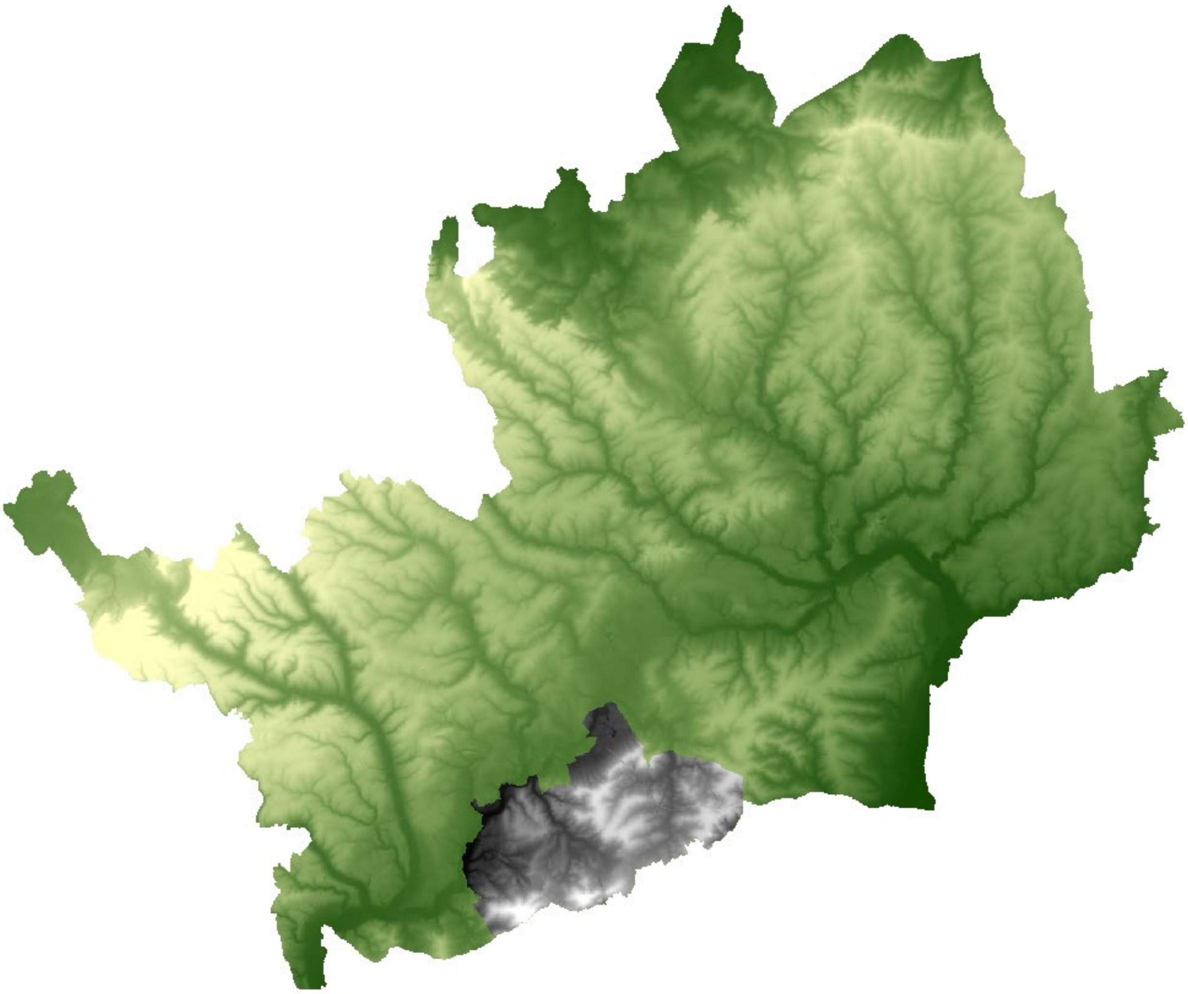

Hertsmere Borough Surface Water Management Plan

Final Report

March 2021

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Revision history

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Contract

This report describes work commissioned by Hertfordshire County Council, by a letter dated 2nd August 2017. Emily Jones, Cheryl Briars and Alistair Clark of JBA Consulting carried out this work.

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Purpose

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Executive summary

The Local Flood Risk Management Strategy (LFRMS) for Hertfordshire 2013 – 2016 identified the need for district scale Surface Water Management Plans (SWMPs) for each of the 10 local authority areas in the county. The Hertsmere Borough SWMP has been prepared alongside parallel studies including, Three Rivers, Stevenage and Welwyn-Hatfield. Together, these four studies will complete coverage of SWMPs for the county.

A SWMP is a framework to improve the understanding of surface water flood risk in an area. The study has been led by Hertfordshire County Council as Lead Local Flood Authority (LLFA), in partnership with key stakeholders; Hertsmere Borough Council, the Environment Agency and Thames Water Utilities Limited to improve the understanding of risk and work together to find the most cost-effective way to manage the risk.

The SWMP includes an intermediate scale assessment of surface water flood risk across the borough to identify key surface water flood risk hotspots, which is then further analysed through detailed catchment scale assessments of the hotspots.

Hertsmere is a borough in Hertfordshire, England. The area is a mix of urban and rural areas in the Metropolitan Green Belt. Settlements in the borough include Bushey, Elstree, Radlett, Borehamwood and Potters Bar which are all covered by the study area. Several main rivers flow through the borough including the River Colne as well as several other ordinary watercourses. In addition to the fluvial flood sources, there is a risk of surface water flooding, which is the dominant risk to all of the identified hotspots. The risk from sewer flooding is also considered as part of the SWMP.

Using the Hertfordshire County Council flood incident record; a Source-Pathway-Receptor model was applied. The application of the model facilitates flood risk management by potentially addressing the source (often very difficult), blocking or altering the pathway and even removing the receptor e.g. finding an alternative location for development. Mapping these flood incidents across the district, by source, provides a visual aid for understanding the cause of flooding in the identified hotspots.

To better understand flood risk in Hertsmere, and identify potential solutions, the SWMP was based around a series of detailed integrated models, each focussing upon a hotspot. All models represented the varying landscape across each hotspot, and incorporated surface water sewer networks and watercourses to understand flood risk to the area. The following areas were identified as highest risk, and therefore modelled:

- HBC3: Moatfield Road;
- HBC6: Bushey (Roads including Moatfield Road, Spring cross, Vale Road, Hayden Road and Homefield Road).

Using the outputs from the detailed modelling, potential actions to alleviate flood risk have been identified, and detailed within the hotspot shortlisting. The implementation of the action plan will be undertaken locally, and it is expected that partners will take forward actions independently and convene as and when appropriate.

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Abbreviations

AStGWF ....Areas Susceptible to Groundwater Flooding
AStSWF ....Areas Susceptible to Surface Water Flooding
BGS..........................British Geological Survey
DRN ....Detailed River Network
EA ....Environment Agency
GIS ....Geographic Information System
HBC..........................Hertsmere Borough Council
HCC ....Hertfordshire County Council
JBA...........................Jeremy Benn Associates
LFRMS ....Local Flood Risk Management Strategy
LLFA.........................Lead Local Flood Authority
LNR ....Local Nature Reserve
LPA ....Local Planning Authority
NFM ....Natural Flood Management
OS ....Ordnance Survey
PFR ....Property Flood Resilience
RMA ....Risk Management Authority
RoFSW.....................Risk of Flooding from Surface Water
SAC ....Special Area of Conservation
SFHD ....Sewer Flooding History Database
SSSI ....Site of Special Scientific Interest
SuDS ....Sustainable Drainage Systems
SWMP ....Surface Water Management Plan
TWUL ....Thames Water Utilities Limited
WFD ....Water Framework Directive
WwNP ....Working with Natural Processes

1 Introduction

1.1 Background

The Local Flood Risk Management Strategy (LFRMS) for Hertfordshire 2013 – 2016 identified the need for district scale Surface Water Management Plans (SWMPs) for each of the 10 district authority areas in the county. This document aims to improve the understanding of surface water flood risk in Hertsmere Borough.

This report has been developed using the Defra Surface Water Management Plan Guidance published in 2010 and details of the SWMP process are set out in Chapter 1.4.

1.2 Study area

The Borough of Hertsmere is in the south of Hertfordshire, to the north-west of London. The borough is a mix of urban and rural areas and includes the towns of Bushey, Elstree, Radlett, Borehamwood and Potters Bar and covers an area of approximately 101km^2.

The overall fall of the land within the borough is from the south-east to north-west, with an area of high ground that runs through the centre of the borough as shown in Figure 1-1.

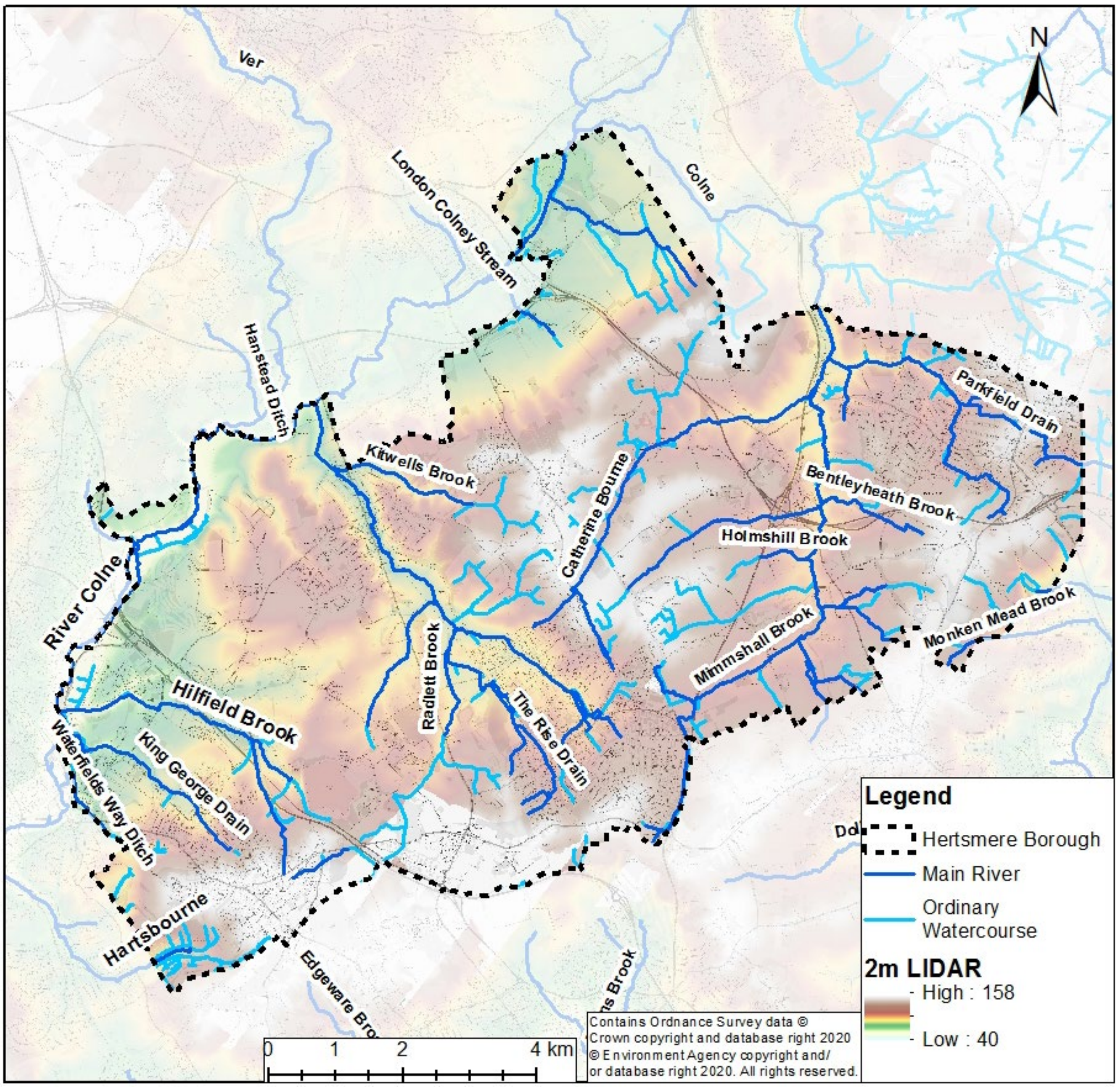

Figure 1-1: Location plan of the SWMP study area and topography of Hertsmere

1.2.1 Geology

The northern band of Hertsmere is underlain by a series of chalk beds which are generally permeable and freely draining geologies, with an ability to retain water below ground. There is a centre band of Hertsmere that is underlain by the Lambeth Group which consists of a sequence of clays, shell beds, fine sands, silts and pebble beds giving low yields, which is in hydraulic continuity with the underlying Chalk aquifer[1]. The southern band and majority of the borough is underlain by Thames Group which consists of clay of up to 140m thick, confining underlying aquifers. Occasional springs exist at the base of the chalk which can occur where the water table rises to the ground surface, often within dry valleys, and after prolonged winter rainfall this could create the presence of groundwater flood risk. Much of the study area bedrock is overlain by superficial deposits, predominately sand and gravel, with areas of glacial sand and gravel in the north and a small amount of alluvium. A simplified map of the bedrock and superficial geology of the borough is shown Figure 1-2.

