with a combination of other SUDS.

Maintenance

Sustainable drainage schemes require ongoing maintenance into order to optimise performance and minimise the risks to long term performance. Operation and maintenance activities can be classed as the following:

- Inspections and monitoring
- Regular Maintenance (e.g. clearing inlets/outlets, grass cutting etc)
- Irregular Maintenance (e.g. responding to problems such as blockages)
- Remedial maintenance (e.g. replacement of geo-textiles, replanting of grass etc)

The operation and maintenance costs will comprise of the following:

- Labour and equipment costs
- Material costs
- Replacement or planting costs
- Disposal costs

Table 5-6 shows the approximate costs of operating and maintaining various SUDS systems as detailed by CIRIA SUDS Manual

Table 5-6: SUDS approximate Operation and Maintenance Costs (CIRIA 2007)

Feature	Annual Cost (for regular maintenance only)	Unit
Filter drain / infiltration trench	£0.26-£1.30	/m^2 of filter surface area
Swale	£0.13	/m^2 of swale surface area
Filter Strip	£0.13	/m^2 of filter surface area
Soakaway	£0.13	/m^2 of treated area
Permeable Paving	£0.65-£1.30	/m^3 of storage volume
Detention / Infiltration basin	£0.13-£0.39	/m^2 of detention basin area
Wetland	£0.13	/m^2 of wetland surface area
Retention Pond	£0.65-£1.96	/m^2 of retention pond surface area
Note: Costs have been scaled up based on inflation.		

Unfortunately the whole life costs of SUDS are difficult to qualify. However, the Flood and Water Management Act 2010 did determine that SUDS schemes were only slightly more expensive per property than traditional piped systems. For that extra investment SUDS offer a wider range of benefits than piped systems such as increased amenity value, increasing ecological value, reducing pollutants and reducing surface water volumes.

Unfortunately due to the number of uncertainties and the large scale of the Brentwood Borough it is not possible to model the implementation of SUDS on a wide scale. However in Section 5.7 areas where SUDS may be applicable have been identified.

5.6.2 Borough Wide Option – Property Level Resilience Measures

The Government's *Making Space for Water* strategy, and Sir Michael Pitt's review following on from the flooding of June and July 2007, have both recognised the need to use a portfolio of measures to manage flood risk and the necessity to include in this portfolio the use of property-level protection (PLP) measures. In 2008 Defra announced a £5 million Property-level Flood Protection Grant Scheme as part of the Government's response to the Pitt Review. Grants could be applied for by local authorities and a total of 63 such schemes were completed during this 2 year pilot. PLP is seen as cost-effective way to provide flood mitigation to communities which are unlikely to qualify for traditional community flood defence schemes on cost-benefit criteria.

Property-level protection is the name given to a package of measures aimed at reducing the likelihood of flood water entering a property (termed resistance) and minimising the impact if it does enter (resilience). Resistance measures can include (but is not limited to) door and window barriers, automatic air brick and vent covers, non-return valves for foul sewer chambers and waste pipes, toilet bungs, and ensuring all external walls are waterproof (and watertight) and appropriately sealed. Door and window barriers provide a relatively low-cost and simple to use means to help prevent the direct entry of flood water into a property. Effectiveness depends on the seal around the individual door or window, and onto the surrounding wall. Research carried out for Communities and Local Government (DCLG) and the Environment Agency, has recommended that the use of resistance measures (barriers for doors) should be limited at depths up to 0.6m. This is because the structural integrity of the building may be compromised above this level, including the increased risk of cracks and leaks. In recent years a number of KiteMarked uPVC flood doors have also entered the market; particularly beneficial in rapid response catchments (or where the risk is from surface water) with limited or no flood warning service giving residents time to respond. Any PLP scheme should commence with a detailed property level flood risk survey. These seek to identify the levels and sources of flood risk at the property, establish the local flood warning arrangements, identify potential routes of ingress at the property, and to define a suite of suitable recommendations for types of product (based on risk, the nature of the property, the ability of the homeowner to deploy them, and homeowner choice). PLP schemes should also be considered in the local community Emergency Flood Plan.

The installation of such measures will not always guarantee that the property will be watertight. Reasons for this include that there may be hidden water ingress routes, or that the standard provided by the mitigation measures may be exceeded. Therefore the following is a list of (resilience) options that can help reduce the damage once flood waters enter a property:

1. ensuring all electrical sockets on the ground floor are situated above the maximum expected height of flooding
2. ensure all ground floors are of concrete having a suitable damp proof membrane connected to the external walls
3. ensuring all external walls are waterproof; this may be achieved through application of waterproof render
4. waterproof internal walls and skirting
5. raised kitchen units and appliances
6. waterproof floor coverings

It is always very important that residents prepare individual flood plans. This includes simple practices like checking the pointing of a build to having a supply of sandbags read in case of flooding. Further details can be found on the Environment Agency website[2].

5.6.3 Maintenance of Drainage Network

The management and maintenance of the drainage network in the Brentwood Borough is the responsibility of a number of organisations:

- Anglian Water – responsible for the main and lateral sewer networks.
- Environment Agency – responsible for the flood risk management assets on main rivers.
- Essex Highways – responsible for highway drainage, including surface water runoff from the Highway
- Network Rail – responsible for railway drainage
- Riparian land owners – responsible for the maintenance of ordinary watercourses through their land. This is enforced and overseen by the Lead Local Flood Authority.

[2] http://www.environment-agency.gov.uk/homeandleisure/floods/31644.aspx

As most of the rivers within the Brentwood Borough are ordinary watercourses the emphasis is on the riparian land owners to maintain the watercourses running through their land. Under the FWMA 2010 EA, LLFAs, district councils and the EA have legal powers to "designate" structures and features that affect flood or coastal erosion risk (whether or not it was originally intended to do so) and are not directly maintained by these organisations.

A designation is a legally binding notice served by the designating authority on the owner of the feature and will automatically apply to anyone dealing with the land and to successive owners or occupiers of a particular property of parcel of land.

Four conditions must be satisfied to enable a structure or feature to be designated. These are outlined in Table 5-7. If any of the four conditions cannot be met than designation is not possible.

Table 5-7: Designation conditions

Conditions	
1	The designating authority thinks the existence of the structure or feature affects a flood or coastal erosion (or both) risk.
2	The designating authority has flood or coastal erosion risk management functions in respect of the risk being affected.
3	The structure or feature is not already designated by another designating authority.
4	The owner of the structure or feature is not a designated authority.

Should a feature/structure be designated the owner should be able to continue to use the structure/feature. They may also alter, remove or replace the structure of feature providing they have the prior consent of the designating authority. However, by designating the structure it is highlighted as an area that contributes to flooding if not properly maintained.

In regards to the Anglian Water assets any improvements to the sewer network that are recommended need to be thoroughly assessed. Anglian Water takes a risk based approach to sewer improvements assessing the viability and cost benefit of any works. This approach is taken across the whole operational service area rather than solely in the Brentwood Borough. Therefore improvement works may be considered low risk in regards to improvements across Anglian Waters operational service area.

There are a number of locations within Brentwood where either siltation or collection of debris can severally constrict the flow through culvert, increasing flood risk to the surrounding area. A number of areas were highlighted in the site visits that offered examples of where maintenance would be beneficial and result in a reduction of flood risk. Photos of these areas can be seen in Figure 5-2.

It is suggested that a review be conducted of culverts around the Brentwood Borough, particularly within the Brentwood area to identify any areas that might be prone to blockage and arrange suitable maintenance regimes such as weed clearance or removal of rubbish.

Also effective cleansing of gully pots and other associated highway drainage features is fundamental to the effective operation of drainage infrastructure across the Borough. Essex Highways operates a regular maintenance regime for gully cleansing. Gully pots are fundamental to integrated urban drainage in that during intense precipitation events, surface water runoff is routed off roadways and other hard-standing and into gully pots and then into the public sewer system or watercourse. In essence, highway drainage features are a critical link in the performance of the overall drainage network. Although some of the highway drainage networks (such as the A12 By-Pass) were not represented the modelling showed what might happen if the drainage network were to become blocked, identifying surface water flow routes.

Figure 5-2: Examples of Maintenance Issues

	<u>Photo 1: Spital Lane, Brook Street</u> The culvert shows excessive signs of siltation which significantly reduces the capacity. This was noted and included in the model, resulting in overtopping of the culvert with water flowing over Spital Lane.
	<u>Photo 3: St Anne Road, Brentwood</u> This culvert running under St Anne Road north of Brentwood is located in a predominantly rural area and is prone to collection of leaf litter and vegetation. In this case the culvert is almost completely blocked and therefore in a severe rainfall event would be highly likely to flood.
	<u>Photo 3: Cadogan Avenue, West Horndon</u> The culvert and trash screen are located north of Cadogan Avenue, West Horndon. The photo shows that the trash screen is approximately 50% blocked with vegetation. At this location the spacing of the trash screen bars is too narrow aiding in the collection of finer material such as leaves.
	<u>Photo 4: Petresfield Way, West Horndon</u> The culvert is nearly 100% blocked with debris and trash. Also there is minimal clearance above the trash screen between culvert soffit and culvert crest..

5.6.4 Public Awareness Education

A programme of education and awareness-raising on local flood risk issues is required to enable effective management of surface water flooding. Not all surface water risk can be mitigated by physical measures. Essex County Council has a primary role in empowering communities to adapt to the impact of future flood risk by helping them to become more resistant and resilient to the consequences of flooding. A programme of education and awareness-raising could be developed to enable social change. Priority issues in the Brentwood Borough include:

- Riparian responsibilities
- Householder responsibilities in particular paving of driveways
- Assistance with techniques for retro-fit of SUDS to homes and other buildings.
- Development of household and community flood plans.
- Tackling nuisance issues such as fly-tipping, which can exacerbate flooding.

The costs associated with this could not be calculated nor could the benefits. It would be recommended that any awareness and education programme be logged and reaction recorded to try and determine how well it would be working.

5.6.5 Strengthening and informing planning policy

Brentwood Borough Council as the local planning authority have overall responsibility for determining that new development takes place in the most appropriate location. Essex County Council and the Environment Agency have an input into Local Plans and Local Development Framework in respect of flood risk management of the development as their position as consultants on planning application.

Currently the Local Plan 2015-2030 for Brentwood sets out the long term vision of how Brentwood will develop and the Council's strategy and polices for achieving that vision. The plan outlines land allocations for development and details the planning policy that guided these decisions. Currently the Local Plan is in a period of consultation.

Within the Local Plan the main two policies which are of interest to the SWMP are policy DM35: Flood Risk and Policy DM36 Sustainable Drainage. Below is an overview of each policy.

Policy DM35: Flood Risk
• All developments in areas of flood risk need to submit a Flood Risk Assessment (FRA) to recognise all the likely sources of flooding. • Proposals should be located in the lowest appropriate flood risk zone as part of the sequential test set in the Brentwood SFRA. • The development is constructed so as to remain operational even at times of flood through resistant and resilient design. • Contact should be made with the sewerage provider to assess the capacity of the receiving foul sewer network and contribute to any additional off site connections for the development. • Developments is allowed within flood risk areas if it can be demonstrated that it will reduce fluvial and surface flood risk and manage residual risks through appropriate flood mitigation methods.
Policy DM36: Sustainable Drainage
• Brownfield sites need to achieve a reduction in existing runoff rates or at least no additional increase. • Sites in Flood Zone 1 larger than 0.25ha need to have a drainage impact assessment. • Design must maximise source control, providing the relevant number of treatment stages and dealing with 'first flush' with appropriate attenuation measures. • Promote improvements in biodiversity and amenity. • On brownfield sites disconnecting surface water drainage from the foul network. • Promoting the preferred drainage hierarchy of managing surface water runoff.

The above two policy's reinforce NPPF guidance which seeks to safeguard new developments and reduce the causes and impacts of flooding. As well as this it aims to enhance and protect the natural environment from new developments. As a means of further strengthening this it is recommended that the following policies are implemented within the Borough to reduce flood risk.

Policy 1: All development within the borough which increases the impermeable area to include at least one SUDS feature to minimise the peak runoff from the site. This SUDS feature could be a feature such as water butt, rainwater harvesting tank or bioretention planter.

Policy 2: All proposed brownfield sites which are more than one property should aim to reduce post development runoff rates for events up to 100-year plus climate change return period to Greenfield or if possible a betterment to the Greenfield runoff rate. This is particularly important in the areas that have been identified as a flooding hotspot in this SWMP.

Further to this it is recommended that a consideration is made for the creation of a Supplementary Planning Document (SPD) for flood risk and development that would complement the Essex SUDS Design and Adoption Guide. The SPD is a document what would also complements the Brentwood Local Plan and aims to assist developers on submitting appropriate flood risk and flood risk management information. It outlines what is required from a developer in regards to flood risk to a site and information more specific to the Brentwood area and can therefore include recommendations from this SWMP. The Essex SUDS Design and Adoption Guide currently gives an overview of guidance for the whole Essex County. It has also been highlighted by the Brentwood Water Cycle Study (2011) that the Brentwood Borough Council may also wish to consider producing a SUDS and Green Infrastructure SPD to provide SUDS guidance on the delivery of SUDS on strategic sites.

Reducing flood risk requires a pro-active stance on planning and building regulations policy across the Borough. Planning policy and guidelines should be strengthened to include individual homes and driveways as well as larger scale developments.

Policies on the application of:

- presumption against culverting,
- management of urban creep and paving of front-gardens,
- management of runoff from developments on brownfield sites,
- SUDS, and
- raising doorway/access thresholds,

should be linked to Planning and Building Regulations such that these measures are applied pro-actively to new build and retro fitted to established property where the opportunity is available.

The FMWA 2010 requires all development to consider sustainable drainage in its design. Currently Essex County Council has guidance on the adoption of SUDS, providing information on planning, design and delivery of SUDS schemes. It is recommended that a policy on SUDS and existing policies of local flood risk are reviewed in light of the findings of this SWMP. The policy should:

- Ensure that SUDS are employed for the drainage of highways, to a standard allowing them to be adopted by ECC (under current highways powers).
- Ensure that SUDS are considered for the drainage of other areas, and as far as possible are designed to be compliant with the SUDS manual and the emerging National Standards, and that options for their long-term maintenance under the current legislation are explored. Essex County Council already have SUDS adoption procedures in place which enable them to adopt SUDS ahead of the expected enactment of the relevant section of the FWMA.

5.7 Options Assessment – Area Specific Options

The option assessments for specific areas are based on the keys areas of flooding highlighted in section 4.2. For each area a number of measures were assessed for suitability with additional comments regarding the cost and placement of options in the area. It has not been possible for the recommended options to be modelled. The reason for this is that the data provided for use in the study was not of sufficient quality to allow the options to be modelled accurately, particularly in the vicinity of watercourses. With no detailed survey of the watercourses it is difficult to model accurately the impact of particular options. Also many discrepancies have been noted with the sewer network data which make it difficult to recommend options where there are uncertainties in the base data.

Where possible recommendations have been made of possible mitigation options however, these should be investigated in more detail if further information becomes available. The suitability of each mitigation option for the specific areas has been displayed using a traffic light colour system in the summary tables.

Suitability	Description
(red)	There are no opportunities for the mitigation option at this location.
(yellow)	There are opportunities for the mitigation option at the location but is likely either require further modelling to determine exactly locations or that other options are initially explored that would provide greater benefits.
(green)	The mitigation option would be recommended for the location and would reduce flood risk. Further study will be required to determine the scale and scope at which the option can be implemented.

Costing Options

Costing of measures was undertaken using a variety of sources summarised below:

- Spons (2013) Civil Engineering and Highway Works Price Book
- The Environment Agency Flood Risk Management Estimate Guide (2007)
- Stovin & Swan (2007) SUDS Retrofit
- Advice from JBA engineers

Costing of measures is highly indicative and is designed to give an estimate of what such a measure would approximately cost. The cost estimates do not take into account additional costs such as that of land purchase, professional fees, statutory fees, VAT, site supervision and compensation costs. An optimism bias of 60% has been added to the cost of measures derived from the Spons Price Book (2013) and Stovin and Swan (2007) to account for unforeseen complexities in project costs and duration. Costs from the Environment Agency Flood Risk Management Estimate Guide (2007) and Stovin & Swan (2007) were increased to take into account inflation since they were devised.

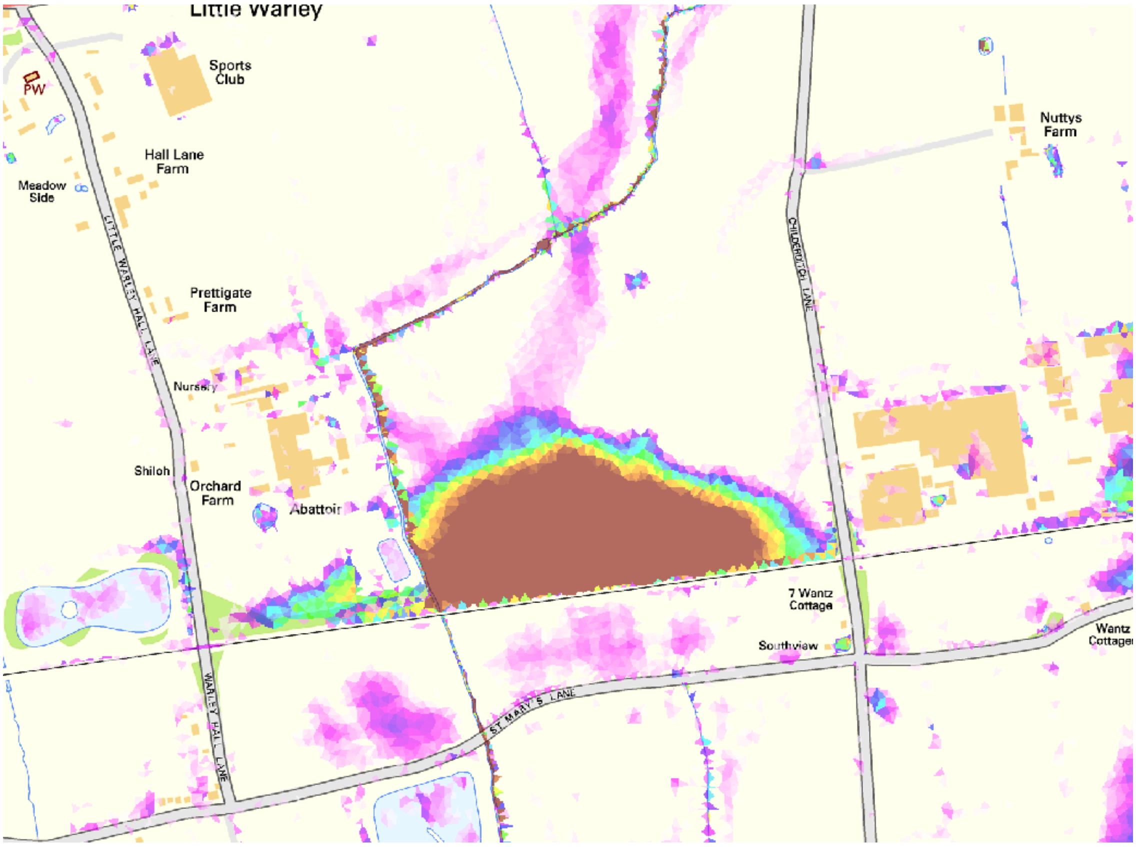
It is recommended that the costs of the recommended measures are revised and refined based on more detailed site specific assessments.

The following tables provide area specific options for the key areas indentified in section 4.2.

This page was left intentionally blank.

5.7.1 West Horndon

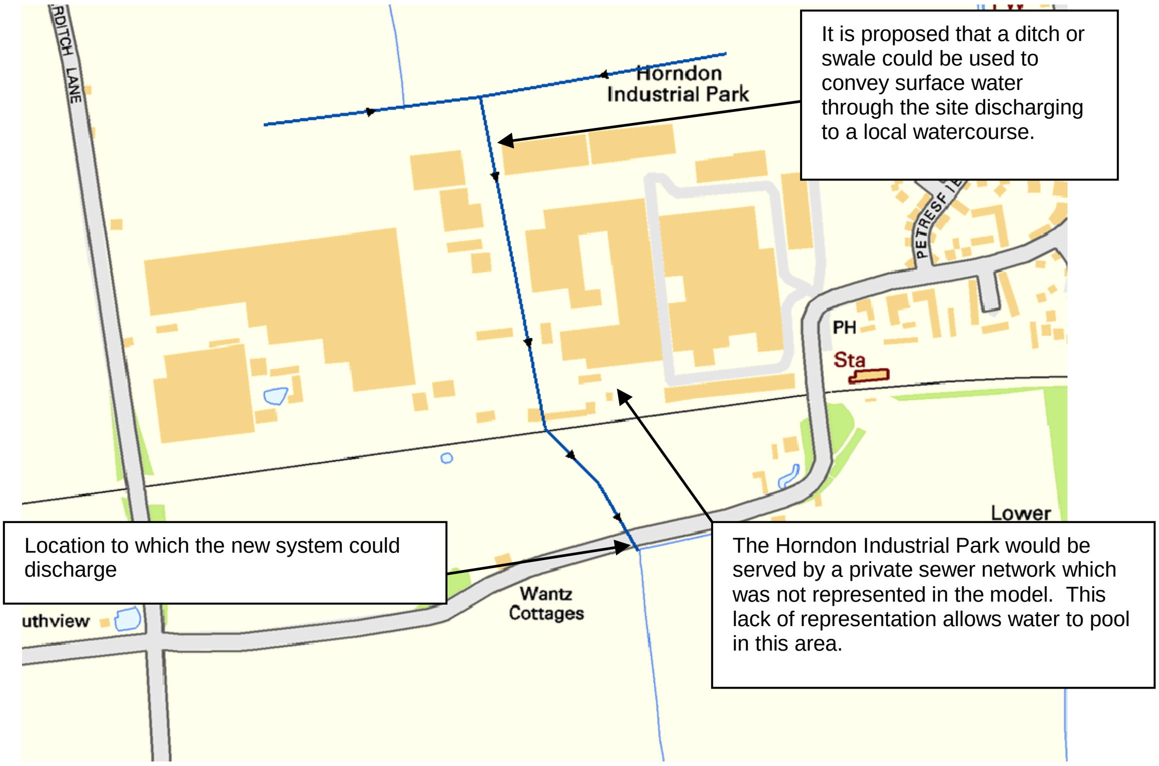
Table 5-8: Area HORN-A - Area West of West Horndon

Location

Comments
This area is predominantly Greenfield in nature. Flooding originates from surface water flow following the topography and pooling against the railway embankment. The culvert under the railway at this location is shown in the modelling not to be surcharge and to perform to a satisfactory level. There are few properties located in this area affected by flooding.
Model Suitability / Improvements
• The model could benefit from improved representation of the watercourses in the area in the future.

Options			Approximate Cost
SUDS / Retrofit SUDS		With few residential properties in the vicinity of the flooding there are no feasible opportunities for SUDS retrofit at this location.	N/A
Property Level Protection (PLP)		With few residential properties in the vicinity of the flooding there are no feasible opportunities for PLP at this location.	N/A
Increase Conveyance		There are no feasible opportunities for increasing conveyance at this location.	N/A
Land Management		It is recommended that this land is allowed to flood	A costing of this measure has not been conducted.
Strategic Storage		There are no feasible opportunities for strategic flood storage at this location.	N/A
Flow Diversion		There are no feasible opportunities for flow diversions at this location.	N/A
Maintenance		No maintenance issues were highlighted in this area during site visits. It is recommended that maintenance regimes continue to ensure there is no increase in flooding.	A costing of this measure has not been conducted.
Flood Defences		There are no feasible opportunities for flood defences at this location.	N/A

Table 5-9: Area HORN-B - Horndon Industrial Park

Location



Comments

The modelling shows surface water pooling against the railway embankment. The surface water originates from farmland located to the north of the industrial site.

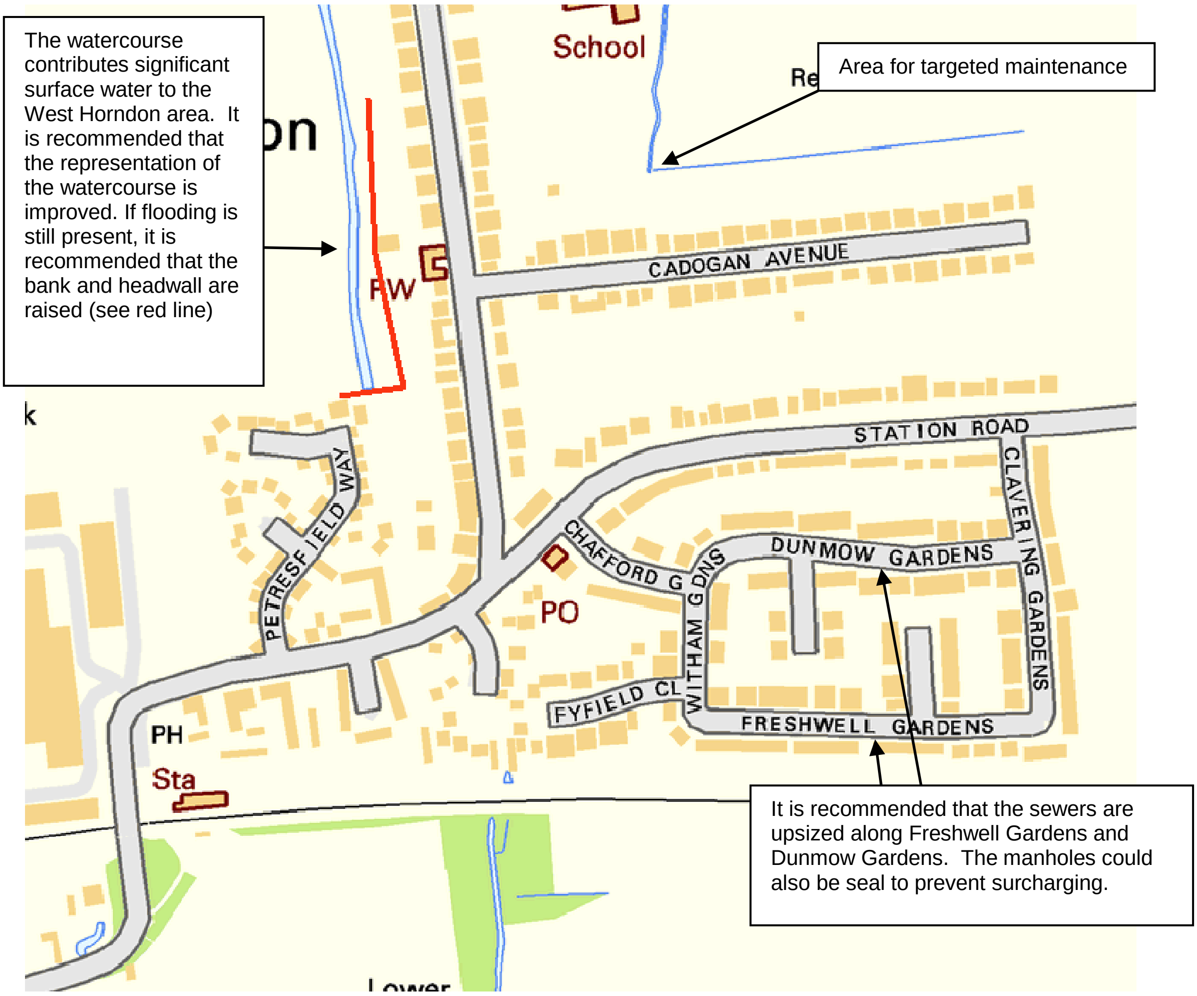
Model Suitability / Improvements

- The model lacks data on the private sewer network that serves the Horndon Industrial Park. It is recommended that data of this network be collected and used to update the model before further options are explored. The inclusion of sewer network may reduce the water levels currently found within the industrial park.
- Mitigation measures have been suggested based on current modelling results but should be revised if further information becomes available.