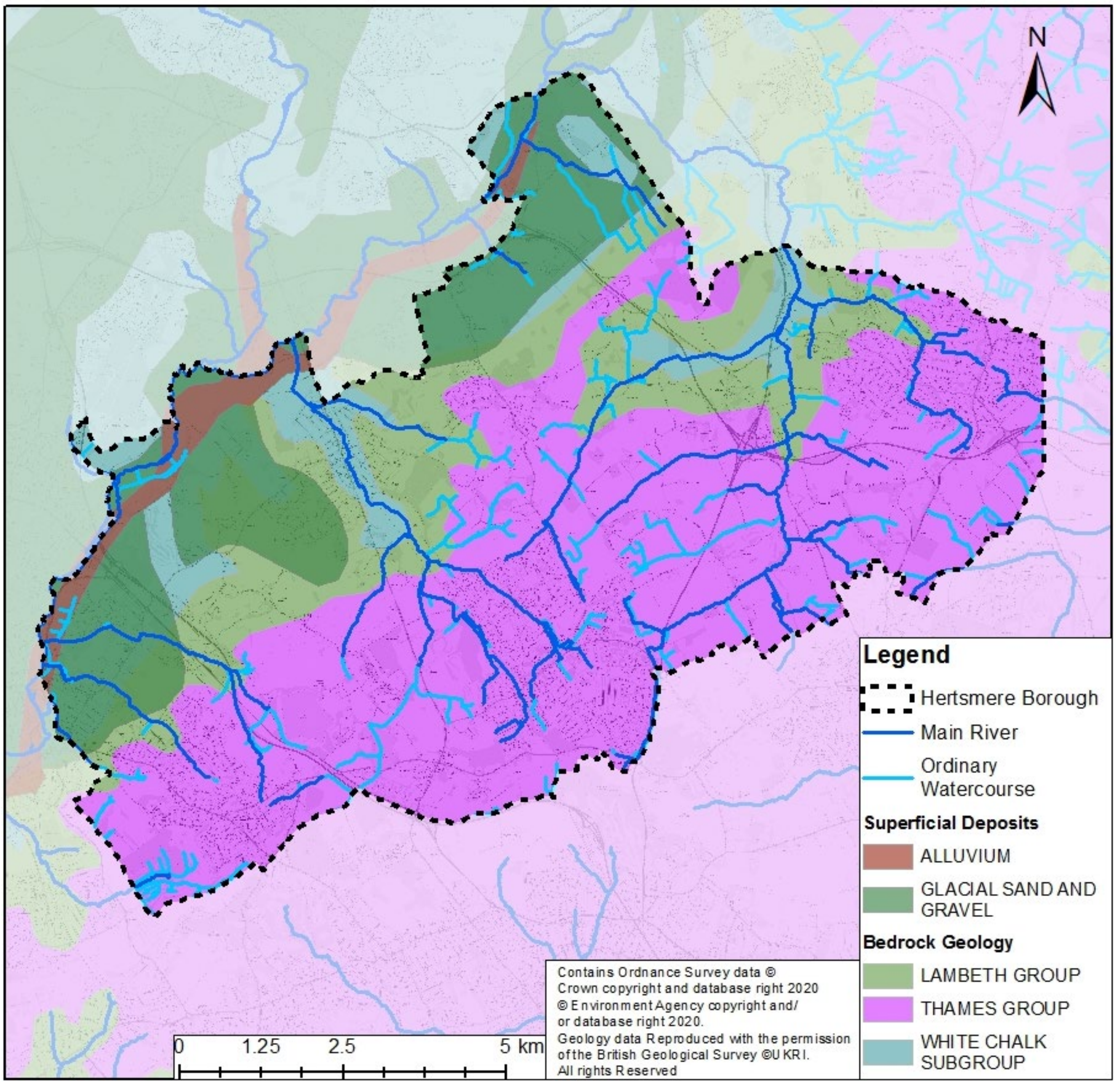

Figure 1-2: Bedrock and superficial geology underlying Hertsmere Borough

1 http://mapapps.bgs.ac.uk/geologyofbritain/home.html

1.2.2 Watercourses

Main river

A Main River is any watercourse which is designated as such on the Environment Agency Main River map, and for which the Environment Agency has responsibilities and powers. Main Rivers are generally larger arterial watercourses, but smaller watercourses can be designated if the watercourse poses a significant flood risk. Where fluvial or tidal flooding from main rivers is the sole source of flooding, it is the role of the Environment Agency to manage the flood risk. Fluvial flooding from Main Rivers is outside the scope of a SWMP and is addressed in the Catchment Flood Management Plan and Flood Risk Management Plan, or other local more detailed studies. However, interactions between a watercourse, the local drainage network and surface water flows may impact on the surface water flood risk in certain areas.

The River Colne is the largest watercourse in the borough and flows along the northern and western boundaries of the borough (Figure 1-3). The River Colne is a tributary of the River Thames and rises perennially from a subterranean river at a spring in North Mymms Park in Hertfordshire and has two occasionally dry tributaries; an unnamed brook and the Mimmshall Brook which runs through the east and south of the borough. Other main rivers in the borough include Catharine Bourne and Potters Bar Brook in the east, Tykes Water that flows through Radlett, and Borehamwood Brook that flows through Borehamwood in the south. Hillfield Brook is another main river in the study area that runs around the town of Bushey.

Ordinary watercourses

In England and Wales, the term ordinary watercourse refers to rivers, streams, ditches and drains which do not form part of a Main River. Hertfordshire County Council (HCC) as a LLFA, has permissive powers to regulate works on ordinary watercourses within Hertfordshire.

Several unnamed ordinary watercourses drain the study area, particularly in the south, next to the A1 Barnet Bypass in Well End and a watercourse that runs through Aldenham Reservoir to the west of Elstree. The ordinary watercourses within the study area are shown in Figure 1-3.

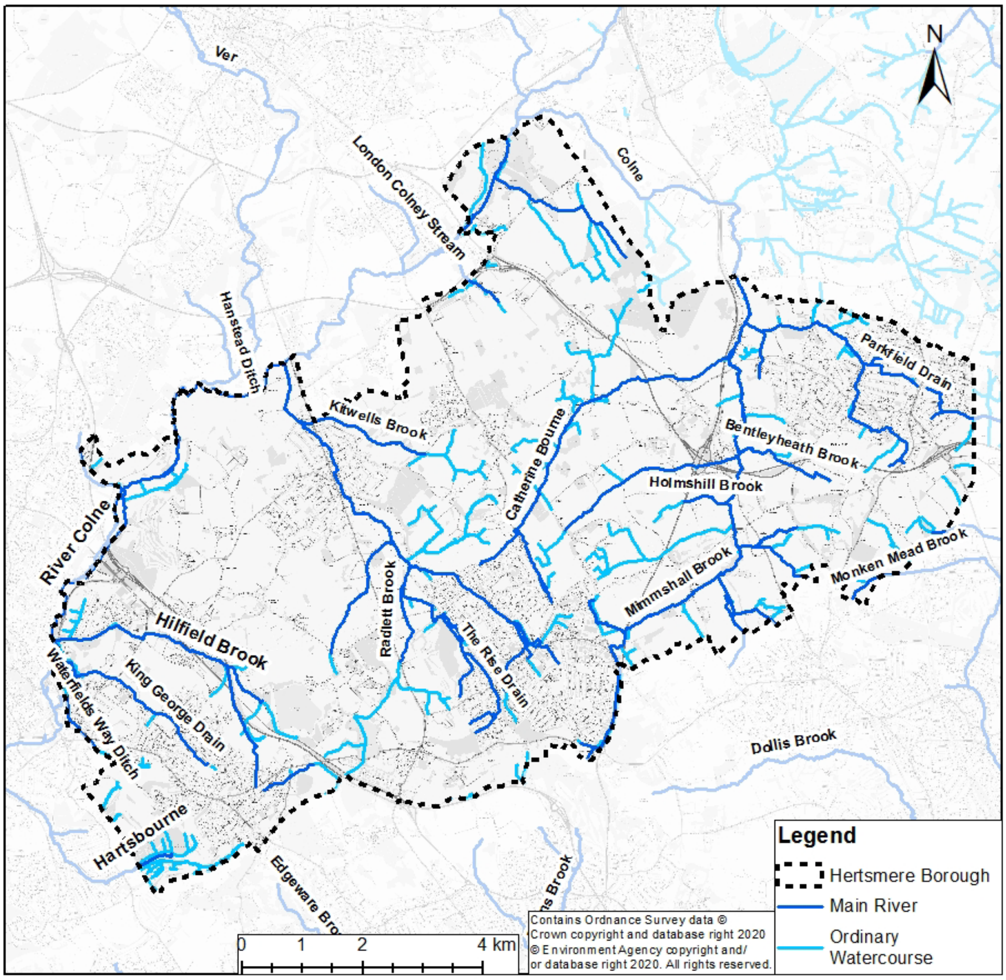

Figure 1-3: Location of main rivers and ordinary watercourses in Hertsmere Borough

1.2.3 Sewers

Sewers describe infrastructure generally below ground, for the conveyance of wastewater. Sewers are categorised by the type of wastewater removed and include:

- Foul sewer;
- Surface water sewer;
- Combined sewer.

Foul sewers convey sewage from houses and commercial properties to treatment works. Surface water sewers take runoff from domestic premises, yards and roofs, and (under agreement) highway drainage. Combined sewers convey a mix of both foul water and surface water.

Thames Water Utilities Limited (TWUL) is responsible for the public sewer network in this area. As a partner of the SWMP process, TWUL has provided records of its assets in Hertsmere. This SWMP will concentrate mainly on surface water and combined sewer networks. The performance of these drainage networks relates directly to the proportion of rainfall which forms pluvial runoff and the inflow into ordinary watercourses from the surface water drainage network.

Sewer flooding from the foul and surface water sewer network is the responsibility of TWUL. Foul water flooding has been considered in the SWMP to examine interactions between foul sewer surcharge and other, local flood sources such as infiltration of groundwater into the sewer network.

Overloaded foul and combined sewer networks can result in sewer outflows which can present potential water quality and public health issues. Although water quality is not the principal driver for this project, a SWMP should provide a framework for improving the quality of water within the area. As a result, some actions resulting from the SWMP may also improve the water quality in the borough.

1.2.4 Surface water

Surface water flooding occurs when rainfall fails to infiltrate into the ground or enter the drainage system. Ponding generally occurs at low points in the topography. The likelihood of flooding is dependent on not only the permeability of the surface, but also saturation of the receiving soils, the groundwater levels and the capacity and condition of the surface water drainage system (i.e. surface water sewers, highway authority drains and gullies, open channels, ordinary watercourses and SuDS).

The Environment Agency Risk of Flooding from Surface Water (RoFSW) mapping will be used to assess the potential areas/valleys that may act as a flow path for surface water, identifying areas of ponding that could occur in areas of lower lying topographic floodplains within the borough.

1.2.5 Climate change

There is still considerable uncertainty regarding the localised impact of climate change, but it is likely that the risk of flooding will increase under a climate change scenario. This increased risk could manifest itself as more frequent flooding, increase in flood extent and an increase in flood depth.

Climate change is predicted to increase rainfall intensity in the future by up to 40%[2] under the new range of allowances published by the EA.

This will increase the likelihood and frequency of surface water flooding, with the greatest impact experienced in impermeable urban areas such as in Borehamwood in Hertsmere. Fluvial flood risk linked to the River Colne will increase with the impact of predicted climate change, which is likely to increase the fluvial flood risk exposure to Hertsmere, and flooding from surface water drainage systems restricted by the higher river levels.

1.3 Integrated flood risk

Where relevant, this SWMP has considered the integrated flood risk that is created by the interaction between sewer exceedance, fluvial flooding, pluvial runoff, restricted outfall and groundwater flooding.

1.4 Surface Water Management Plans

A SWMP outlines the preferred surface water management strategy for a specified location. Defra defines surface water flooding as "flooding from sewers, drains,

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[2] Environment Agency (2016) Flood Risk Assessments: climate change allowances. Available at: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

groundwater, and runoff from land, small watercourses and ditches that occurs as a result of heavy rainfall".

This SWMP was undertaken to explore the local flood risks in the borough. It was carried out to provide a strategy for managing surface water in the area.

At the heart of the SWMP process there is recognition that surface water is managed by a complex patchwork of organisations and responsibilities, and therefore requires a partnership approach in order to deliver joined-up solutions.

This SWMP has been developed in line with the Defra guidance for the preparation of SWMPs[3], which follows a four-stage "wheel" of preparation, risk assessment, options and implementation shown in Figure 1-4.