Options			Approximate Cost
SUDS / Retrofit SUDS		It is recommended opportunities to retrofit SUDS into the industrial park are explored. Industrial parks tend to have car parking suitable for permeable paving and less restricted land available for structures such as swales.	See Section 4.6.1 for estimated costs of implementing SUDS.
Property Level Protection (PLP)		PLP could be explored in this area to prevent against surface flows from the north.	A costing of this measure has not been conducted.
Increase Conveyance		There are opportunities for increasing conveyance of surface water through this area. This idea is explored further in the Flow Diversion section below.	See Flow Diversion below.
Land Management		Land management could be considered to the north in order to reduce the amount of surface water flow travelling towards the railway embankment.	A costing of this measure has not been conducted.
Strategic Storage		There are no feasible opportunities for strategic flood storage at this location.	N/A
Flow Diversion		It is recommended that a ditch could be constructed to the north of the industrial park to intercept surface water flows. This could be conveyed to a watercourse located to the south of the industrial park.	Embankment to north of the industrial estate (approx. length 440m) = £133,047 Channel behind embankment (approx. Length 450m) = £14,983 New culvert linking channel to the unnamed watercourse to the south of the industrial estate. (approx. length 450m x450mm) = £174,347 Total cost = £322,377
Maintenance		There are no known maintenance issues in this area.	N/A
Flood Defences		There are no feasible opportunities for flood defences at this location.	N/A

Table 5-10: Area HORN-C - West Horndon

Location



Comments

The modelling of this area shows flooding to originate from the unnamed watercourse running adjacent to Thorndon Avenue. Surface water also originates from the sewer network surcharging along Freshwell Gardens and Dunmow Gardens. This is caused by the coarsely represented interaction between the sewer outfall and the watercourse. The deepest flooding in this location was located between Freshwell Gardens and the rail embankment. Due to the residential nature of the area there are many mitigation options that could be examined to reduce surface water flood risk.

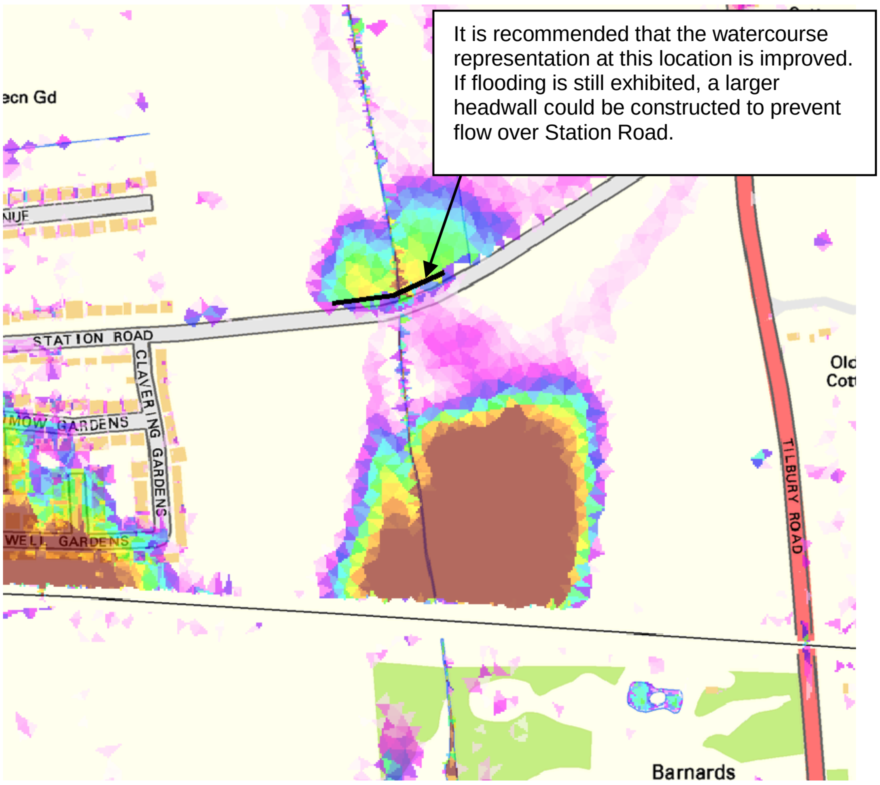
Model Suitability / Improvements

- The model in this location was shown to not represent the watercourse along Thorndon Avenue and to the south of West Horndon particularly well. It is recommended that before optioneering measures are suggested that this aspect of the model is updated and improved. With a large proportion of the surface water flooding originating from these watercourses improved representation could less the severity of flooding.
- Mitigation measures have been suggested based on current modelling results but should be revised if further information becomes available.

Options			Approximate Cost
SUDS / Retrofit SUDS		There are opportunities for SUDS retrofit in this area. SUDS could have a positive effect on the amount of surface water that is conveyed into the sewer network.	See Section 4.6.1 for estimated costs of implementing SUDS.
Property Level Protection (PLP)		It is recommended that this area would be suitable for PLP schemes to prevent or limit the amount of damage caused by surface water flooding particularly in the vicinity of Fyfield Close and Freshwell Gardens.	Freshwell Gardens (120 Properties) = £720,000 Wider West Horndon Area (190 properties) = £902,500
Increase Conveyance		It is proposed the sewer network in Freshwell Gardens and Dunmow Gardens could be upsized to improve conveyance. The culvert running underneath the railway embankment could also be upsized to allow increased flow.	Upsizing the sewer at Freshwell Gardens to 450mm (approx. length 250m) = £103,536
Land Management		There are no feasible opportunities for land management at this location.	N/A
Strategic Storage		There are no feasible opportunities for strategic flood storage at this location.	N/A
Flow Diversion		There are no feasible opportunities for flow diversions at this location.	N/A
Maintenance		The culvert north of Cadogan Avenue was identified during site visits blockage by debris. It is recommended that there is increased maintenance at this location.	A costing of this measure has not been conducted.
Flood Defences		Currently surface water originates from the watercourse running along Thorndon Avenue. If this is still the case following improvements to the representation of the channel it is recommended that the headwall and left bank are raised to prevent surface water flowing into West Horndon.	Flood Wall adjacent to Thorndon Avenue (250m long x 1.2m high) = £118,045

Table 5-11: Area HORN-D - East of West Horndon

Location



Comments

The majority of flooding in this area is generated from the watercourse. This is coarsely represented and therefore can allow water to spill out of the channel at certain locations. As the area is predominately Greenfield there are few risks to people or property.

Model Suitability / Improvements

- The representation of watercourse at this location could be improved in future. However, no properties are flooded within this area
- Mitigation measures have been suggested based on current modelling results but should be revised if further information becomes available.

Options			Approximate Cost
SUDS / Retrofit SUDS		With few residential properties in the vicinity of the flooding there are no feasible opportunities for SUDS retrofit at this location.	N/A
Property Level Protection (PLP)		With few residential properties in the vicinity of the flooding there are no feasible opportunities for PLP at this location.	N/A
Increase Conveyance		There are no feasible opportunities for increasing conveyance at this location.	N/A
Land Management		It is recommended that this land is allowed to flood	A costing of this measure has not been conducted.
Strategic Storage		There are no feasible opportunities for strategic flood storage at this location.	N/A
Flow Diversion		There are no feasible opportunities for flow diversions at this location.	N/A
Maintenance		Maintenance issues were highlighted in this area during site visits. It is recommended that maintenance regimes ensure there is no increase in flooding caused by blockages at Station Road.	A costing of this measure has not been conducted.
Flood Defences		It is recommended that the headwall be increased in height to prevent flooding over Station Road.	Flood Wall on north face of Station Road (120m long x 1.2m high) = £56,661

5.7.2 Ingatestone

Table 5-12: Area INGATE-A - Ingatestone High Street

Location

Comments
This area is shown to mainly flood around the two watercourses running through Ingatestone. Water from these locations then follows surface water routes particularly down the High Street. There are some areas that flood due to incapacity in the sewer network such as at The Furlongs however; this is caused by discrepancies in the sewer data that could be improved at a later data.
Model Suitability / Improvements
• The model is shown in this location to be poor represent the watercourses. It is suggested that due to amount of flooding originating from the two watercourses in Ingatestone that detailed survey is conducted and the model improved before any mitigation measures can be accurately measured. • Although the mitigation measures cannot be modelled at this time a number of recommendations have been provided of what would be suitable at this location which could be investigated further.

Options			Approximate Cost
SUDS / Retrofit SUDS		There are opportunities for retrofit SUDS into Ingatestone to reduce the amount of surface water that is transferred to the sewer network or local watercourses.	See Section 4.6.1 for estimated costs of implementing SUDS.
Property Level Protection (PLP)		It is recommended that PLP schemes are explored particularly in the areas adjacent to the two watercourses travelling through Ingatestone.	PLP Schemes in the vicinity of the two watercourse (approx. 44 properties) = £209,000
Increase Conveyance		There are no feasible opportunities for increasing conveyance at this location.	N/A
Land Management		There are no feasible opportunities for land management at this location.	N/A
Strategic Storage		An area to the north west of Ingatestone has been identified as a location of strategic flood storage. At this location water could be attenuated and reduce the flood extent further downstream.	A costing of this measure has not been conducted.
Flow Diversion		There are no feasible opportunities for flow diversions at this location.	N/A
Maintenance		Maintenance regimes should be targeting culverts within Ingatestone to prevent flooding relating to blockage.	A costing of this measure has not been conducted.
Flood Defences		There are no feasible opportunities for flood defences at this location.	N/A

Table 5-13: Area INGATE-B - A12 Ingatestone By-Pass

Comments

The model shows the southern carriageway is the primary route for surface water flow. However flooding at this location is likely to be over exaggerated due to the lack of highway drainage data. It does give an indication of possible flow routes if the highway drainage network were to become blocked.

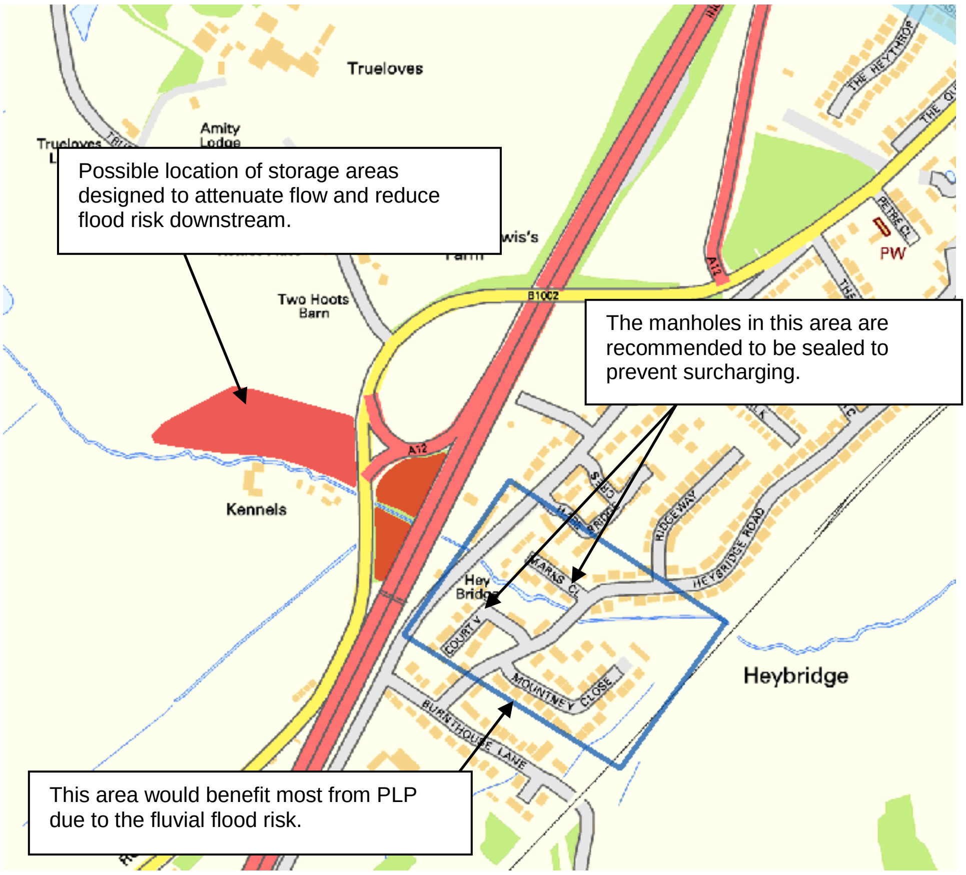
Model Suitability / Improvements

- Improved representation of the highway drainage by inclusion of highway drainage data.
- Mitigation measures have been suggested based on current modelling results but should be revised if further information becomes available.