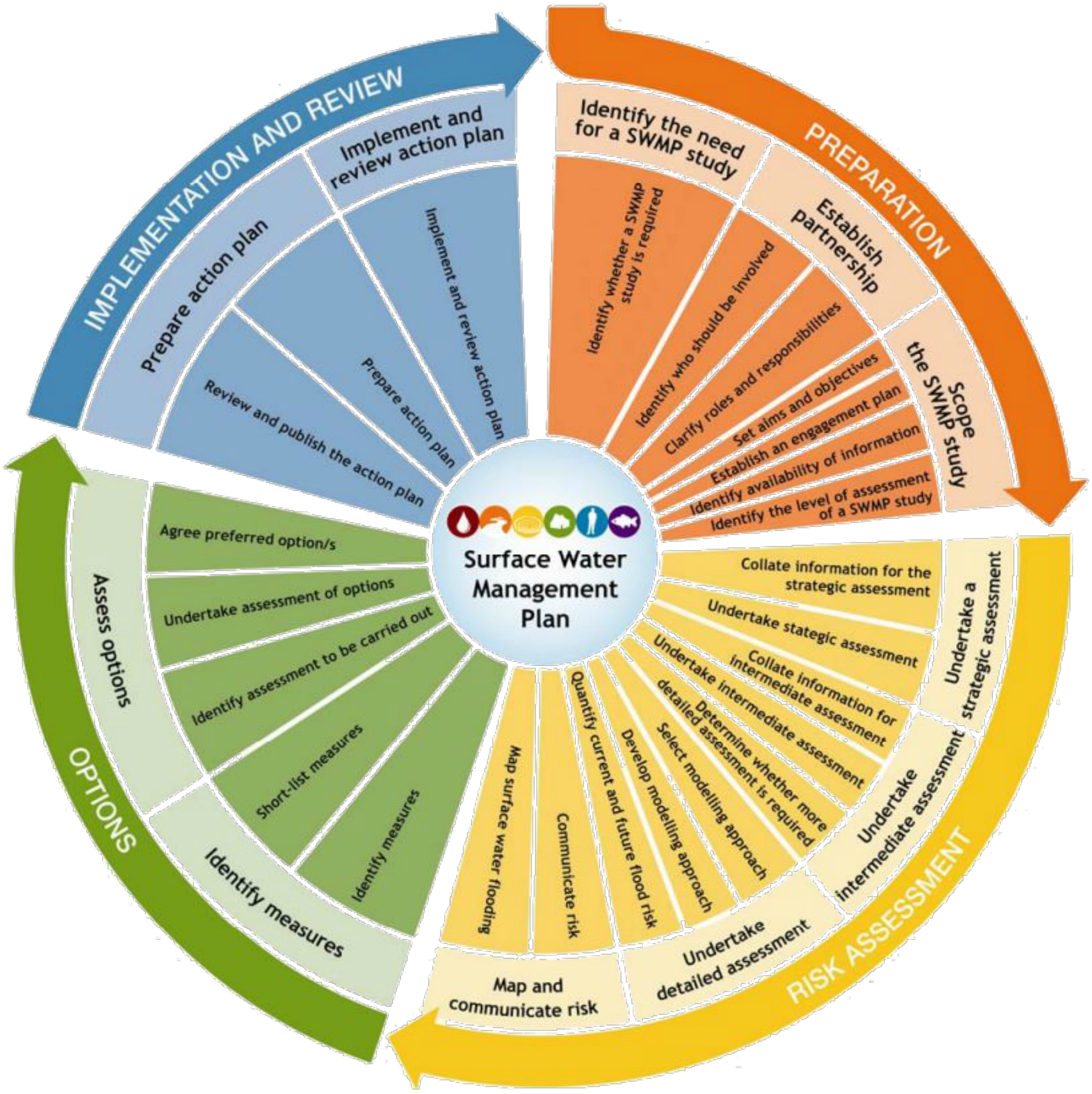

Figure 1-4: Defra Surface Water Management Plan "Wheel"

1.5 Stages of a SWMP

The four phases to be completed as part of a SWMP study as set out by the Defra guidance are as follows:

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3 Surface Water Management Plan Technical Guidance, 2010. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69342/pb13546-swmp-guidance-100319.pdf. Accessed on 26/09/2017.

- **Preparation** – The first phase of SWMP study focuses on preparing and scoping the requirements of the study. Once the need for a SWMP study has been identified the LLFA and the key stakeholders should identify how they will work together to deliver the SWMP study. The aims and objectives of the study should be established, as well as details of how all parties should be engaged throughout the SWMP study. An assessment should subsequently be undertaken to identify the availability of information. Based on the defined objectives, current knowledge of surface water flooding, and the availability of information, an agreement is made regarding the level of assessment at which the SWMP study should start.
- **Risk assessment** – The outputs from the preparation phase will identify which level of risk assessment will form the first stage of the SWMP study. The first stage is likely to be the strategic assessment where little is known about the local flood risks. The strategic assessment focuses on identifying areas more vulnerable to surface water flooding for further study. The intermediate assessment, where required, will identify flood hotspots in the chosen study area, and identify quick win mitigation measures, and scope out any requirements for a detailed assessment. A detailed assessment of surface water flood risk may be required to enhance the understanding of the probability and consequences of surface water flooding and to test potential mitigation measures in high risk locations. Guidance is provided on undertaking modelling to support a detailed assessment of surface water flood risk and mitigation measures. The outputs from the strategic, intermediate and/or detailed assessment should be mapped and communicated to all stakeholders including spatial planners, local resilience forums, and the public.
- **Options** – In this phase a range of options are identified, through stakeholder engagement, which seeks to alleviate the risk from surface water flooding in the study area. The options identified should go through a short-listing process to eliminate those that are unfeasible. The remaining options should be developed and tested using a consideration of their relative effectiveness, benefits and costs. The purpose of this assessment is to identify the most appropriate mitigation measures which can be agreed and taken forward to the implementation phase.
- **Implementation and Review** – Phase 4 is about preparing an implementation strategy (i.e. an action plan), delivering the agreed actions and monitoring implementation of these actions. The first step is to develop a coordinated delivery programme. Once the options have been implemented, they should be monitored to assess the outcomes and benefits, and the SWMP should be periodically reviewed and updated, where required.

2 Preparation

2.1 Identify the need for a SWMP

Action 8.2.4 of the first LFRMS for Hertfordshire[4] identified a need to develop 10 SWMPs across the county based on the boundaries of the district/borough authorities. As the LLFA, HCC is seeking to gain an improved understanding of local flood risk. SWMPs within Hertfordshire are being prepared at the district/borough scale in order to:

- Ensure a complete coverage of SWMPs across the county;
- Reinforce the linkage between surface water management and the Local Planning Authorities (LPAs);
- Align with the role of district and borough councils as Risk Management Authorities (RMAs).

This SWMP was prepared alongside parallel studies covering Stevenage, Three Rivers and Welwyn-Hatfield. Together, these four studies complete the coverage of SWMPs for the whole county. This SWMP commenced at the intermediate scale, moving on to detailed scale assessments covering hotspots.

2.2 Establish a partnership

A SWMP is a framework to improve the understand of surface water flood risk in an area and enable key stakeholders with responsibility for surface water and drainage to work together to find the most cost-effective way to manage the risk.

Organisations managing flood risk in Hertsmere include:

- Hertfordshire County Council;
- Hertsmere Borough Council;
- Thames Water Utilities Limited; and
- The Environment Agency.

The borough council has powers for managing flood risk from ordinary watercourses. Often, urban flooding is caused by multiple mechanisms, which are the responsibility of different organisations. Therefore, a holistic approach is required to manage a flooding issue. As such, partnership working is key to the SWMP process.

To make the best of the opportunity to work with partners afforded by a SWMP, a series of engagements were undertaken as set out in Table 2-1, below.

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[4] Local Flood Risk management Strategy for Hertfordshire, 2011, https://www.hertsmere.gov.uk/Documents/09-Planning--Building-Control/Planning-Policy/Local-Plan/SADMS-EB05-Local-Flood-Risk-Management-Strategy-13-16-full.pdf

Table 2-1: Planned meetings, workshops and site visits

Meeting	Attendees	Purpose
Monthly progress (teleconference)	HCC, JBA	Monitor progress, budget, programme, risks.
Inception meeting (1no.)	HCC, JBA, EA, TWUL, LAs	Agree stage 1 methodology, agree data provision.
Hotspot selection site visit (4 no.)	HCC, JBA, EA, TWUL, LAs	Select hotspots, gather additional information on hotspots.
Hotspot selection workshop (1no.)	HCC, JBA, EA, TWUL, LAs	Select hotspots.
Options workshop (2no.)	HCC, JBA, EA, TWUL, LAs	Discuss draft options, costings etc.

2.2.1 The communications and engagement plan

A Stakeholder Communications and Engagement Plan was drafted at the project inception and maintained as a live document through the project. This is included in Appendix B.

2.3 Scoping of the study

HCC have undertaken a series of SWMPs across the county to improve the understanding of local flood risk following an initial assessment of risk in the first LFRMS published in 2013.

The key aims and objectives of the SWMP, are as followed:

- **Objective 1:** To identify areas within the borough or district that are linked by significant flood risk from surface water runoff and its interactions with sewers, drains, groundwater, ordinary watercourses, ditches, and Main Rivers.
- **Objective 2:** To deliver a list of potential hotspot sites; these hotspot sites will likely be a combination of hotspots identified through GIS and Multi-Criteria Analysis, as well as hotspots identified by key stakeholders (desk-based identified hotspots and stakeholder identified hotspots), though the two may often coincide. Selection of the hotspot sites must be via a robust methodology for prioritisation.
- **Objective 3:** To identify up to five hotspots from each district / borough for detailed hydraulic modelling.
- **Objective 4:** To propose potential options to reduce the flood risk to the hotspot sites identified for hydraulic modelling, and recommend a preferred option per site, which is community focused and feasible in terms of funding and sustainability.
- **Objective 5:** To produce user friendly SWMPs, which are well written, clear, concise and understandable.

3 Strategic and intermediate risk assessment

3.1 Introduction

The main purpose of the Strategic Assessment is to identify broad areas that may be susceptible to surface water flooding and considers available flood risk mapping and historical flood events

The Intermediate assessment develops on the initial assessment to improve the understanding of the sources of flood risk and identify key flooding hotspots for more detail investigation as set out below.

3.2 Overview of the hotspot selection process

Figure 3-1 provides an overview of the activities followed to select hotspots. These are explained in detail in the following sections.

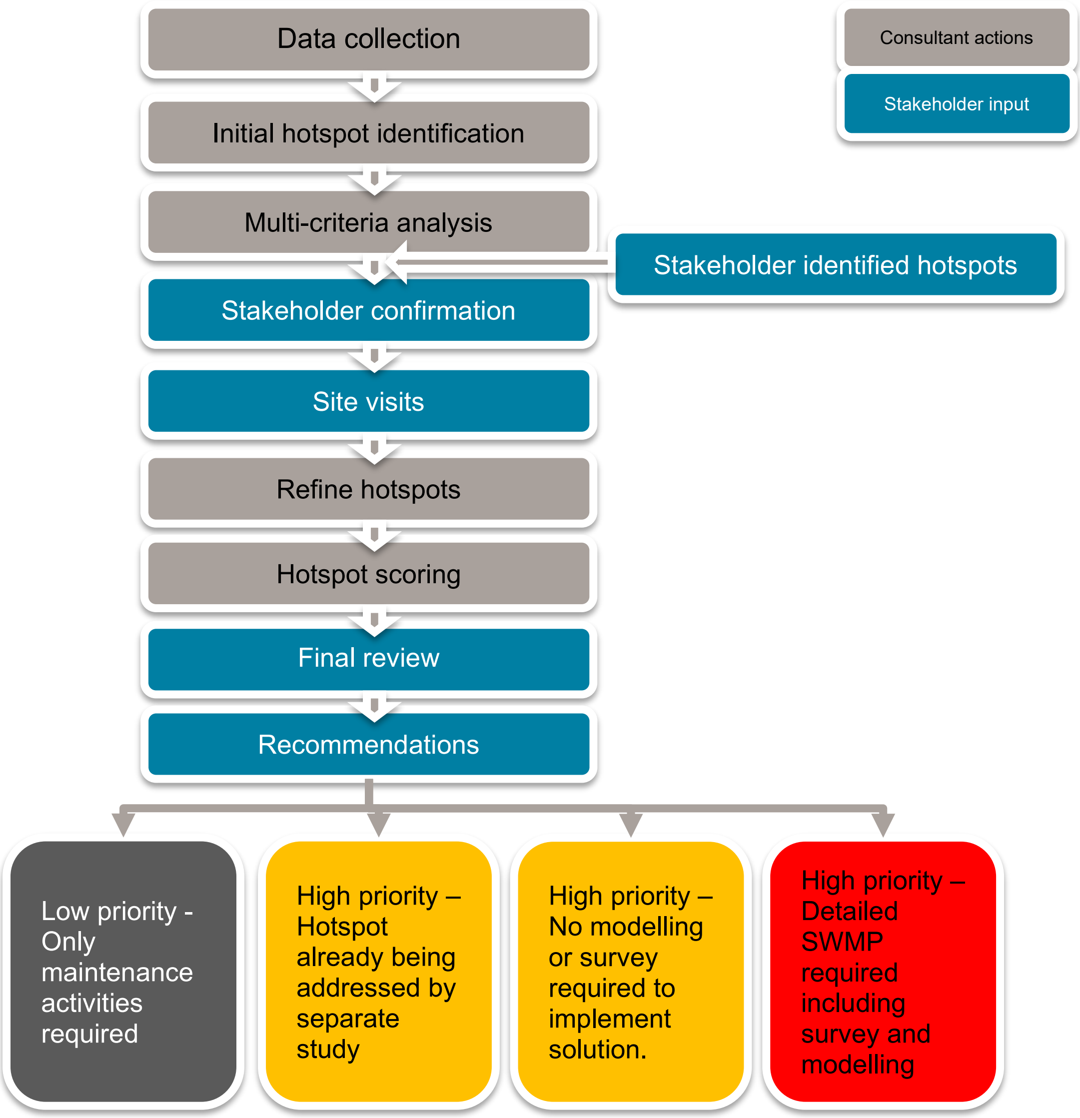

Figure 3-1: Hotspot selection process flow chart

3.3 Data collection

Relevant data was collected and analysed for Hertsmere, from Hertsmere Borough Council (HBC), HCC, TWUL, the EA and from Open Data Sources online, for the purpose of identifying surface water flood risk. These are summarised in Table 3-1.

Table 3-1: Summary of data received for the intermediate-scale assessment

Source	Description / Title
BGS Website	British Geological Survey Geology (BGS) - bedrock and surface
BGS Website	British Geological Survey Hydrogeology
Hertsmere Borough Council	Evidence of flood history
Hertsmere Borough Council	Strategic Flood Risk Assessment
EA Data Catalogue	1m and 2m LiDAR DTM
EA Data Catalogue	EA Chalk River dataset
EA Data Catalogue	EA Main River Network
EA Data Catalogue	Flood Zones 2 & 3
EA Data Catalogue	Historic Flood Map
EA Data Catalogue	Water Framework Directive data
Environment Agency	History of flooding
Environment Agency	River model coverage polygons
Environment Agency	Obstructions to fish passages
Hertfordshire County Council	Detailed River Network (DRN)
Hertfordshire County Council	Environment Agency Risk of Flooding from Surface Water maps
Hertfordshire County Council	Highways gully and grip locations
Hertfordshire County Council	HCC Highways incident data
Hertfordshire County Council	HCC Highways Inspection reports of culverts
Hertfordshire County Council	Section 19 reports and reports of other studies
Hertfordshire County Council	Hertfordshire County Council Flood Incident Database
Hertfordshire County Council	National Receptor Database
Hertfordshire County Council	Ordinary watercourses
Hertfordshire County Council	Polygons of committed development (allocations, windfall sites etc.)
Hertfordshire County Council	SWMPs for other boroughs within Hertfordshire
Ordnance Survey	OS Open Greenspace
Thames Water Utilities Limited	Sewer flooding history database (SFHD) report of incidents at the postcode sector level.
Thames Water Utilities Limited	Sewerage models
Thames Water Utilities Limited	Thames Water sewer network in GIS format

3.4 Initial hotspot identification

All incoming data was reviewed and, where appropriate, loaded into ArcGIS to identify potential hotspot locations. Some new GIS layers were created, for example the locations of Section 19 flooding investigation reports were digitised.

The initial identification of hotspots was carried out by visual identification of locations with modelled and / or reported flood risk to residential properties, businesses or other receptors. The Defra definition of surface water flooding; *"flooding from sewers, drains, groundwater, and runoff from land, small watercourses and ditches that occurs as a result of heavy rainfall."* was used to identify areas where surface water was the key source of flood risk. Flooding from main rivers (identified using Flood Zone 2 and 3 outlines and the Main River layer) was discounted, unless a secondary surface water issue was also thought to be present. The EA's national RoFSW map was the primary source of modelled risk. The HCC flooding history register, along with accompanying Section 19 flood investigation[5] and other technical reports were the primary sources of Hertfordshire's flood history.

TWUL provided numbers of properties at risk of internal and external sewer flooding on their Sewer Flooding History Database (SFHD). In order to anonymise this data, they were summarised by postcode sectors by TWUL. Postcode sectors (e.g. "SG1 2") cover relatively large areas, and therefore cannot be used to pinpoint sewer flooding risk to specific streets. Consequently, this information has not been used in the hotspot selection process, except where other information, for example in Section 19 reports, could be used to point to sewer flooding issues. TWUL advised that they would be able to provide additional information, in confidence, following the hotspot selection.

Boundaries were drawn to designate hotspot areas, guided by the existing RoFSW mapping, the LiDAR and sewer mapping to define hydraulically discrete areas. Not all hotspots were hydraulically discrete; consideration was also given to land use, for example defining an industrial estate as a hotspot even if it had two or more hydraulic flow pathways.

Note that the hotspot areas digitised do not necessarily contain the whole upstream catchment contributing surface water, but rather they define areas of concentrated flood risk. Upstream catchment areas and the extents of modelling were defined later in the hotspot selection process alongside the modelling methodology.

Available information relating to the character, flooding history and flood risk for each hotspot were summarised in a hotspot selection report included in Appendix C.

A total of 8 draft hotspots were identified within HBC. Hotspots were given unique identification codes, for example HBC1, as shown in Table 3-2 and Figure 3-3 below.

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[5] Lead Local Flood Authorities are required, under Section 19 of the Floods and Water Management Act 2010, to carry out investigations into flooding within their boundaries, in order to identify which Risk Management Authorities (RMAs) have relevant flood management functions and whether these have been or are proposed to be exercised. HCC has set out its criteria for triggering a Section 19 investigation, and published draft and final investigations here: https://www.hertfordshire.gov.uk/services/recycling-waste-and-environment/water/flood-investigations.aspx#

Table 3-2: Hertsmere draft hotspots

Hotspot Reference	Location
HBC1	Radlett
HBC2	Mead Way, Bushey
HBC3	Moatfield Road, Bushey
HBC4	Prowse Avenue, Bushey
HBC5	Crown Road, Borehamwood
HBC6	Bushey (Roads including Moatfield Road, Spring cross, Vale Road, Hayden Road and Homefield Road)
HBC7	Napier Drive, Bushey
HBC8	Highview and Darkes Lane, Potters Bar

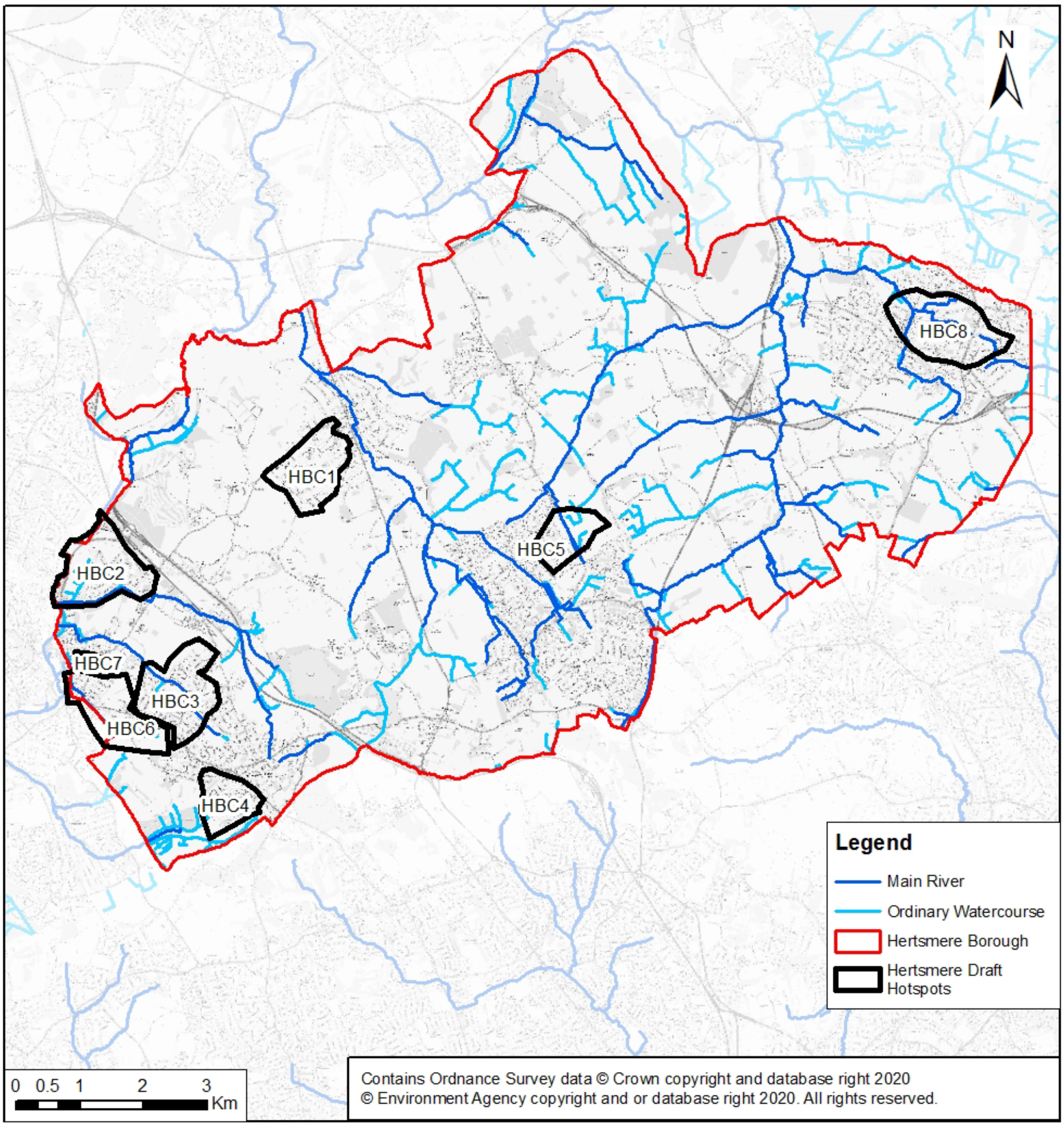

Figure 3-2: Hertsmere draft hotspot

3.5 Multi-criteria analysis

Experience in Hertfordshire and elsewhere indicates that it is rare that Flood and Coastal Erosion Risk Management (FCERM) funding will cover all or even most of the cost of surface water management schemes. Therefore, it is common practice for other sources of funding (Partnership Funding) to be sought to implement surface water schemes.

The benefits of Sustainable Drainage Systems (SuDS) extend beyond flood risk management, and may include, depending upon the type of SuDS implemented, water quality, amenity, biodiversity and air quality benefits.

Given the above, HCC are seeking to identify, at an early stage, what additional opportunities and funding sources may be available within each hotspot.

The following sources of information were reviewed, within and around each hotspot:

- **Committed development:** Boundaries of committed developments were provided by HCC who collated the information from the Local Planning Authority. Significant development within a hotspot may represent opportunities for improving the management of surface water at source, redeveloping brownfield sites in ways that eliminate or reduce flood risk, and as a potential additional source of funding.
- **Green spaces:** These were identified using the new Ordnance Survey Greenspace layer, which identifies green spaces open to the public (though not necessarily publicly owned), including allotments, sports and play facilities, public parks and religious grounds. The presence of green spaces within or near to hotspots may present opportunities for storing and controlling surface water runoff.
- **Environmental designations:** These include international, national and local designations including Special Areas of Conservation (SACs), Sites of Special Scientific Interest (SSSI), Local Nature Reserves (LNR). These can represent both opportunities for improved surface water management to enhance or prevent deterioration of designated areas, but also may represent constraints; for example limiting use of these areas for flood storage where this is not compatible with the conservation objectives.
- **Working with Natural Processes (WwNP):** The EA published a set of online maps in October 2017 identifying areas where WwNP type interventions could be applied to manage flood risk.[6] The primary focus of the WwNP mapping is for flood risk reduction, however WwNP measures may also have benefits to water quality and bio-diversity. The mapping identifies areas of potential opportunity for runoff attenuation features, floodplain reconnection, woodland in riparian zones and floodplains and the wider catchment. The term NFM (Natural Flood Management) is generally used interchangeably with WwNP.
- **Water quality and the Water Framework Directive (WFD):** It is a requirement of the WFD that deterioration of waterbodies as a result of human activities should be prevented, and an objective for all waterbodies to reach Good Ecological Status (GES) or, where the waterbody is already highly modified, Good Ecological Potential (GEP). Flood risk management activities should, therefore, be designed to protect waterbodies and where

possible assist towards improving their status. At this initial stage, the 2016 overall classification of waterbodies within or downstream of each hotspot was identified. In all cases where a waterbody was present and had a current status, the 2016 classification was “Moderate”, with an objective of achieving “Good” status by 2021.

This first stage of identification of other opportunities will be developed in more detail for those hotspots which progress to the detailed SWMP stage.

3.6 Stakeholder confirmation of hotspots and site visits

Draft hotspot assessment sheets were provided to HCC, HBC, EA and TWUL for review. Subsequently, a one-day site visit was carried out to visit all the draft hotspots within the Borough. The site visits were attended by representatives of JBA, HCC, HBC and the EA. The site visits provided an opportunity to discuss the various RMAs’ experiences of flood history in each hotspot, to identify potential flood routes and receptors and, where flood mechanisms were clearly identifiable, to consider the types of interventions which could reduce risk. The site visits were also an opportunity to review the hotspot boundaries, and to ensure that no known hotspots of risk had been missed in the initial selection.