Options			Approximate Cost
SUDS / Retrofit SUDS		There are no feasible opportunities for SUDS retrofit at this location.	N/A
Property Level Protection (PLP)		There are no feasible opportunities for PLP at this location.	N/A
Increase Conveyance		There are no feasible opportunities for increasing conveyance at this location.	N/A
Land Management		There are no feasible opportunities for land management at this location.	N/A
Strategic Storage		An area to the north west of Ingatestone (identified in Area A) has been identified as a location of strategic flood storage. At this location water could be attenuated and reduce the flood extent further downstream	A costing of this measure has not been conducted.
Flow Diversion		There are no feasible opportunities for flow diversions at this location.	N/A
Maintenance		Maintenance should ensure that the highway drainage is working effectively and clear from blockage. Modelling highlights that the A12 could become a surface water flow route worsening flooding elsewhere.	A costing of this measure has not been conducted.
Flood Defences		There are no feasible opportunities for flood defences at this location.	N/A

Table 5-14: Area INGATE-C - Heybridge, Ingatestone

Location



Comments

Flooding in this area is shown to be mainly fluvial in nature with current flood zones covering the most affected roads (notably Marks Closes, Court View and Heybridge Road). Flooding in this area relates to the sewer network which discharges at various locations in the watercourse, backing up due to high water levels at the outfalls. There are also a number of surface water pathways which originate from the A12 by-pass and along Roman Road which contribute surface water to the area.

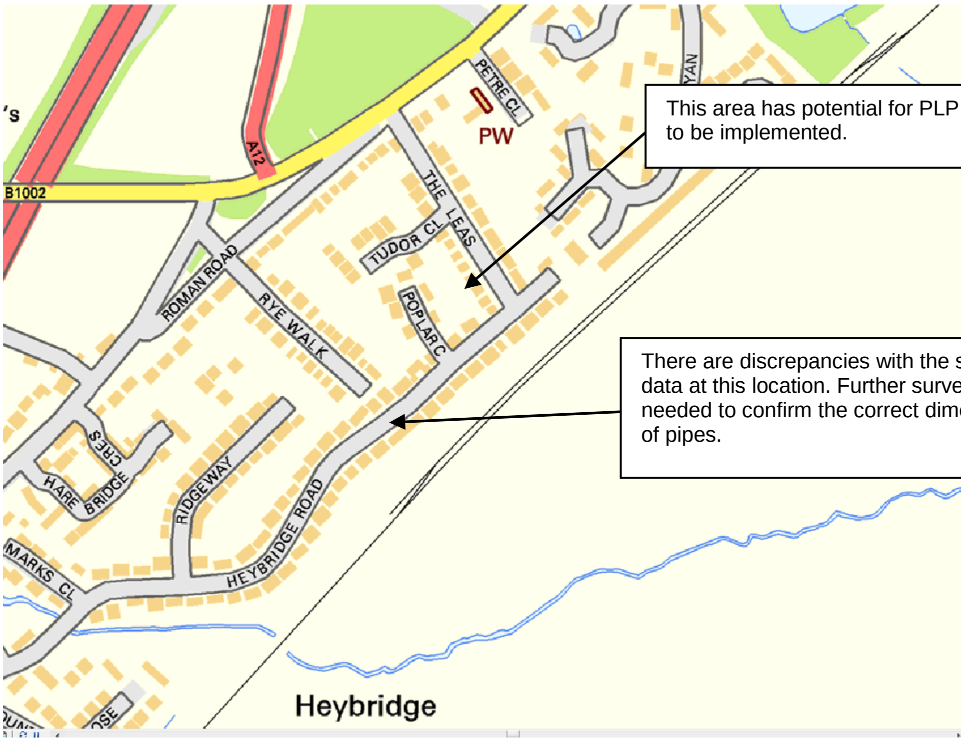
Model Suitability / Improvements

- Improve the representation of highway drainage which contributes surface water to the area.
- Mitigation measures have been suggested based on current modelling results but should be revised if further information becomes available.

Options			Approximate Cost
SUDS / Retrofit SUDS		Opportunities to retrofit SUDS in the area should be explored in order to reduce the amount of water entering the sewer network and local watercourse.	See Section 4.6.1 for estimated costs of implementing SUDS.
Property Level Protection (PLP)		An area in the vicinity of the watercourse (Marks Close, Court View and Heybridge Road) would be suitable for PLP. This would be beneficial particular because of the area being located in Flood Zone 2.	PLP schemes in the vicinity of the watercourse in Heybridge (approx. 57 properties) = £270,750
Increase Conveyance		There are no feasible opportunities for increasing conveyance at this location. Increasing conveyance in this location would increase in flood risk further downstream.	N/A
Land Management		It is recommended that areas upstream of Heybridge on the left bank and in unused areas of the A12 junction be considered to be storage areas. Attenuation of water at these locations would aim to reduce flood risk further downstream.	A costing of this measure has not been conducted.
Strategic Storage		It is recommended that areas upstream of Heybridge on the left bank and in unused areas of the A12 junction be considered to be storage areas. Attenuation of water at these locations would aim to reduce flood risk further downstream.	A costing of this measure has not been conducted.
Flow Diversion		There are no feasible opportunities for flow diversions at this location.	N/A
Maintenance		Maintenance should ensure that the highway drainage is working effectively and clear from blockage. Modelling highlights that the A12 is a surface water flow route to the area. Maintenance should also target culverts within the residential area to prevent blockage.	A costing of this measure has not been conducted.
Flood Defences		Opportunities could be investigated if fluvial flooding continues to be a problem in this area. To confirm this, a more detailed study would be required outside of the scope of this study.	A costing of this measure has not been conducted.

Table 5-15: Area INGATE-D - Poplar Close

Location



Comments

Flooding in this area relates to the surcharging of the sewer network. This surcharging is caused from surface water flowing into the sewer network and the increase in water levels in the watercourse causing water to back up within the sewer network. It was noted at this location a number of discrepancies with sewer data which should be investigated further.

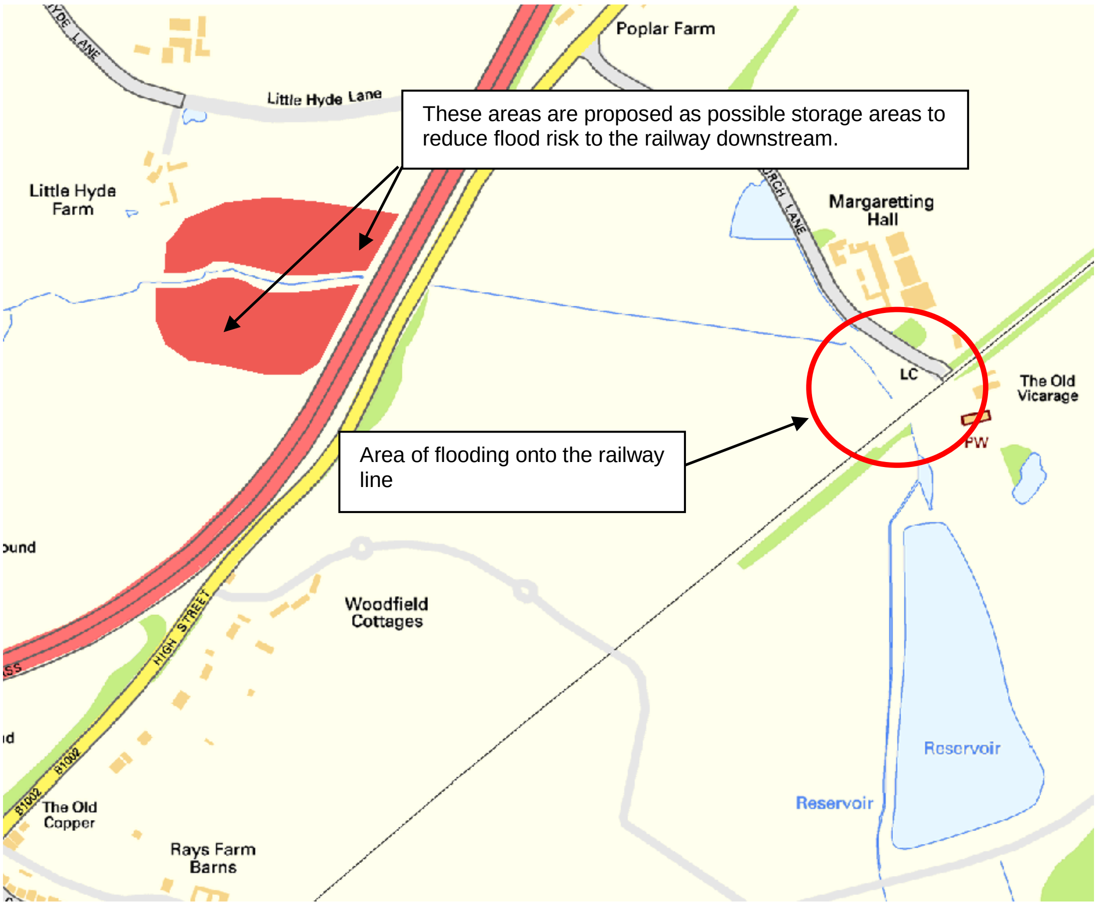
Model Suitability / Improvements

- Further investigation of the sewer network in the vicinity of Heybridge Road. There are a number of different pipe sizes at this location which constrict flow. Survey should confirm the dimensions of the pipes and if incorrect allow the model to be updated.

Options			Approximate Cost
SUDS / Retrofit SUDS		Opportunities to retrofit SUDS in the area should be explored in order to reduce the amount of water entering the sewer network and local watercourse.	See Section 4.6.1 for estimated costs of implementing SUDS
Property Level Protection (PLP)		The area surround Poplar Close could be investigated for suitable of PLP schemes. However, other measures may reduce flooding in this area reducing the need for PLP. Properties on Heybridge Road would also benefit from PLP due to their proximity to the watercourse.	PLP in the vicinity of Poplar Close (approx. 65 properties) = £308,750
Increase Conveyance		At this location a number of small pipes are shown to be have insufficient capacity. If further survey confirms these are the correct dimensions then these pipes along Heybridge Road / Poplar Close should be up-sized.	Increasing the sewer capacity to 450mm along Heybridge Road (approx. Length 350m) = £144,917
Land Management		There are no feasible opportunities for land management at this location.	N/A
Strategic Storage		There are no feasible opportunities for strategic flood storage at this location.	N/A
Flow Diversion		There are no feasible opportunities for flow diversions at this location.	N/A
Maintenance		There are no maintenance issues at this location.	N/A
Flood Defences		There are no feasible opportunities for flood defences at this location.	N/A

Table 5-16: Area INGATE-E - Ingatestone Railway Line

Location



Comments

The north-east section of railway line is shown to flood for all return periods. Flooding extends from the railway station, (in vicinity of Halls Lane) in a north-easterly direction, reaching the edge of the model domain. Unfortunately no drainage network information was supplied for the railway; therefore if future more information becomes available the modelling should be rerun to reassess the flood risk. The current modelling results however give an indication of what might happen if the railway drainage network were to become compromised.

Model Suitability / Improvements

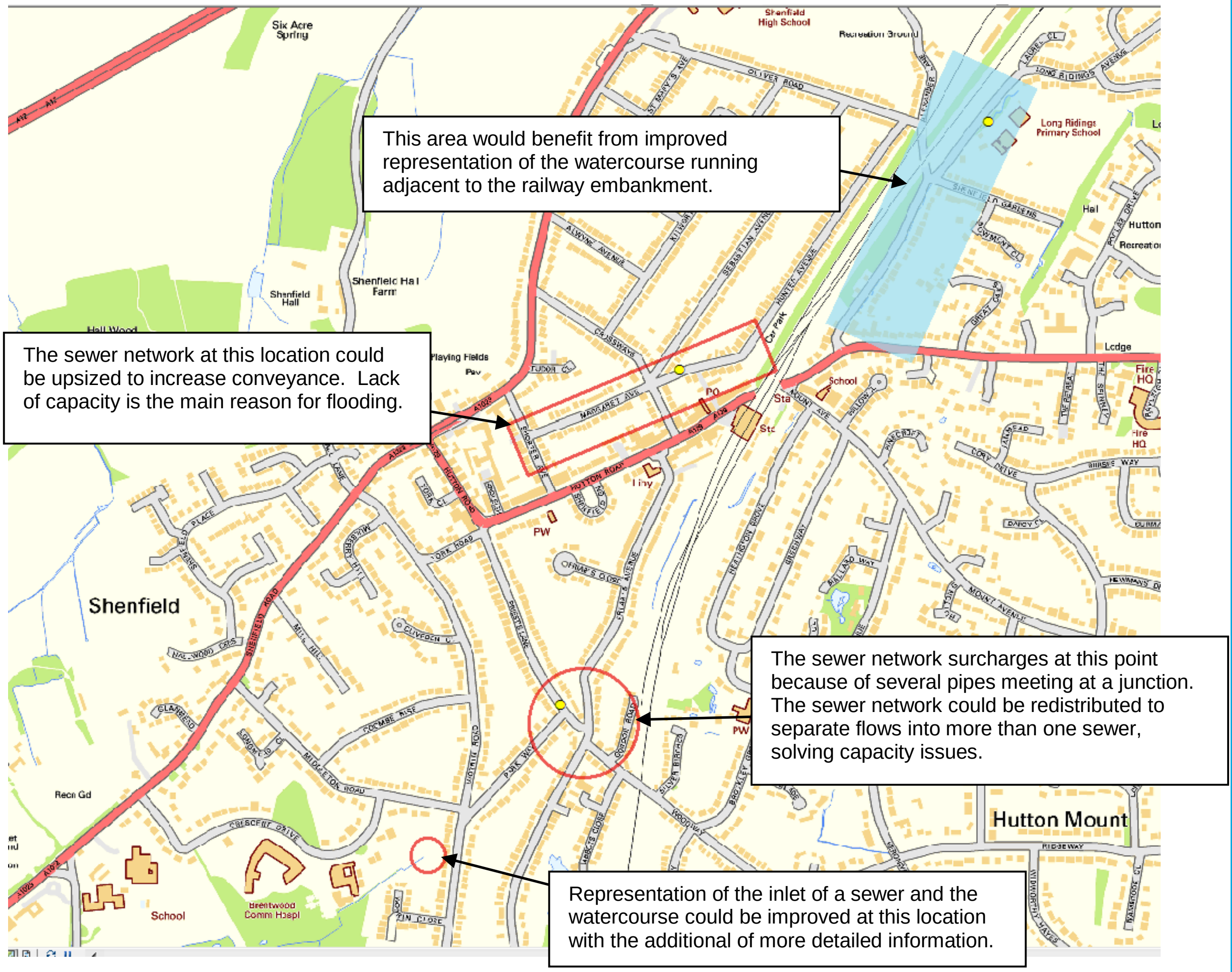
- Railway drainage networks data was not available and therefore could improve the model accurate if added at a later date.
- The watercourse is coarsely represented and would require more accurate modelling to justify detailed mitigation measures.
- Mitigation measures have been suggested based on current modelling results but should be revised if further information becomes available.