3.7 Refining the hotspots

Following this first stakeholder review and site visit, the number of hotspots within HBC remained at 8, with minor alterations to some hotspot boundaries being taken forward. No additional hotspots were identified by stakeholders.

The hotspot assessment sheets (Appendix C) were updated with further information gained from the site visits and from additional information provided by the partners. The coverage of existing river and sewerage models was identified at each hotspot, using data provided by the EA and TWUL.

Within Hertsmere, only HBC2 is covered by the EA’s Upper Colne model. All hotspots are covered by TWUL’s Maple Lodge model; however this is a relatively coarse “macro” model and does not include surface water sewerage systems. The TWUL modelled coverage for the borough is displayed in Figure 3-3.

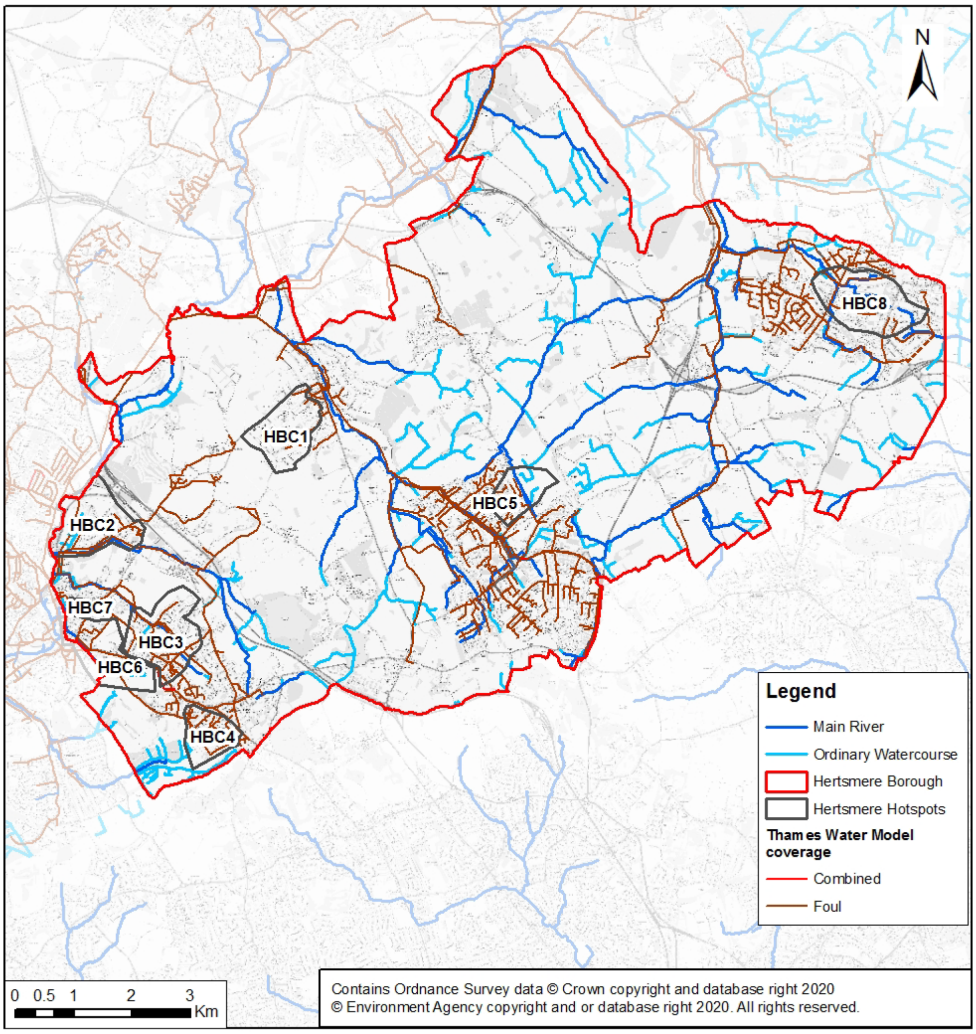

Figure 3-3: Map displaying TWUL model coverage for Hertsmere

3.8 Hotspot scoring

A scoring system was used to help assess whether hotspots should progress to detailed SWMPs. The scoring was based on the following weighting and set out in Table 3-3:

- Count of properties at risk in the RoFSW mapping “medium risk” (1 in 100 year) event - 40%;
- Count of properties on the HCC flooding records - 40%;
- A qualitative assessment of the other needs and opportunities within the hotspot - 20%.

Scores were applied as follows and results are shown in Table 3-4:

Table 3-3: Hotspot scoring system

Score given	RoFSW score (receptor count)	Historic flooding score (property count)	Other needs and opportunities score
40%	>20	>20	Not used
30%	11-20	11-20	Not used
20%	6-10	6-10	High
10%	1-5	1-5	Medium
0%	0	0	Low

Table 3-4: Hotspot scoring results

Hotspot code	Scoring - RoFSW Medium (%)	Scoring - LA properties (%)	Scoring - Other Needs / Opportunities (%)	Overall score (%)
HBC1	10	10	10	30
HBC2	40	10	10	60
HBC3	40	30	20	90
HBC4	10	10	10	30
HBC5	10	10	10	30
HBC6	40	10	20	70
HBC7	10	10	0	20
HBC8	30	10	10	50

The scoring was not normalised by size or number of receptors at this stage, and therefore there was some bias towards larger hotspots getting higher scores, where they contain high numbers of reported or modelled flooding receptors.

The hotspot scoring was used as a tool to inform the selection of sites for further analysis in detailed SWMP's; alongside judgement based on experience and the history of flood risk in each hotspot.

3.9 Summary of hotspots

The hotspots identified are shown in Figure 3-4, and the recommended way-forward is summarised in Table 3-5. See Appendix C for the full hotspot assessment sheets.

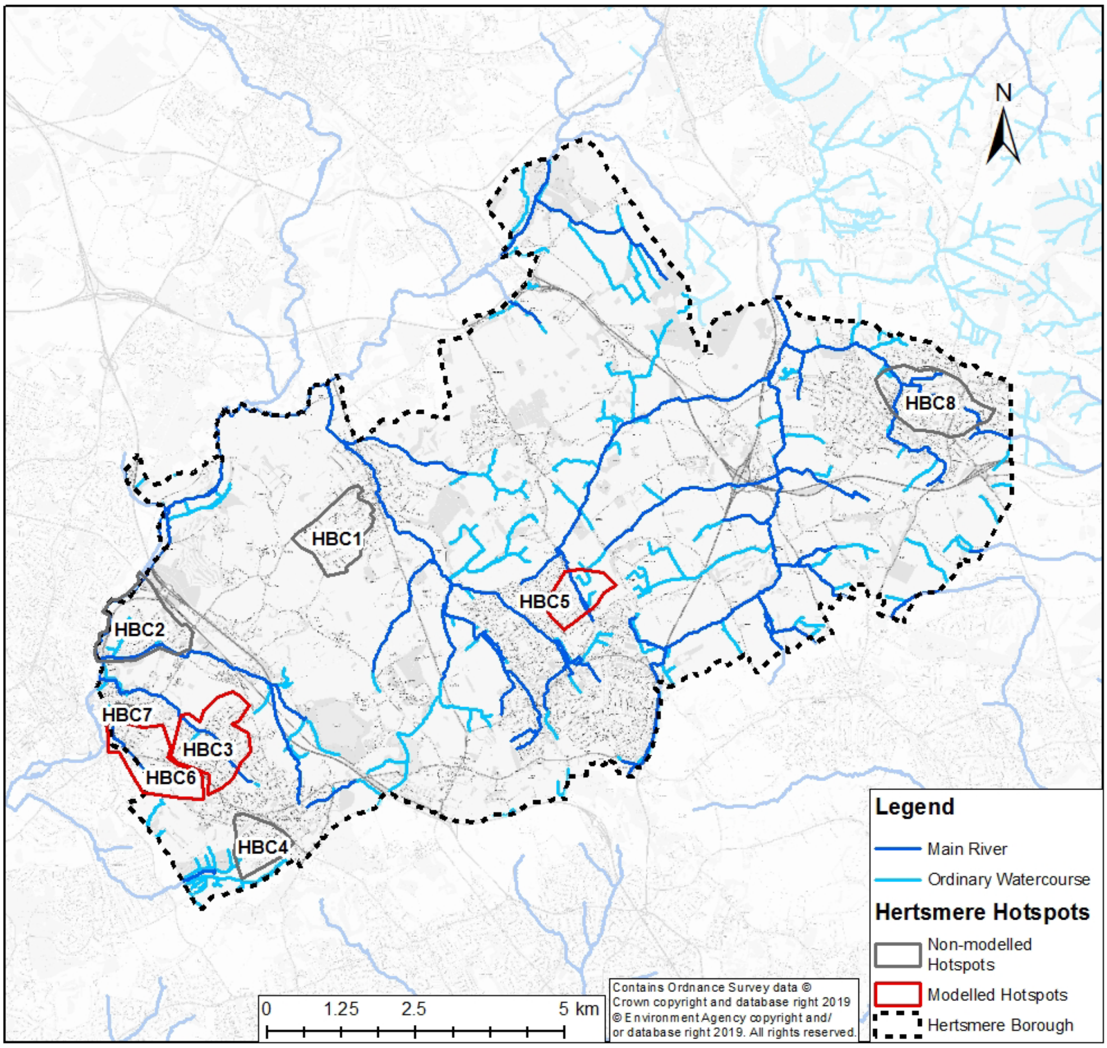

Figure 3-4: Map of modelled hotspots for Hertsmere Borough

Table 3-5 - Summary of Hotspot assessment

Hotspot Code	Recommended way forward	Decision: Significant risk identified and further modelling required	Decision: Non-modelled hotspot	Decision: No further actions
HBC1 - Radlett	Discussions during the site visit on 29 November 2017 suggested an option going forward is to assess the measures that could be put in place to hold the flow of water upstream, or to efficiently drain water across/beneath the B462. Modelling may not be justifiable with only 2 internal flooding properties. Little benefit of modelling to confirm RoFSW, however modelling could assist option design.	✓	N/A	N/A
HBC2 - Mead Way, Bushey	Discussion during the site visit highlighted that HBC have already commissioned a local investigation to be carried out on Mead way and Bushy Hill Lane. The evidence of surface water flood risk that has been collated for this hotspot area is very scattered and there is not enough to make it warrant a modelling study at this stage.	N/A	N/A	✓
HBC3 - Moatfield Road, Bushey	This hotspot area is the focus of flood risk in the borough of Hertsmere, with 16 recorded surface water flood incidents and a further 15 sewer flood incidents in this hotspot. The flood incidents are closely correlated with mapped flood risk areas. It is recommended that this hotspot is modelled and includes both the surface water and foul sewer networks to improve the understanding of the flood mechanisms in the hotspot.	✓	N/A	N/A

Hotspot Code	Recommended way forward	Decision: Significant risk identified and further modelling required	Decision: Non-modelled hotspot	Decision: No further actions
HBC4 - Prowse Avenue, Bushey	It has been decided that this hotspot will be taken forward as a non-modelled hotspot due only 1 property confirming internal/external flooding. It would be difficult to implement any flood prevention measures due to the fence line and the location of property at risk. The recommended action is to undertake PFR work at this location. Note that there is a TWUL (foul) SPS along the road. Maintenance on the drainage curb that has been implemented is a potential option here.	N/A	N/A	✓
HBC5 - Crown Road, Borehamwood	This hotspot has been considered to have lower priority and doesn't warrant detailed modelled - however it is to be considered at the workshop. Should the hotspot be revisited in the future one options that was discussed during the site walkover was retaining surface water within the highway to convey it away from at risk properties e.g. at Gateshead Road. It is advised that this hotspot is taken forward for PFR work and that the known flood incidents are looked at in more detail.	N/A	N/A	✓
HBC6 - Bushey (Roads including Moatfield Road, Spring cross, Vale Road, Hayden Road and Homefield Road)	It is recommended that this hotspot is taken forward as a modelled hotspot to include the ordinary watercourse that runs through Attenborough Fields, the culverted reach of the watercourse and outlet at Vale Road. To model this hotspot, ordinary watercourse survey would need to be carried out.	✓	N/A	N/A

Hotspot Code	Recommended way forward	Decision: Significant risk identified and further modelling required	Decision: Non-modelled hotspot	Decision: No further actions
HBC7 – Napier Drive, Bushey	The flood risk along Napier Drive was not considered to be significant enough to warrant modelling and it is advised that if anything, localised PFR action would be the way forward. An assessment of the highway drainage is recommended as part of any future investigations in this location.	N/A	N/A	✓
HBC8 – Highview and Darkes Lane, Potters Bar	There is currently a modelling study that is being carried out here by HCC to improve the fluvial mapping in the area. As a result, this other study that is being carried out will take account of recommendations and actions. This study will be taken forward as a non-modelled hotspot to recognise the risk associated with the site/continued identification of the potential risk.	N/A	✓	N/A

In summary, within Hertsmere Borough, three hotspots were recommended for a detailed SWMP investigation, three as a non-modelled hotspot and two for no further action. Hotspots recommended for detailed SWMP investigation:

- HBC3 - Moatfield Road, Bushey;
- HBC6 – Bushey (Roads including Moatfield Road, Spring cross, Vale Road, Hayden Road and Homefield Road).

3.10 Hotspot selection workshop

A hotspot selection workshop was carried out on 16 January 2018, attended by representatives of HCC, HBC, EA and TWUL. The workshop confirmed the decisions regarding which ones to take forward to the modelling phase, which ones to take forward as non-modelled hotspots and which ones that do not require any further action.

3.11 Recommendations

The recommendations are outlined in Table 3-5 and are attached in Appendix C with the full hotspot assessment sheet, outlining the details of each hotspot area, images from the site visits and the recommended way forward.

4 Detailed Risk Assessment - approach

4.1 Introduction

The intermediate assessment identified three hotspots for a detailed assessment of the surface water flood risk using hydraulic modelling in line with the Defra guidance. The modelling has been developed to be outcome-focused and provide an improved understanding of the surface water flood risk within the hotspots.

4.2 Data collection and surveys

The models have been developed using a range of topographic and asset data as outlined below.

4.2.1 Topography

EA LiDAR data was used as the basis of the Digital Terrain Model (DTM) for all hotspots. The data was provided at a composite 1m resolution for the study.

4.2.2 Topographic Survey

Survey data was collected for key open channel watercourses in the hotspot areas and included major structures such as bridges, weirs and culvert inlets.

This data was also used to ground truth the LiDAR data provided by the EA.

4.2.3 Drainage infrastructure

No detailed Thames Water models of the public surface water network were available for the borough; therefore, the GIS sewer network information was made available to support the study.

4.2.4 Survey

Manhole surveys of the surface water network were undertaken to support the model development and targeted areas where information such as pipe dimensions or sewer invert levels was missing within the TWUL GIS sewer data, or where the sewer network required validation checking.

In addition, manholes were identified on culverted watercourses, which may interact with the public surface water sewer network or combined sewer network via Combined Sewer Overflows (CSOs).

4.3 Model build and validation

Using the data and surveys described above, integrated models were constructed to represent all the key components of the drainage systems within each hotspot, including the catchment surfaces from which rainfall-runoff is generated, the sewers and minor watercourses. This type of model allows the interactions between different parts of the drainage system to be investigated – for example, runoff from a field can run down a road, enter a sewer, cause this to become overloaded and to flood back onto the surface further downstream.

The model was run using a set of design rainfall events with a range of annual event probabilities (50%, 20%, 5%, 3.3%, 1.3%, 1% and 0.1%). The model results include a two-dimensional representation of flood extents, depths, velocities and hazard (a measure of how dangerous the flooding is to people). The models were also run for future scenarios to represent the impacts of climate change resulting in increased river flows and rainfall.

The hydraulic model outputs form an assessment of flood hazard. To assess flood risk, these were combined with mapping of flood receptors (residential properties, businesses, public buildings etc) to calculate a range of flood risk metrics including the number of properties at risk of the direct economic damages as a result of internal flooding.

Details of flood risk metric analysis, information about the survey specification, general schematisation of the models, modelling approach and model review process used in the development of the models for Hertsmere Borough are included in Appendix D.

4.4 Options development

A long list of potential options to help better manage and mitigate flood risk within the Hertsmere hotspots was compiled and the feasibility of their implementation, including consideration of their advantages and constraints, was assessed in each area using the criteria set out below.

The long list of options was developed using the outputs of the updated detailed surface water modelling, previous studies and local guidance as well as publicly available information such as EA LiDAR data, British Geological Survey (BGS) maps and online mapping, as well as notes from the site walkovers and other data provided by HCC such as TWUL asset maps.

The viability of each longlisted option has been subjectively assessed using engineering judgement considering the buildability, possible benefits and likely reasonableness of costs.

4.4.1 Assessment Criteria:

- **Disruption for construction and maintenance are minimised**: An ideal scheme would have little disruption to the public during its construction and future maintenance. For example, a scheme including upsizing of sewers would have large disruption when digging to the pipes.
- **Number of properties protected from flooding by surface water runoff:** This is crucial when considering the cost-benefit of the scheme.
- **Level of additional environmental benefit provided:** A proposed scheme should aim to enhance the environment. For example, retrofitting of SuDS can involve conversion to green space, which would potentially create habitat space.
- **Risk to maintenance operatives is minimised:** Any future maintenance scheme would require planning ahead of construction. Any design should ensure that maintenance operatives can complete their job safely.
- **Overall acceptability of the scheme to the public:** This is crucial to a scheme being accepted and taken aboard by the public. Consultation with people within the surrounding area would aid understanding of what would be accepted/rejected.

- **No adverse ecological effect on flora and fauna:** Any negative impact upon the existing ecology should be avoided when considering schemes.
- **Scheme minimises visual impact on surrounding area:** A scheme to manage flood risk should aim to work with its setting. For example, construction of artificial surfaces (e.g. concrete and brick) would be detrimental within an existing green environment.
- **Design can be easily adapted to accommodate climate change impacts:** The changing climate means that a scheme built today may not be suited within the future. It is advised that climate change is considered when schemes are constructed, however it would be preferred if the scheme could easily be updated.
- **Low capital investment required:** costs associated with the proposed scheme are considered against properties that would likely benefit. Where there are only few properties at risk, a low-cost scheme would be more cost-effective.
- **Low maintenance costs:** it is key to consider any costs that are incurred following completion of the construction and who is responsible for these.

The scoring of the options is included within the longlist for each hotspot. The total score was used to understand which of the suggested options would be most beneficial. These were then taken to the final shortlist of proposed actions.

4.5 Economic assessment

Damage estimates have been derived from direct tangible flood damages, emergency costs and vehicle damages. The approach to assess the damages was undertaken in accordance with FCERM-AG (EA, 2010), the MCM (FHRC, 2013), the MCM Handbook (FHRC, 2016) and The Green Book (HM Treasury, 2011).

4.6 Methodology

This application of the MCM has been undertaken using JBA Consulting's in-house Flood Risk Metrics (FRISM) software.

FRISM is a GIS based impact analysis software that computes a range of metrics, including property damages, in accordance with the techniques outlined in the MCM. FRISM computes these by combining flood modelling results together with receptor data. The metrics that can be calculated depend on the geometry type of the receptor data and the type of modelling results used. As depths grids were produced for this project, detailed property level analysis was computed, which includes minimum, maximum and mean depths and damages at each property. Property level analysis was then summed across the study area to determine the total impact (e.g. the total damages for a particular flood event). As multiple events were modelled, the Annual Average Damages (AADs) were computed for each metric. FRISM has also been used to provide property counts for each event. These figures can be used to determine the potential economic viability of any proposed works.

4.7 Available data

The following datasets were used to calculate the damages estimates and property counts:

- RoFSW mapping – Flood extents from the national scale RoFSW mapping were used as a baseline.
- Hydraulic modelling results – depths grids generated by the modelling give the flood depths across the study area for each flood event for each scenario.
- National Receptor Data (NRD; 2014) – the property point dataset contains information such as building type, class description, floor area, floor level, and MCM code.
- Office for National Statistics Consumer Price Inflation (CPI; 2018) – provides the CPI to enable uplift of values to present-day.
- Ordnance Survey (OS) MasterMap – the building footprint polygon layer was extracted from the OS MasterMap and used to determine whether a property would be flooded or not. For this assessment, if any part of the building footprint is within the flood extent, then the building is considered flooded.

4.7.1 Property data

All property data is based upon the NRD. The NRD was processed to remove property points which should be excluded from the assessment, in accordance with FCERM-AG (EA, 2010). The full property exclusion list is taken from the NRD2014 guidance as non-reportable property points. These include, but are not limited to, street records, PO boxes, property shells and advertising hoarding. All the remaining properties within the study have been included within the analysis.

The following assumptions were made:

- Only properties which had an associated OS MasterMap building footprint were included within the analysis.
- Property floor areas used were taken directly from the NRD opposed to the associated OS MasterMap building footprint.
- All upper floor properties were removed from the analysis as direct flood damages are unlikely to impact upon first floor properties and above.

4.7.2 Property types

The MCM code and class description were used to categorise the NRD points into:

- Residential – all properties with an MCM code of ‘1’ or a class description of residential.
- Non-residential – all properties which are not categorised as above, therefore included retail and office spaces, places of worship and workshops.

4.7.3 Property footprints

Property areas were taken directly from the NRD data. However, only properties with an associated OS MasterMap footprint were included within the calculations for a more accurate representation of properties.

4.7.4 Property values

Due to the flood levels estimated by the modelling which would not result in extensive damage to properties, none of the properties were assigned a property value as investigation of the results indicates that non-residential damages are low compared to property values and so capping of damages based on property values would not be implemented.

4.7.5 Present value damages threshold survey

A floor level threshold of 100mm was applied to all properties within the study area. This average threshold was determined from site visit observations of the study area. This 100mm was applied directly within the damage assessment.

4.8 Direct damage estimation methodology

This section outlines the damage calculations undertaken. In assessing the damages, it has been assumed that the flood duration is less than 12 hours, with no warnings prior to the damages occurring.

4.8.1 Property damages

Damages were calculated at the property level in accordance with the MCM (FHRC, 2013). For this economic appraisal, the flooding scenario is taken to be fluvial water with a short duration (i.e. less than 12 hours) and no flood warning, and the associated MCM 2013 depth-damage curves were used. The depth-damage curves, were uplifted to August 2018 values using the CPI, as recommended in the MCM (FHRC 2013; p86). Within the FRISM code, the 2013 MCM depth-damages curves have been uplifted and calibrated to January 2017, with an additional manual uplift to 2018 added with a CPI of 106.5. The CPI value was taken from the Office of National Statistics on 26 September 2018 for August 2018 as the most recently published data at the time.

The MCM code field within the NRD dataset was used to assign an appropriate MCM curve to each property to calculate the AAD. Damages were not calculated for upper floor properties or those assigned an MCM code of ‘999’.

4.8.2 Capping

As the predicted damages to properties is unlikely to exceed the market value the Present Value damages (PVd) of individual residential properties have not been capped at the market value of the property, nor have non-residential properties been capped. Investigation of the results indicate that capping of properties would not impact upon the outcome of this economic appraisal as the non-residential damages are low compared to property values and so capping would not be implemented.

4.8.3 Write-off

A property can be written-off within the economic assessment if it is considered to flood in a 33.33% AEP event, or more frequent, as stated in the MCM (FHRC, 2013; p82). This is based on the assumption provided by the Environment Agency that three years is required for a property to be repaired and return to full use after the impact of flood event. Write-off has not been applied for this economic assessment due to the low flood depths within this study area which are not likely to result in the property needing to be abandoned, and hence written off.

4.8.4 Indirect and intangible damages

In addition to the direct tangible property damages calculated using depth-damage curves, emergency costs, vehicle damages, indirect property damages and intangible property damages have also been calculated in accordance with the MCM (FHRC, 2013). Emergency costs have been included as an uplift of 5.6% on property damages as appropriate for urban areas. Vehicle damages have been calculated at £3,600 per residential property where flood depths are greater than 0.35m.

5 Detailed risk assessment – Results

5.1 Introduction

The modelled outputs have been reviewed for each hotspot and a detailed Source-Pathway-Receptor assessment of the key flooding mechanisms and flood risk areas have been identified. Possible flood mitigation measures have been considered for each hotspot and the details of the options considered and preferred short-listed options are set out below.

5.2 Hotspot HBC3 – Moatfield Road

This hotspot, shown in Figure 5-1, was identified as the focus of surface water flood risk within the borough and includes the area around Moatfield Road, Spring Crofts, and Homefield Road. It was identified as requiring further detailed modelling following the Phase 1 multi-criteria analysis. The hotspot is largely urbanised, with two central green spaces (namely the King George Recreation Ground and Moatfield Road Recreation Ground) and further greenspace in the north of the hotspot, which is used as agricultural land and allotments.