Options			Approximate Cost
SUDS / Retrofit SUDS		There are no feasible opportunities for SUDS retrofit at this location.	N/A
Property Level Protection (PLP)		There are no feasible opportunities for PLP at this location.	N/A
Increase Conveyance		There are no feasible opportunities for increasing conveyance at this location. Increasing conveyance at either the culvert under the A12 or under the rail embankment as it would increase flood risk downstream.	N/A
Land Management		It is recommended that the opportunity to create flood storage on the western side of the A12 is explored to reduce flood risk downstream.	A costing of this measure has not been conducted.
Strategic Storage		It is recommended that the opportunity to create flood storage on the western side of the A12 is explored to reduce flood risk downstream.	A costing of this measure has not been conducted.
Flow Diversion		There are no feasible opportunities for flow diversions at this location.	N/A
Maintenance		Maintenance should ensure that the railway drainage network is working effectively and is clear of blockages.	A costing of this measure has not been conducted.
Flood Defences		There are no feasible opportunities for flood defences at this location.	N/A

5.7.3 Brentwood

Table 5-17: Area BRENT-A - Brentwood High Street

Location



Comments
Flooding in this location relates to both the sewer network surcharge due to incapacity and flooding from local watercourses. Initially flooding originates from a watercourse overtops the inlet to the sewer system and proceeds to flow along Park Way. At the end of Park Way the water surcharges the sewer network with water pooling at the junction with Priest Lane. The flooding then follows the local watercourse, filling sewers to capacity at several locations. There are also conveyance issues on Margaret Avenue where the sewer surcharges and flooding collects in a depression on Hunter's Avenue.

Model Suitability / Improvements

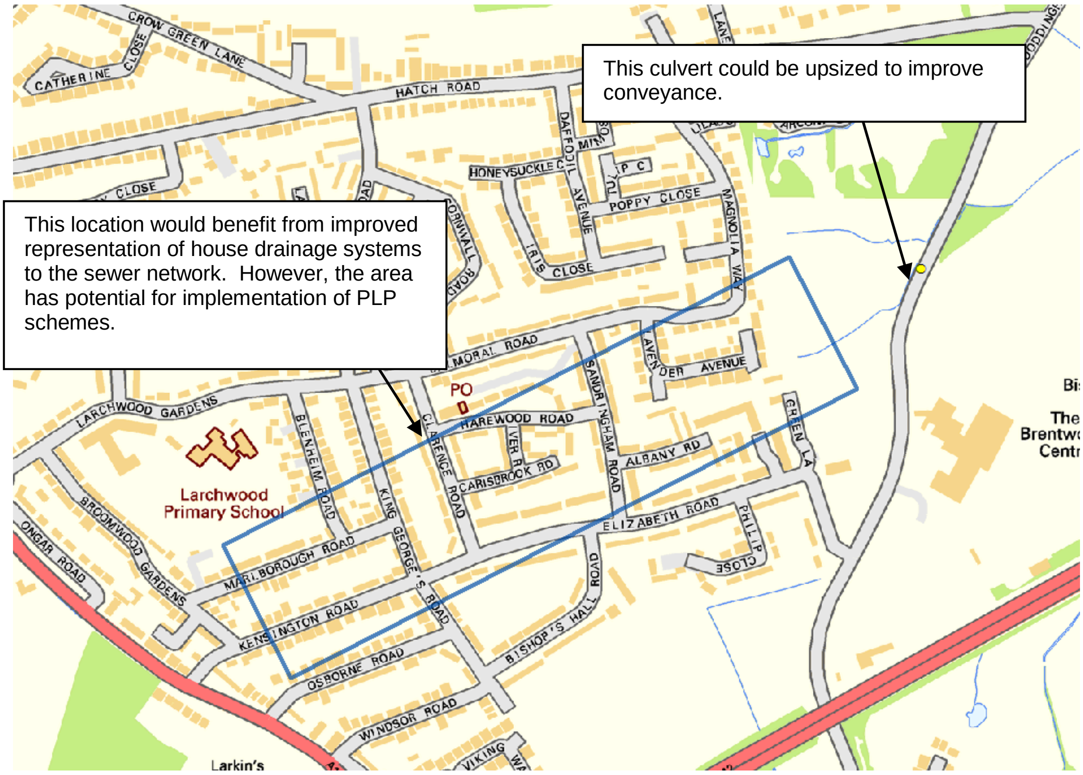
- Railway drainage networks data was not available and therefore could improve the model accurate if added at a later date.
- The watercourse is coarsely represented and would require more accurate modelling to justify detailed mitigation measures. Improvements could be made to the interaction between the sewer network and the watercourses if more detailed data was available, possibly reducing flooding.
- Mitigation measures have been suggested based on current modelling results but should be revised

if further information becomes available.

Options			Approximate Cost
SUDS / Retrofit SUDS		There are opportunities for retrofitting SUDS to reduce the volume of surface water that is conveyed by the sewer network.	See Section 4.6.1 for estimated costs of implementing SUDS.
Property Level Protection **(PLP)**		There are opportunities for PLP for properties in close proximity to the watercourse. However, before this is recommended more detailed or improved representation of the watercourses would be needed.	A costing of this measure has not been conducted.
Increase Conveyance		There are a number of locations where conveyance could be increased. The first is Margaret Avenue where the sewer is shown to surcharge and therefore would benefit from upsizing of the pipe network. Another location is at the junction of Park Way and Priest Lane where several culverts join into a singular pipe. At this location it is recommended that the culverts a split up and diverted so that fewer culverts join at the same location, reducing the chance of surcharging.	Upsizing the sewer at Margaret Avenue to 450mm piping (approx. Length 450) = £186,365 Redirecting sewer piping at the junction of Park Way and Priest Lane by installing a new 450mm pipe to convey some flow to Hunter Avenue by an alternative route (approx. Length 50m) = £20,702
Land Management		There are no feasible opportunities for land management at this location.	N/A
Strategic Storage		There are no feasible opportunities for strategic flood storage at this location.	N/A
Flow Diversion		There are no feasible opportunities for flow diversions at this location.	N/A
Maintenance		Maintenance should be conducted to ensure that the drainage systems are function effectively.	A costing of this measure has not been conducted.
Flood Defences		A flood wall could be constructed at the inlet of the sewer network (at the west end of Park Way) to prevent overtopping from the watercourse.	Flood wall at the inlet of the sewer network, west of Park Way (approx. 1.20m high and 30m in length) = £14,165

Table 5-18: Area BRENT-B - Pilgrims Hatch

Location



Comments

Throughout this area the majority of the sewer network is shown not to surcharge with the likely course of flooding being that surface water is following the natural topography. This flooding is likely to be more extreme than in reality with the interaction between the housing and the sewer network not effectively represented due to the broad scale nature of the modelling approach. Being a residential area there are numerous opportunities for retrofitting SUDS and possible PLP schemes.

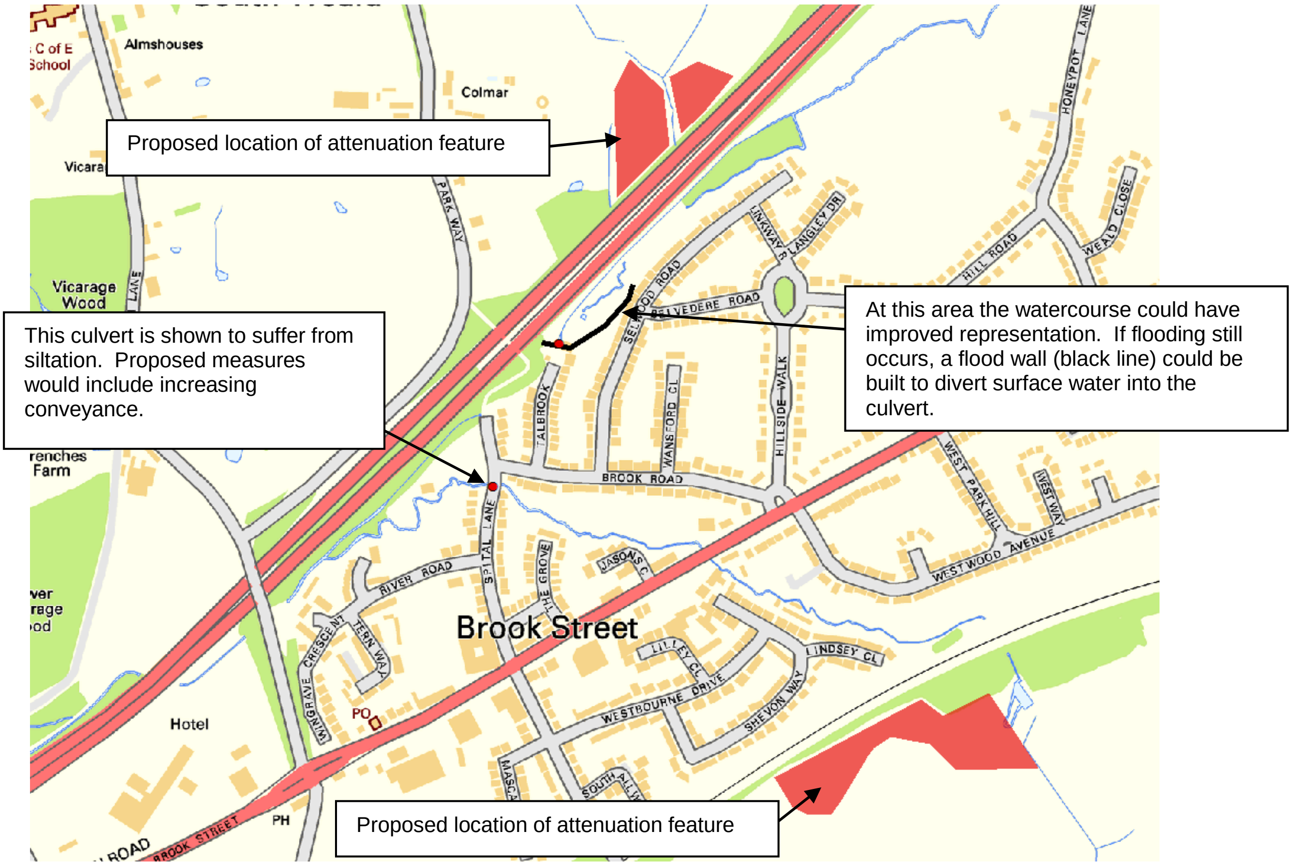
Model Suitability / Improvements

- Improve the representation of housing drainage network and the sewer network.
- Mitigation measures have been suggested based on current modelling results but should be revised if further information becomes available.

Options			Approximate Cost
SUDS / Retrofit SUDS		Opportunities to retrofit SUDS in the area should be explored in order to reduce the amount of water entering the sewer network and local watercourse.	See Section 4.6.1 for estimated costs of implementing SUDS.
Property Level Protection (PLP)		There are opportunities for PLP in the area highlighted above. However, improved representation of the housing drainage network to the sewer by dramatic reduce the level of flooding and the need for PLP.	A costing of this measure has not been conducted.
Increase Conveyance		Increased conveyance is recommended at the Doddinghurst Road culvert in order to prevent water backing up behind the structure.	Upsizing the culvert under Doddinghurst Road using a pre-cast concrete culvert (10m in length and 1.2m wide) = £108,000
Land Management		There are no feasible opportunities for land management at this location.	N/A
Strategic Storage		There are no feasible opportunities for strategic flood storage at this location.	N/A
Flow Diversion		There are no feasible opportunities for flow diversions at this location.	N/A
Maintenance		Maintenance should be conducted to ensure that the drainage systems are functioning effectively.	A costing of this measure has not been conducted.
Flood Defences		There are no feasible opportunities for flood defences at this location.	N/A

Table 5-19: Area BRENT-C - Brook Street, Brentwood

Location



Comments

Flooding at this location is originates from fluvial sources. The first is from the watercourse north of Talbrook. This relates to the coarse representation of the watercourse within the model. The second is at Spital Lane where siltation (represented within the model) causes water to overtop the culvert and flow over the road. Further downstream the culvert under Wigley Bush Lane appears to be operating normally. There are numerous opportunities for mitigation options such as SUDS, PLP and improving conveyance. In the wider area there are also opportunities to offer additional flood storage in an attempt to decrease flood risk downstream.

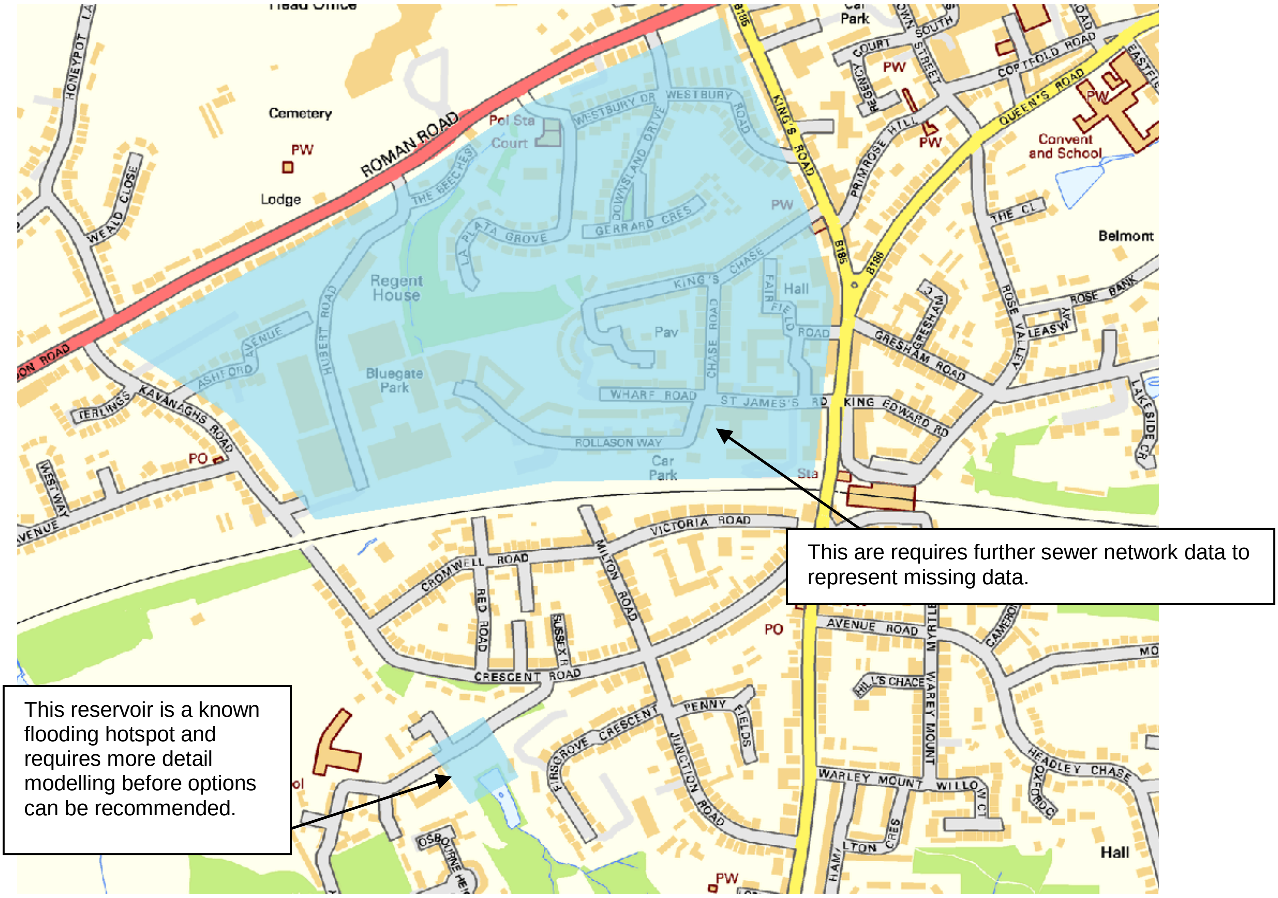
Model Suitability / Improvements

- Improve the representation of the watercourses, particular the one adjacent to Selwood Road.
- Limited data of the sewer network was supplied for Brook Street. This would likely intercept a number of surface water flow routes and limited the number flooded properties in the area. This makes it difficult to model mitigation options in this area.
- Mitigation measures have been suggested based on current modelling results but should be revised if further information becomes available.

Options			Approximate Cost
SUDS / Retrofit SUDS		The residential nature of the development makes this an area that would be suitable for SUDS retrofit.	See Section 4.6.1 for estimated costs of implementing SUDS.
Property Level Protection (PLP)		Due to the proximity of residential properties to the floodplain PLP would be an option to explore at this location. In particular Brook Road, Spital Lane and Talbrook could benefit from PLP.	PLP in the vicinity of Brook Road, Spital Lane and Talbrook (approx. 75 properties) = £356,250
Increase Conveyance		The culvert at Spital Lane was shown during the site visits to be heavily silted. This location would benefit from behind upsized to provide extra capacity.	Upsizing the culvert under Spital Lane using a pre-cast concrete culvert (10m in length and 1.2m wide) = £126,000
Land Management		It is proposed that to reduce the amount of flooding in Brook Street that a number of storage areas are created. The first is north of Brook Street on the western side of A12. This would reduce the flow downstream and reduce flood risk. The second area is on the east side of the railway embankment, south-east of Brook Street. This area is already shown to flood and therefore would be a good candidate for sacrificed for attention storage.	A costing of this measure has not been conducted.
Strategic Storage		Two storage areas are proposed. The first is north of Brook Street on the western side of A12. The second area is on the east side of the railway embankment, south-east of Brook Street. This would both aim to reduce the flow into Brook Street and reduce flood risk.	A costing of this measure has not been conducted.
Flow Diversion		There are no feasible opportunities for flow diversions at this location.	N/A
Maintenance		The culvert at Spital Lane was shown during the site visits to be heavily silted. This was represented in the model and resulted in flows over Spital Lane. It is recommended that this area is consistently targeted for maintenance to prevent blockage or reducing in culvert capacity	A costing of this measure has not been conducted.
Flood Defences		The model should initially be re-run with improved representation of the watercourse adjacent to Selwood Road. If flooding still originates from this location a flood wall could be constructed (See above image) to divert flow back into the culvert, protecting Selwood Road and Talbrook.	Flood wall at the inlet of the sewer network, adjacent to Selwood Road (approx. 1.20m high and 150m in length) = £70,800

Table 5-20: Area BRENT-D - Area surrounding Brentwood Station

Location



Comments

Flooding in this area originates from two main locations. The first is from a reservoir in Warley which is shown to overtop and flood Crescent Road. The second point is from the north of the railway line where there is little to no sewer network representation due to incomplete datasets. The railway line also does not have drainage systems represented. It therefore makes determining if flooding in this area is realistic and therefore it is not appropriate to use in assessing mitigation options

Model Suitability / Improvements

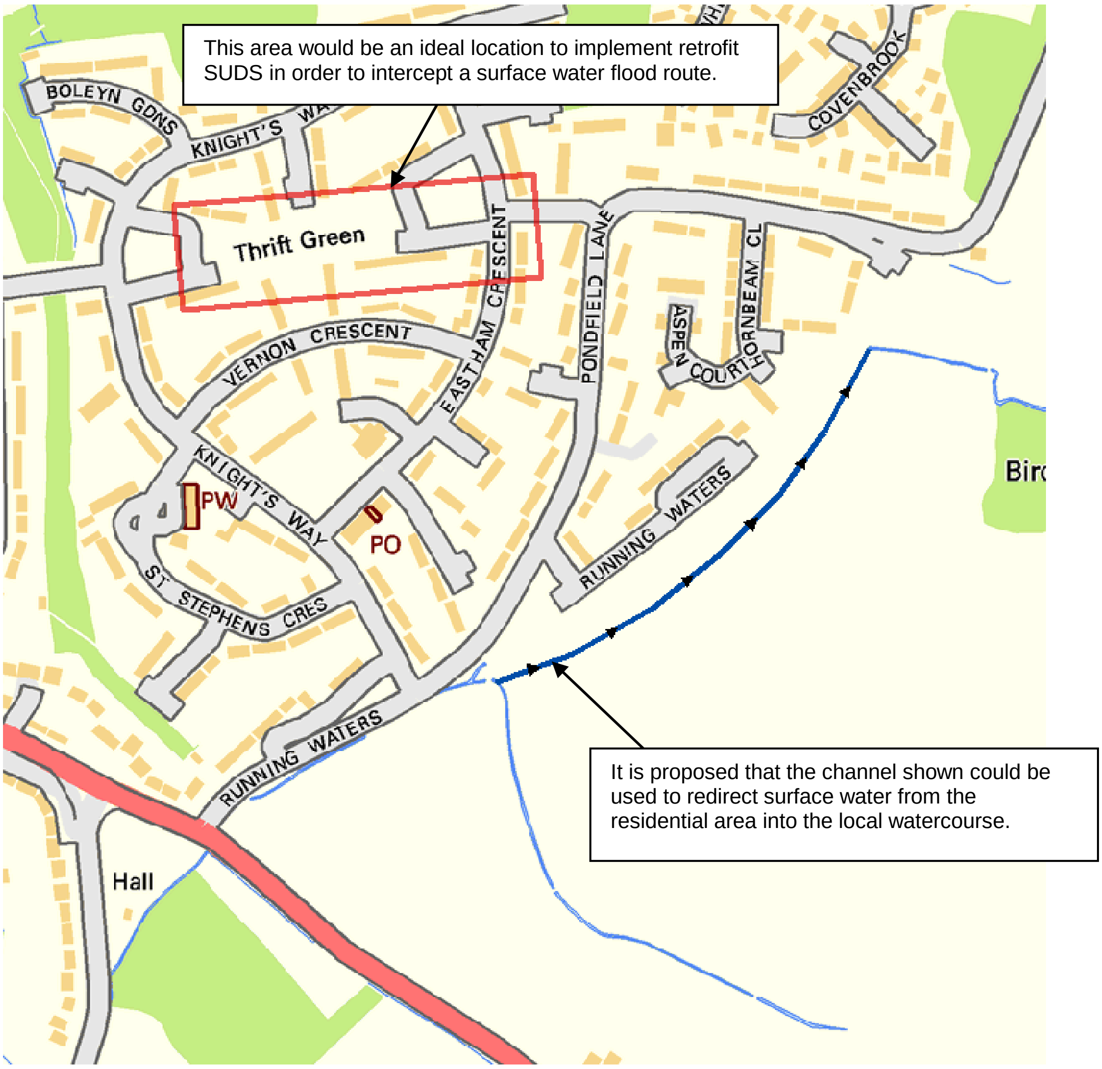
- Improve the representation of the reservoir in Warley.
- Limited data of the sewer network was supplied large sections of this area. This would likely intercept a number of surface water flow routes and limited the number flooded properties in the area. This makes it difficult to model mitigation options in this area.
- Railway drainage networks data was not available and therefore could improve the model accurate if added at a later date.
- Mitigation measures have been suggested based on current modelling results but should be accompanied by a detailed assessment if they are too considered for specific areas.

Options			Approximate Cost
SUDS / Retrofit SUDS		There are opportunities in this area to retrofit SUDS into the residential area to further reduce the amount of surface water entering the sewer network. Unfortunately due to the lack of sewer data it is impossible to target troublesome areas	See Section 4.6.1 for estimated costs of implementing SUDS.
Property Level Protection (PLP)		PLP are unlikely to be applicable in this area. It is also difficult to recommend a location where they would be applicable due to the lack of sewer data.	A costing of this measure has not been conducted.
Increase Conveyance		Without accurate data on where large sections of the sewer network are located no increases in conveyance can be recommended.	A costing of this measure has not been conducted.
Land Management		There are no feasible opportunities for land management at this location.	N/A
Strategic Storage		There are no feasible opportunities for strategic flood storage at this location.	N/A
Flow Diversion		There are no feasible opportunities for flow diversions at this location.	N/A
Maintenance		It is recommended that the highway drainage network is regularly inspected to ensure it is working effectively. The railway has been shown to be the source of a surface flow route.	A costing of this measure has not been conducted.
Flood Defences		Following further survey of the lake in Warley flood defences could be created to prevent water spilling out of the lake. This is a known flooding hotspot.	A costing of this measure has not been conducted.