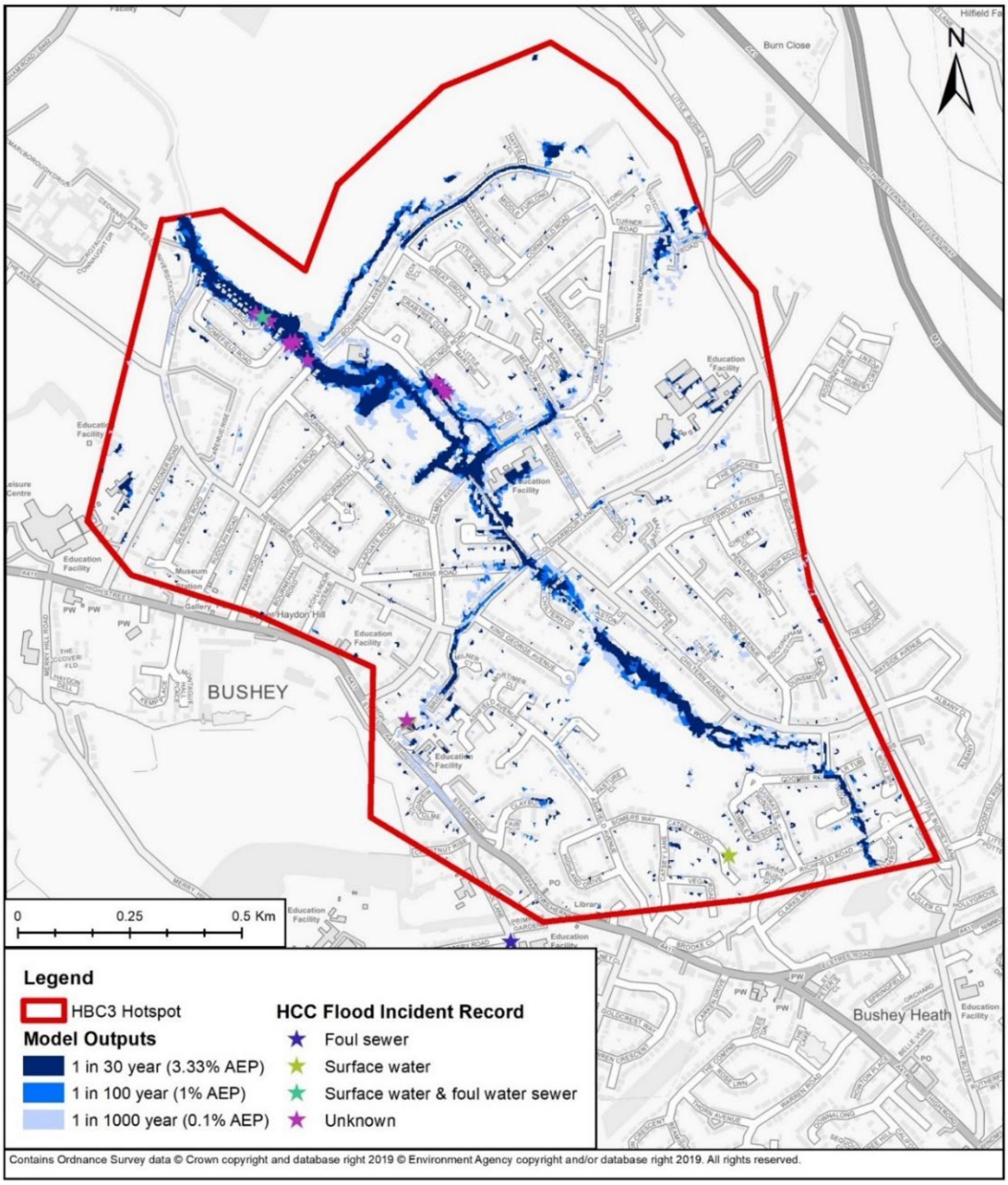

Figure 5-1: Detailed model outputs for HBC3 – Moatfield Road

5.2.1 Assessment of flood mechanisms - Source-Pathway-Receptor

Within the hotspot area, a network of surface water flow paths has been identified.

Figure 5-1 shows the surface water flood risk within the detailed modelling. The primary flow path is from the southeast to northwest and is associated with the King George Drain, a watercourse that has been culverted for the majority of its length through the urban area of the hotspot. The flow path follows the natural topography of the area, originating in the south of the hotspot and flowing in a north-westerly direction from the King George Recreation Ground. It impinges on several roads, including Coldharbour Lane and Palmer Avenue before it continues through Moatfield Road Recreation

Ground. Here, the flow path affects Moatfield Road, Homefield Road and Spring Crofts; it is here that the majority of the reported flood incidents have occurred.

In addition to the primary flow path, there are numerous smaller flow paths. These are generally focused along roads, including Farm Way, Palmer Avenue and Bridgewater Way. The primary flow path is present in the 1 in 30-year storm event (Figure 5-2), as well as flow paths along the roads named above. In the greater return periods, the number of smaller flow paths increases, including several other roads.

Maps showing flood depths in the 1 in 30, 100 and 1,000 year return periods are included within Appendix E.

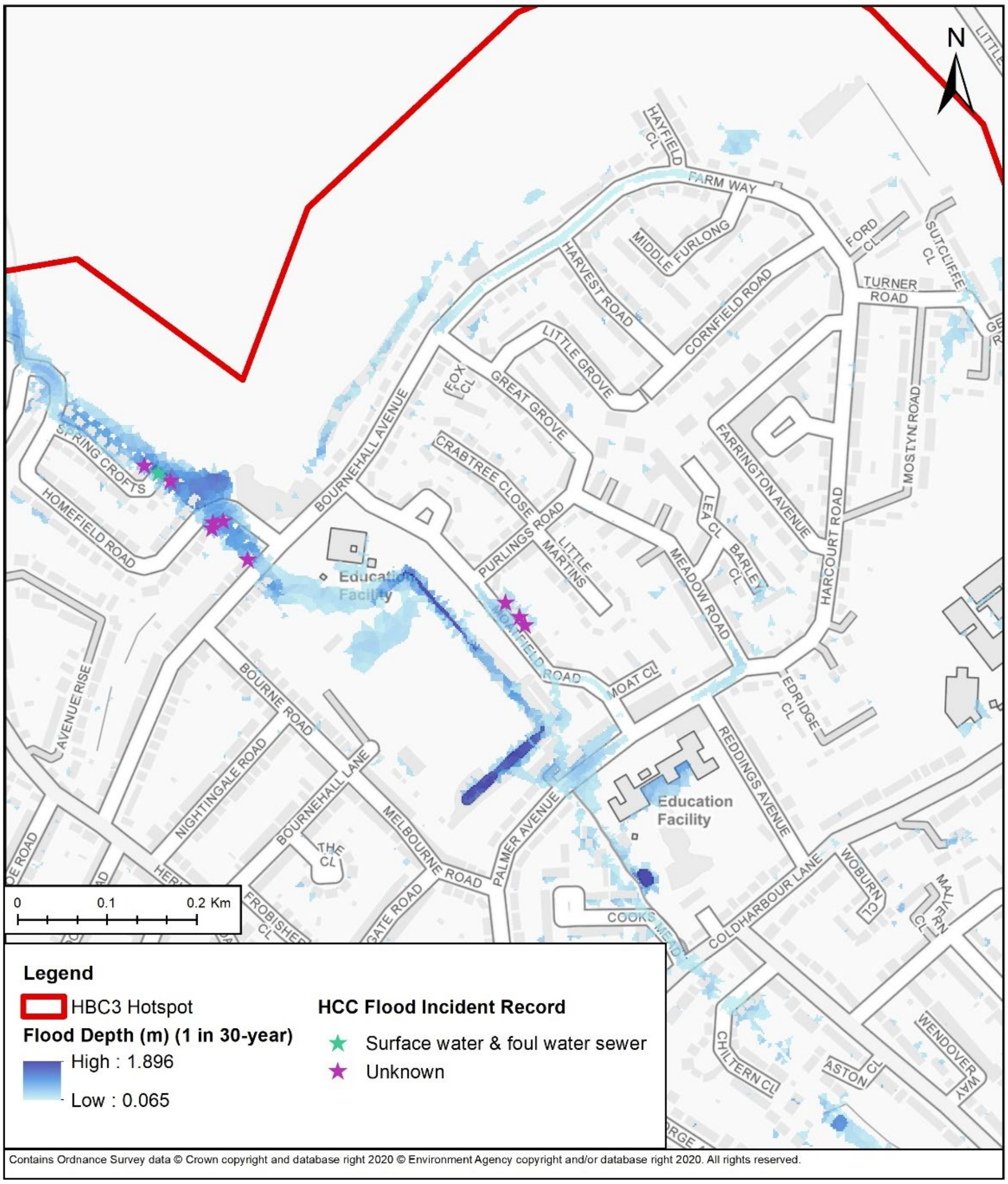

Figure 5-2: Flow paths along Palmer Avenue and Farm Way

Table 5-1 show the number of properties shown to be at risk by the EA RoFSW mapping and by the detailed flood modelling, respectively. Generally, the surface water flooding predicted by the RoFSW mapping aligns with the modelled outputs and in both the dominant flow paths are apparent. The main difference between the two outputs is the small areas of localised flooding that are included within the detailed modelling. These areas of ponding mostly occur against buildings (in the detailed modelling) and therefore result in larger numbers being shown to be at risk of flooding. It should be noted that any ponding areas smaller than $25m^2$ were excluded when counting the properties at risk of flooding.

Table 5-1: HBC3 Properties at risk from surface water

Number of residential properties at risk	1 in 20 year	1 in 30 year	1in 75 year	1 in 100 year	1 in 200 year	1 in 1,000 year
RoFfSW	N/A	202	N/A	439	N/A	1326
HBC2 detailed modelling	659	681	717	800	858	1057
Number of non-residential properties at risk	**1 in 20 year**	**1 at risk of in 30 year**	**1 of in 75 year**	**1 in 100 year**	**1 in 200 year**	**1 in 1,000 year**
RoFfSW	N/A	15	N/A	31	N/A	85
HBC3 detailed modelling	0	83	86	89	96	105

Within the hotspot area, ten flood incidents have been reported in total, all of which occurred in June 2016. Of these, nine of have an unknown cause, and the other is attributed to foul and surface water sewers. Despite the unconfirmed cause, reports of the incidents noted surcharging manholes. The flooding occurred along Moatfield Road, Homefield Road, and Spring Crofts. Internal flooding was reported within eight of the properties, and depths of 75mm (3 inches) were recorded.

5.2.2 HBC3 Mitigation Options Considered

The detailed modelling was used to understand the flood mechanisms that impact the at-risk areas within the hotspot and as part of the longlisting process, several methods were considered to alleviate the flood risk within the hotspot. These options are summarised in Table 5-2 and further information about the options considered and the locations for options is included in Appendix F and Appendix G respectively.

Table 5-2: Summary of options for HBC3

Option Number	Option Type	Description	Areas Applicable	Shortlisted?
Option 1	Allocation of Land within Local Planning	Land designation based upon at-risk areas	Not applicable within hotspot	×
Option 2	Flow restriction from new development	Recommending greenfield runoff rates for new developments within hotspot	Hotspot-wide application	×
Option 3	Natural Flood Management (NFM)	Utilisation of natural methods to reduce flood risk downstream	Moatfield Road and King George Recreation grounds	×
Option 4	Property Flood Resilience	Protection to individual properties	Spring Crofts, Homefield Road, Moatfield Road	✓
Option 5	Storage of flood waters	Construction of a flood bund to detain flows within recreation ground	Moatfield Road Recreation Ground	✓
Option 6	Obstruction of flow path	Construction of a flood bund beyond allotments to obstruct flow path	Beyond allotments behind Bournehall Avenue	×
Option 7	Surface water management	Localised management of surface water to reduce volumes reaching Spring Crofts area	Area surrounding Finch Lane/ Herkomer Road	✓
Option 8	Upsizing of sewers	Increased sewer capacity to reduce volumes	Herkomer Road	×

Option Number	Option Type	Description	Areas Applicable	Shortlisted?
		remaining on the surface		
Option 9	Daylighting of culverts	Returning the King George Drain to a more natural state	Culverted watercourse near Spring Crofts	×
Option 10	Retrofitting of SuDS	Disconnection of runoff from public sewers using SuDS	Bournehall Avenue and Farm Way	×

Option 1 and Option 2 considered possible measures that HBC could put into place in its role as the LPA, with the support of HCC. These included the allocation of land at higher risk of surface water flooding for less vulnerable uses as part of the Local Plan process. For example, where land at higher surface water flood risk becomes available for redevelopment consider allocating as recreational space or for water compatible development (Option 1). The model results highlight the importance of runoff generated within the hotspot on local flood risk. Therefore to address this, a hotspot-wide policy to limit any additional flows from new development could be implemented (Option 2). It is noted that, while some small-scale urban creep may occur, at the time of writing there are no known largescale developments within the hotspot where this policy is most likely to be beneficial. Therefore, it is considered that this option will provide no overall enhancement to the hotspot if it were to be shortlisted.

The principal source of risk is associated with the flow path moving north-west along the natural route of the King George Drain, through the hotspot, and options were initially considered here. The two recreation grounds located along the principal flow path provide ideal areas for actions to be implemented. Option 3 considered the potential use of Natural Flood risk Management (NFM) techniques, such as increased vegetation and constraining flow with the existing wooded channel on the northern boundary of the playing fields. This can also provide environmental enhancement and has no direct impact upon properties. However, the volumes associated with the flow path are unlikely to be fully controlled through these techniques.

The areas around Moatfield Road and Spring Crofts and Homefield Road include a number of properties which have reported flood incidents in the past. These areas are associated with the main flow path through the hotspot as well as locally sourced runoff which there are limited opportunities to manage at source. Based on site observations and a desk-based review of the area, it is observed that the properties generally have low thresholds, resulting in flooding from even shallow flood depths, particularly in Moatfield Road. Option 4 therefore considered the suitability of these areas for the installation of PFR measures. This would likely involve the installation of flood doors which would be a permanent fixture, not requiring any temporary installation during the time of flood. This would be most suited to the surface water flood risk as there is often little warning that surface water flooding is going to occur. Other points of potential ingress, for example airbricks, would also need to be considered and fitted with resilience devices. This option may also be considered alongside larger construction options to manage residual risk.