Table 5-21: Area BRENT-E - Brentwood Railway Line

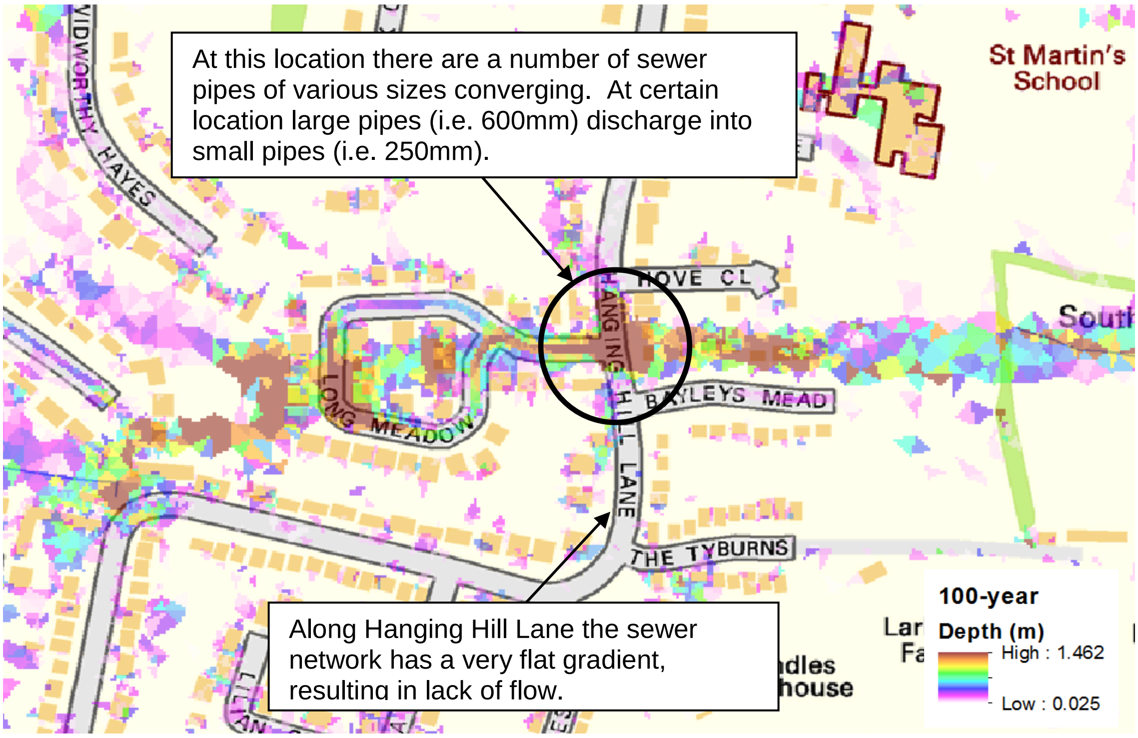
Comments			
The railway line is shown to flood between Shenfield Station and Brentwood Station. Flooding is shown to spill out of the railway line at low points located in both stations car parks. Unfortunately the railway drainage network was not represented and therefore these flows may be large than they would be in reality. It is recommended that improves are made to the model, including the missing data to determine a realistic picture of surface water flow paths.			
Model Suitability / Improvements			
• Railway drainage networks data was not available and therefore could improve the model accurate if added at a later date. • Mitigation measures have been suggested based on current modelling results but should be revised if further information becomes available.			
Options			**Approximate Cost**
SUDS / Retrofit SUDS	(red)	There are no feasible opportunities for SUDS retrofit at this location.	N/A
Property Level Protection (PLP)	(red)	There are no feasible opportunities for PLP at this location.	N/A
Increase Conveyance	(red)	There are no feasible opportunities for increasing conveyance at this location.	N/A
Land Management	(red)	There are no feasible opportunities for land management at this location.	N/A
Strategic Storage	(red)	There are no feasible opportunities for strategic flood storage at this location.	N/A
Flow Diversion	(red)	There are no feasible opportunities for flow diversions at this location.	N/A
Maintenance	(green)	Maintenance should ensure that the railway drainage network is working effectively and is clear of blockages.	A costing of this measure has not been conducted.
Flood Defences	(red)	There are no feasible opportunities for flood defences at this location.	N/A

Table 5-22: Area BRENT-F - Thrift Green, Brentwood

Location

Comments
Surface water contributes to this area from the west along Thrift Green and south-west along Running Waters. Sewers in this location are shown not to be surcharging even though there is surface water flooding.
Model Suitability / Improvements
• Improve the representation of the watercourses. • Improve the representation of housing drainage network and the sewer network. • Mitigation measures have been suggested based on current modelling results but should be revised if further information becomes available.

Options			Approximate Cost
SUDS / Retrofit SUDS		It is recommended that SUDS are used in the open areas around Thrift Green (as highlighted above) to intercept surface water flows. Retrofit SUDS would also reduce the amount of surface water that would be entering the existing sewer network.	See Section 4.6.1 for estimated costs of implementing SUDS.
Property Level Protection (PLP)		It is suggested that PLP could be investigated on Running Water. However, this is not the preferred option. The preferred option is the diversion of the channel around Running Waters.	A costing of this measure has not been conducted.
Increase Conveyance		It is recommended that conveyance is increased within the watercourse to allow water leave the area more efficiently.	See Flow Diversion below.
Land Management		There are no feasible opportunities for land management at this location.	N/A
Strategic Storage		There are no feasible opportunities for strategic flood storage at this location.	N/A
Flow Diversion		The prefer option at this location would be to construct a channel to divert water around Running Waters and into a watercourse located at Birches Wood. This would remove a surface water pathway through a residential area.	New diversion channel (approx. Length 380m) = £91,200
Maintenance		Maintenance should be considered along the watercourses in the area to ensure they have maximised conveyance. They may include removing debris and cleaning vegetation.	A costing of this measure has not been conducted.
Flood Defences		There could be scope for flood defences such as flood walls to prevent water coming out of bank. These should only be investigated when the watercourse representation is improved in the model.	A costing of this measure has not been conducted.

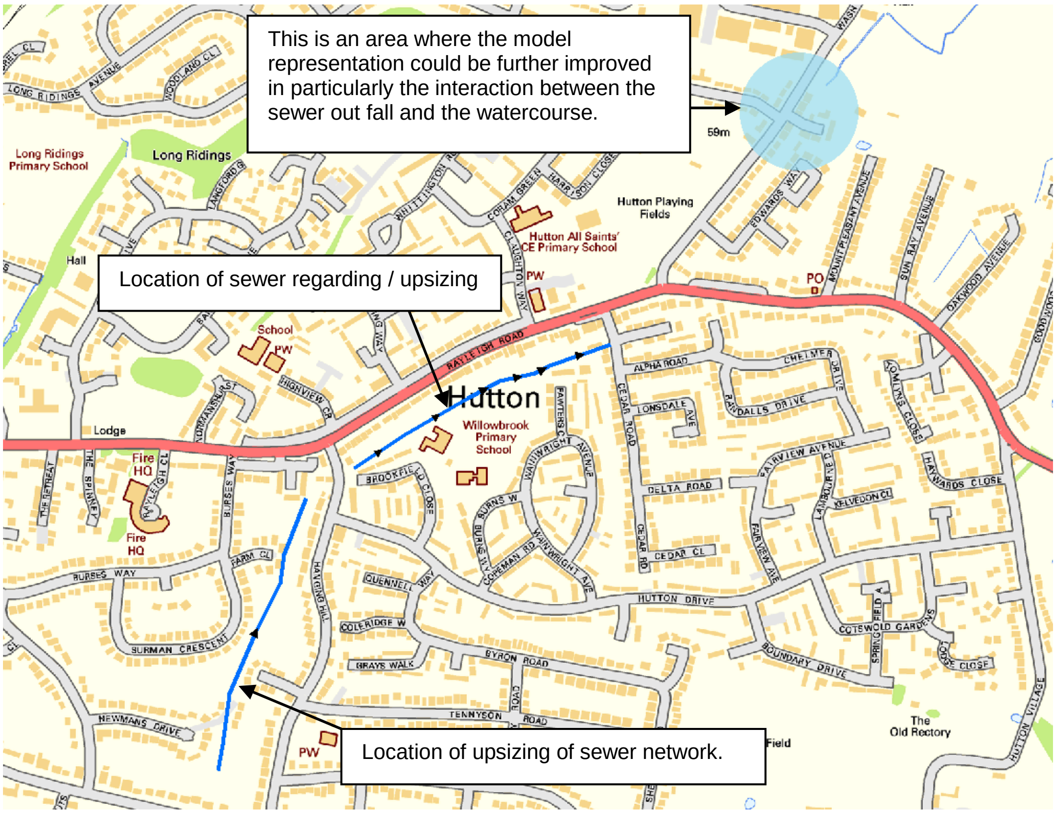
Table 5-23: Area BRENT-G - Hanging Hill Lane, Brentwood

Location

Comments
Flooding in this area relates to areas of flat or shallow gradient piping as well as undersized pipes at the junction of Hanging Hill Lane and Long Meadow. Surface water appears to follow the topography before re-joining with a local watercourse, east of the residential development. The primary mitigation measure is recommended to be increasing conveyance in the sewer network.
Model Suitability / Improvements
• The model is deemed to be suitable for this location. Additional checks could be conducted at this location to confirm the sizes of pipes before mitigation measures are recommended.

Options			Approximate Cost
SUDS / Retrofit SUDS		Source control retrofit SUDS could be used at this location to reduce the amount of surface water that is generated.	See Section 4.6.1 for estimated costs of implementing SUDS.
Property Level Protection (PLP)		PLP measures should only be considered if other measures are not suitable.	A costing of this measure has not been conducted.
Increase Conveyance		It is recommended that there is up-sizing of the pipe network at Long Meadow and re-grading of the flatter piping on Hanging Hill Lane.	Upsizing the sewer at Long Meadow to 450mm piping (approx. Length 200m) = £82,810 Installing new 450mm sewer piping at Hanging Hill Lane (approx. Length 150m) = £62,107
Land Management		There are no feasible opportunities for land management at this location.	N/A
Strategic Storage		There are no feasible opportunities for strategic flood storage at this location.	N/A
Flow Diversion		There are no feasible opportunities for flow diversions at this location.	N/A
Maintenance		There are no maintenance issues at this location. However, regular maintenance should be conducted to ensure the sewer network is functioning correctly.	A costing of this measure has not been conducted.
Flood Defences		There are no feasible opportunities for flood defences at this location.	N/A

Table 5-24: Area BRENT-H - Hutton

Location



Comments

At this location the main cause of flooding is the sewer network with pipes either having too flat a gradient or being an insufficient size. There are also issues where the sewer network discharges into a local watercourse in the vicinity of Edwards Way. There are opportunities for improving conveyance as well retrofitting SUDS into the residential areas in order to reduce the volume of runoff generated.

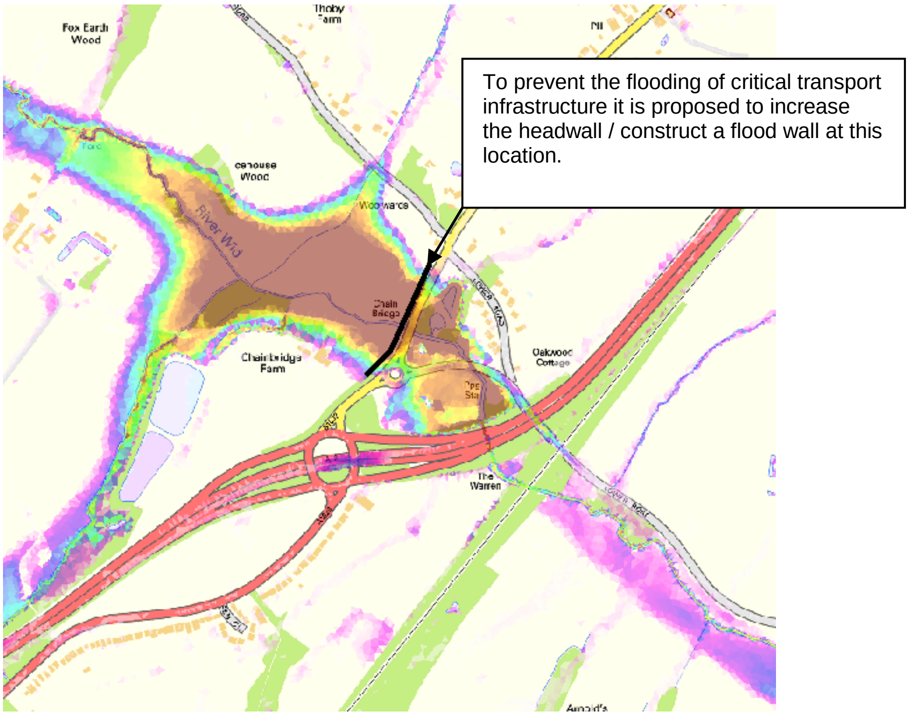
Model Suitability / Improvements

- Improve the representation of the watercourses, particular in the vicinity of Edwards Way where the sewer network outfalls into a watercourse.
- Mitigation measures have been suggested based on current modelling results but should be revised if further information becomes available.

Options			Approximate Cost
SUDS / Retrofit SUDS	(green)	There are opportunities to retrofit SUDS into the residential developments. This would aim to reduce the volume of surface water produced and reduce the volume that was connected to the sewer network in the area.	See Section 4.6.1 for estimated costs of implementing SUDS.
Property Level Protection (PLP)	(green)	Opportunities for PLP could be explored especially in the vicinity of Edwards Way	PLP in the vicinity of Edwards Way (approx. 37 properties) = £175,750
Increase Conveyance	(green)	Conveyance can be increased in a number of locations. The sewer could be up-sized in the vicinity of Surman Way. At this location the sewer pipes are shown to surcharge. And cause overland flows. Another location would be north of Willowbrook Primary School. At this location the sewer has a very flat gradient which would benefit from regarding to encourage more flow and less pooling within the pipe network.	Upsizing the sewer adjacent to Hanging Hill to 450mm piping (approx. Length 450m) = £186,322 Installing new 750mm sewer piping adjacent to Rayleigh Road (approx. Length 150m) = £134,720
Land Management	(red)	There are no feasible opportunities for land management at this location.	N/A
Strategic Storage	(red)	There are no feasible opportunities for strategic flood storage at this location.	N/A
Flow Diversion	(red)	There are no feasible opportunities for flow diversions at this location.	N/A
Maintenance	(yellow)	There are no maintenance issues at this location. However, regular maintenance should be conducted to ensure the sewer network is functioning correctly.	A costing of this measure has not been conducted.
Flood Defences	(red)	There are no feasible opportunities for flood defences at this location.	N/A

Table 5-25: Area BRENT-I - A12 & River Wid

Location



Comments

Flooding at this location is dominated by fluvial flooding from the River Wid. The majority of the flooding is in Greenfield land which has no properties. The only key infrastructure is the A12 which is a critical transport link for the region. The most important mitigate options at this location will relate to ensure that the A12 does not flood and is safe to travel on in times of flooding.

Model Suitability / Improvements

- Mitigation measures have been suggested based on current modelling results but should be revised if further information becomes available.

Options			
SUDS / Retrofit SUDS		There are no feasible opportunities for SUDS retrofit at this location.	N/A
Property Level Protection (PLP)		There are no feasible opportunities for PLP at this location.	N/A
Increase Conveyance		There are no feasible opportunities for increasing conveyance at this location.	N/A
Land Management		There are no feasible opportunities for land management at this location.	N/A
Strategic Storage		There are no feasible opportunities for strategic flood storage at this location.	N/A
Flow Diversion		There are no feasible opportunities for flow diversions at this location.	N/A
Maintenance		There are no known maintenance issues at this location.	N/A
Flood Defences		It is recommended that a flood wall is built or the height increased to prevent flood from the River Wid overtopping and flooding the road infrastructure linking to the A12.	Flood wall at the A12 to protect from high levels in the River Wid (approx. 1.20m high and 200m in length) = £94,400

6 Implementation & Review

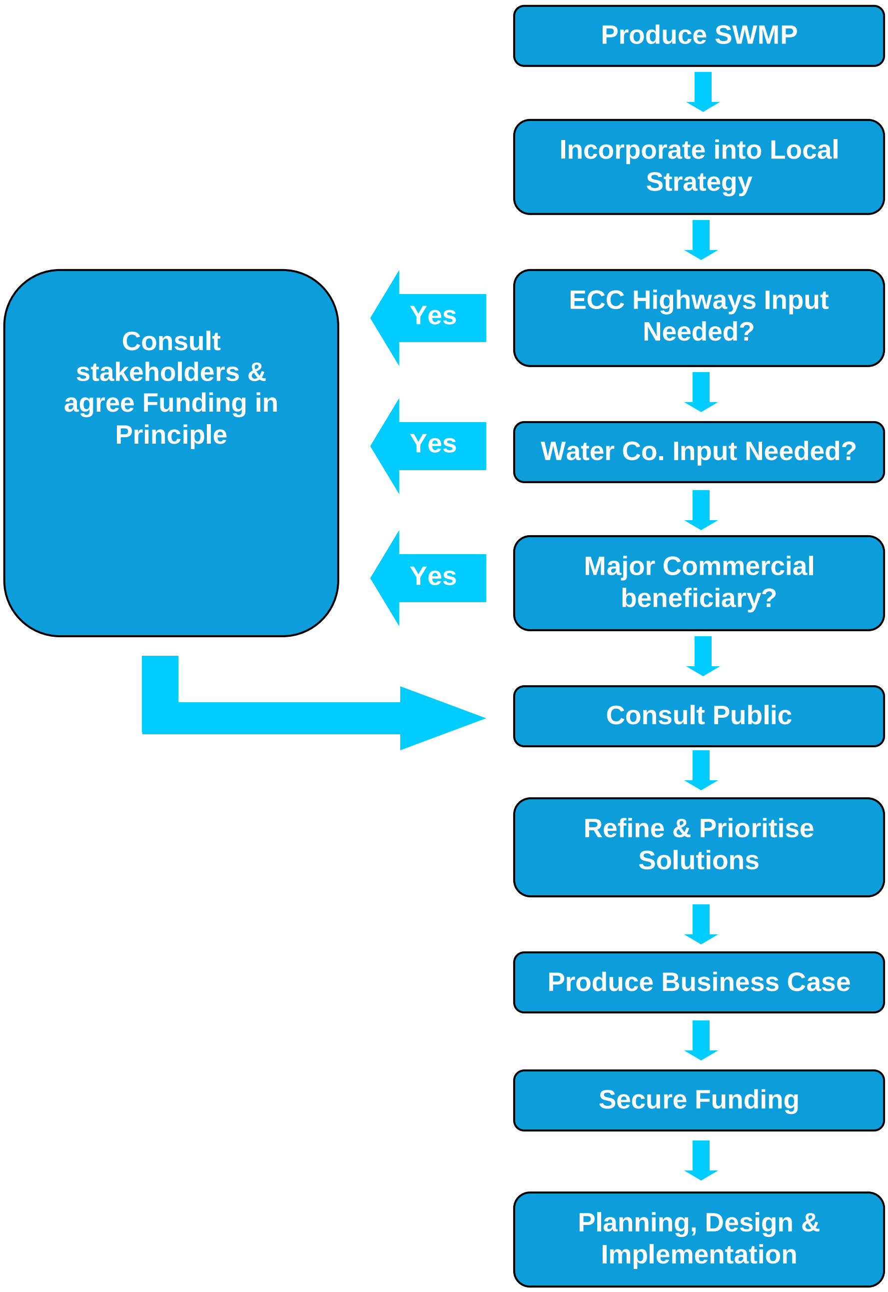
6.1 Approach

The action plan for this SWMP has been developed by using the outputs from the detailed assessment to define a way forward for managing surface water for the key areas considered. It is acknowledged that the action plan developed is subject to change as and when stakeholders meet to discuss the outputs of this project and its fit with the Local Flood Risk Management Strategy (LFRMS).

6.2 Action Plan

A broad process to take forward this SWMP and the options prepared is outlined in Figure 6-1, with more detailed objectives, advice, follow up actions, and how/when this SWMP should be reviewed and updated provided in the recommendations below.

Figure 6-1: Surface Water Management Plan Action Plan



6.2.1 Recommendations

The project has the following recommendations

Brentwood

- Refine and improve data at certain locations. There are currently areas which lack sewer network data which would improve the accuracy of modelling results. In particular there is currently no represent of railway or highway drainage systems. Data for these areas is being collated through the asset register survey and can be incorporated into the models at a later date.
- Further fluvial modelling on watercourses in Brook Street and Thrift Green should be used to provide further details on flood risk. This would allow recommended options in these areas to be further assess, refine and prioritised.

Ingatestone

- Further fluvial modelling of the two watercourses running under the High Street and at Heybridge should be used to provide further details on fluvial flood risk to the surrounding area. This would help in refining the available measures which can be implemented.
- Investigation of the sewer network data in areas such as Poplar Close. Currently there are discrepancies which if addressed would improve the accuracy of the model.

West Horndon

- Refining and improve data at certain locations. Currently areas of private drainage are not included such as Horndon Industrial Park. Inclusion of such data would improve the accuracy of modelling results and allow mitigation measures to be modelled.
- Further fluvial modelling of the watercourse running through West Horndon. This would allow greater accuracy in measuring flood risk to the area.

Other Areas

- Surface water flood risk for Doddinghurst was not assessed due to lack of LIDAR data for the area. If further data should become available the modelling should be refined to include this area.
- Flood risk in Blackmore was shown to mainly originate from watercourses running through the village. Additional more specific hydraulic modelling is recommended to understand flood risk in this area.
- Flood risk in Coxtie Green was shown to be driven by several private ponds. It is recommended that a study of historic events is conducted to further understand the drivers of flooding for the area.

General Recommendation

- It is recommended that information from asset register surveys is used to refine the model. The modelling should also be refined if further public and private sewer network data should become available.
- The indicative costs of measures in Chapter 4 should be used for assisting in the prioritisation of concept solutions with further refinement based on improvements in data and model representation.
- If options are pursued it is recommended that a full outline and detailed design process be undertaken. This should include a detailed cost-benefit assessment and use of threshold surveys for determining avoided damages.

From the recommendations above an Action Plan has been produced. The Action Plan can be found in Appendix L.

6.3 Review Timeframe and Responsibilities

Proposed actions have been classified into the following categories:

- Short term: Actions to be undertaken within the next one to three years;
- Medium term: Actions to be undertaken within the next one to five years; and
- Long term: Actions to be undertaken beyond five years.

The Action Plan identifies the relevant partnerships that should be consulted and asked to participate when addressing an action. To allow for easier separation of the individual actions a colour coded system has been utilised to highlight what the action relates too e.g. maintenance, general flood risk management etc. After an action has been addressed, it is recommended that the department responsible for completing the action should review the Action Plan and update it to reflect any issues (communication or stakeholder participation) which arose during the completion of an action and whether or not additional actions are required.

It is recommended that the Action Plan is regularly reviewed and updated to reflect any necessary amendments. In order to capture the works undertaken by the ECC and other stakeholders, it is recommended that the Action Plan review should be on a not greater than annual basis.

For clarity, it is noted that the FWMA 2010 places immediate or in some cases imminent new responsibilities on LLFAs. The main actions required are summarised below:

- Develop, maintain, apply and monitor a Strategy for local flood risk management of the area.
- Duty to maintain a local flood risk asset register.
- Investigate flood incidents and record in a consistent manner.
- Establish a SUDS Approval Body (SAB).
- Contribute towards achievement of sustainable development.
- On-going responsibility to co-operate with other authorities through sharing of data and expertise.
- Preparation of Local Flood Risk Management Strategies

6.4 On-Going Monitoring

It is intended that the partnership arrangements established as part of the SWMP process, will continue beyond the completion of the SWMP in order to discuss the implementation of the proposed actions, review opportunities for operational efficiency and to review any legislative changes.

The SWMP Action Plan should be reviewed and updated annually as a minimum, but there may be circumstances which might trigger a review and/or an update of the Action Plan in the interim. In fact, Action Plan updates may be as frequent as every few months. Examples of something which would be likely to trigger an Action Plan review include:

- Occurrence of a surface water flood event;
- Additional data or modelling becoming available, **which may alter the understanding of risk within the study area**;
- Outcome of investment decisions by partners is different to the preferred option, which may require a revision to the action plan, and;
- Additional (**major**) development or other changes in the catchment which may affect the surface water flood risk.

It is in the interest of District and the residents of the catchment, that the SWMP Action Plan remains current and up-to-date. To help facilitate this, ECC will liaise with other flood risk management authorities and monitor progress.

This page was left intentionally blank.

Appendices

A Product Data Register

Data Type	Source	Format	Quality	Uncertainties	Post-Processing
OS Mastermap	Essex County Council	MapInfo .TAB files	Complete coverage of the study area.	Low uncertainty. The Mastermap is a snap shot of land-use at one point in time.	Mastermap data was used within the InfoWorks ICM model and within Frism to determine building footprint locations.
LIDAR	Environment Agency (Geomatics Group)	GIS - ASCII	0.5m, 1m and 2m resolution	LIDAR Ground levels using filtered data usually have an uncertainty of ±150mm depending on the land use	Filtered LIDAR used. GIS data checked by JBA staff.
National Receptor Dataset	Environment Agency	MapInfo .TAB File	QA checked by JBA Staff.	Low uncertainty. The NRD data is a snap shot of land-use at one point in time.	NRD data was used in Frism to identify building types and to determine the cost of flood damage.
Flood Zone Maps	Environment Agency	MapInfo .TAB Files	-	Low uncertainty.	N/A
Sewer Asset Information	Anglian Water	MapInfo .TAB file	Inconsistencies and missing data were noted throughout the data set.	Inconsistencies were noted in the data where manhole data was missing. This information was inferred from other datasets.	The files were imported into InfoWorks ICM and had a number of levels inferred based on ground levels and pipe dimensions.
Records of Historic Flooding	Essex County Council, Brentwood District Council, Fire and Rescue Service	Excel worksheets	A number of the records were vague or did not have additional comments that allowed determination of the cause of flooding.	A number of the records were rather vague on the cause of the flooding. Often judgements on the cause of flooding were based on geographical location and proximity to more detailed records of similar date.	The records were geo-referenced into ArcGIS to allow a visual representation of the flood records.
Gully Asset Information	Essex County Council	MapInfo .TAB & Microsoft Excel	QA Checked by JBA Staff.	The gully information is a snap shot of a moment of time and is the most up to date version available.	The information was reviewed for use within the model.
Various Local Plan Mapping Layers	Essex County Council	MapInfo.TAB File	QA Checked by JBA Staff.	Low uncertainty	Datasets used as part of the other appraisal section of the SWMP.

Infiltration Maps	British Geological Survey	ArcGIS .shp	QA Checked by JBA Staff.	Low uncertainty	Datasets used as part of the other appraisal section of the SWMP
Area Susceptible to Surface Water Flooding Maps (ASTSWF)	Essex County Council	ArcGIS .shp	QA Checked by JBA Staff.	The surface water flooding maps are based on broad mapping and therefore have a degree of uncertainty.	N/A

B Brentwood Historic Flood Records

This page was left intentionally blank.

C Intermediate Assessment – Number of Flooded Properties based on Frism Analysis

This page was left intentionally blank.

D Surface Water Flooding Hotspots

This page was left intentionally blank.

E Ingatestone Depth & Hazard Maps

This page was left intentionally blank.

F West Horndon Depth & Hazard Maps

This page was left intentionally blank.

G Brentwood Depth & Hazard Maps

This page was left intentionally blank.

H Ingatestone Detailed Frism Outputs

This page was left intentionally blank.

I West Horndon Detailed Frism Outputs

This page was left intentionally blank.

J Brentwood Detailed Frism Outputs

This page was left intentionally blank.

K Infiltration SUDS Feasibility Map

This page was left intentionally blank.

L SWMP Action Plan

This page was left intentionally blank.

M Partner Organisations

This page was left intentionally blank.

M.1 Project Partners

This SWMP study has been undertaken in consultation with key local partners who are responsible for and involved with surface water management and drainage in the Brentwood Borough. This included Brentwood Borough Council, Essex County Council, Essex Highways, the Environment Agency and Anglian Water. The Partners have worked together to understand the causes and effects of surface water flooding and identify the most cost effective way of managing surface water flood risk for the long term. The key contacts from each partner organisation are shown below.

Organisation	Project Lead
Essex County Council	Jo Carrington
Brentwood Borough Council	Camilla James
Anglian Water	Jonathan Glerum
Environment Agency	Phillip Spearman
JBA Consulting	David Kearney

Offices at

Coleshill

Doncaster

Edinburgh

Exeter

Haywards Heath

Leeds

Limerick

Newcastle upon Tyne

Newport

Saltaire

Skipton

Tadcaster

Thirsk

Wallingford

Warrington

Registered Office
South Barn
Broughton Hall
SKIPTON
North Yorkshire
BD23 3AE

t:+44(0)1756 799919
e:info@jbaconsulting.com

Jeremy Benn Associates Ltd
Registered in England
3246693

Visit our website
www.jbaconsulting.com