The construction of a flood bund within Moatfield Recreation Ground (Option 5) was shown to be the most effective method of reducing flood risk. The bund is proposed at the northern boundary of the field, as this also reduces modelled flood risk to Bournehall Primary School. Figure 5-3 shows how this bund was represented within the modelling.

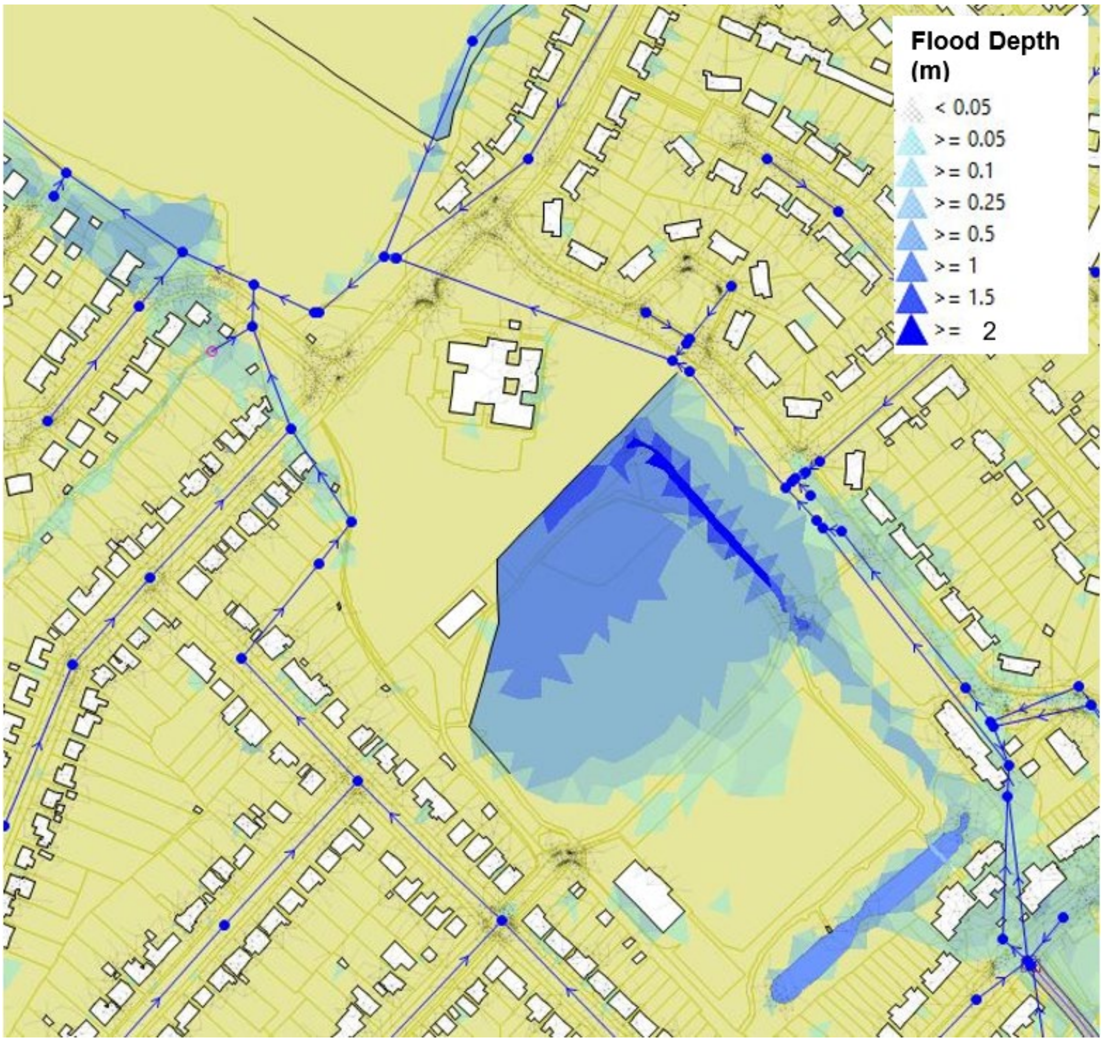

Figure 5-3: Option 5 - Modelled flood bund in Moatfield Recreation Ground

A flood bund within this area would have little degradative impact but would equally provide no additional environmental enhancement. Modelling showed that properties around the Homefield Road area are still at a risk of flooding however at much lesser depths, allowing for the implementation of complementary PFR measures considered in Option 4. A bund of this scale would however incur a higher cost than other options and would have to be considered against the benefit provided. It should be noted that the inclusion of the bund within the model is to highlight the impact of the flow path being obstructed, and it may be preferable that a series of bunds and/or storage areas are utilised to accommodate the flood volumes.

With the principal flow path obstructed, the modelling suggested that there were other inflows of surface water to the at-risk area. The area surrounding Herkomer Road naturally drains towards the at-risk properties with little obstruction. Figure 5-4 shows the area that drains towards Homefield Road and Spring Crofts.

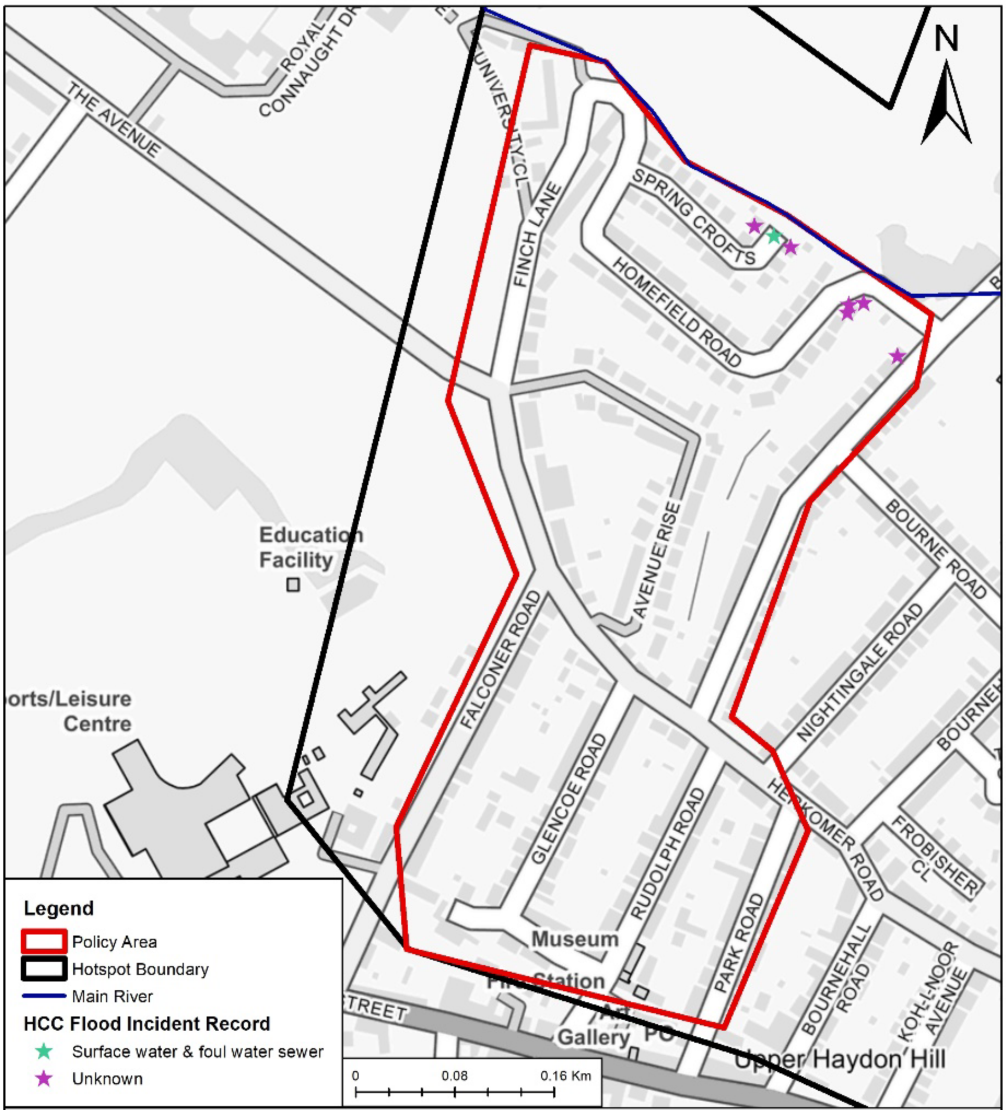

Figure 5-4: HBC3 - Option 7 – Area identified as source of surface water risk and suggested management zone

The flows, shown in Figure 5-5 are generally shallow and of low risk but accumulate in the low point around Homefield Road. It is suggested that policy is implemented for this area (shown in Figure 5-4) to be treated as a surface water management zone (Option 7), whereby property-scale actions should be adopted to result in an area-wide impact. Overall, this would have little disruption to the area with no proposed construction. Relative to large management schemes, it would also have relatively low cost attached. However, it would require community-wide adoption for the benefit to be achieved.

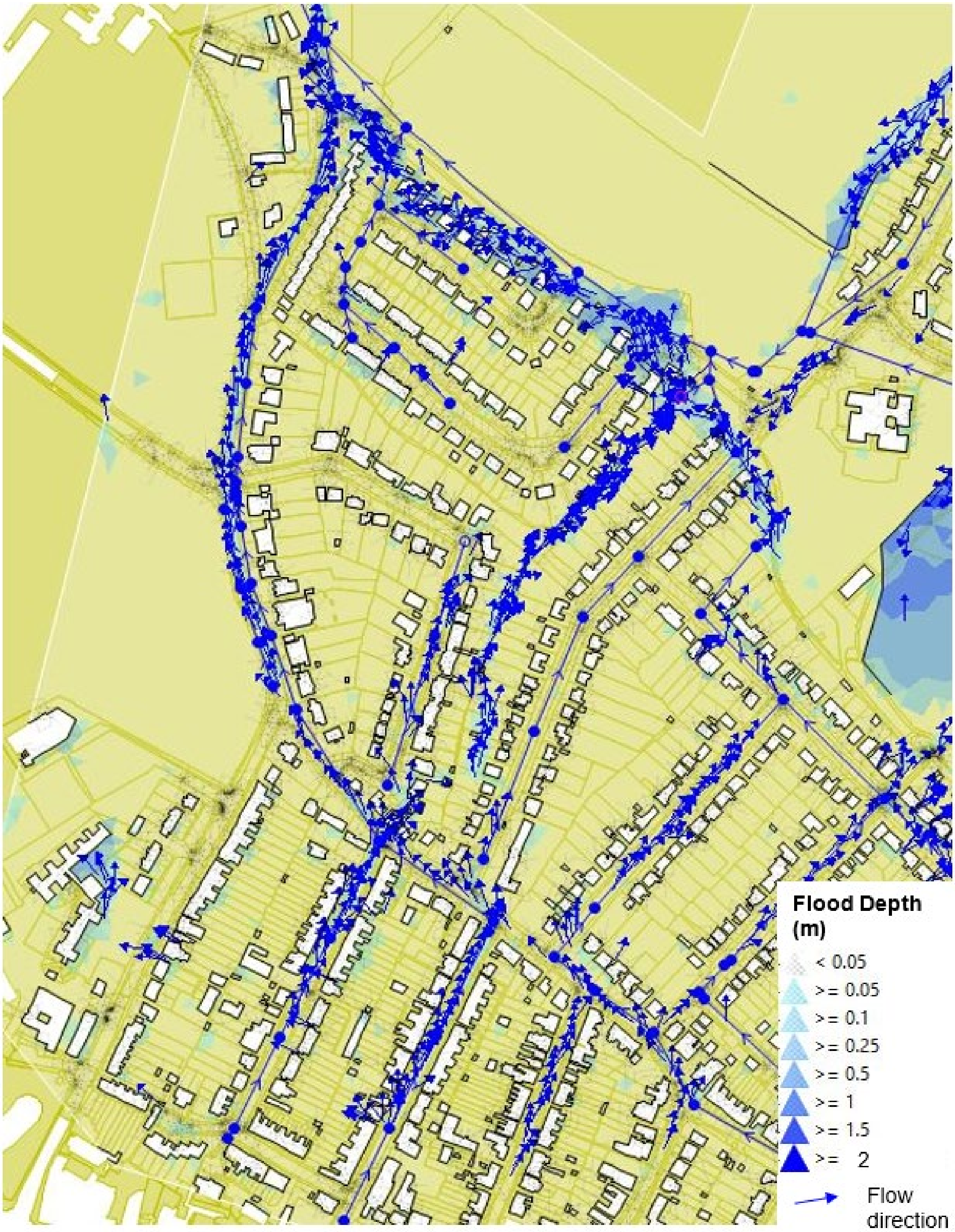

Figure 5-5: Locally derived flood flows in the Herkomer Road area

It is noted within the modelling that the sewer system around Herkomer Road is at capacity in events greater than a 1 in 5-year storm and flooding from the sewer network follows the road network to the north. Increasing sewer capacity by upsizing the surface water sewer network is included as a long-listed option (Option 8). This was not considered a viable option for the shortlist due to the significant disruption that would occur during the upgrades. Furthermore, this would provide no other additional benefits, such as amenity or environmental enhancement.

Properties around Homefield Road sit at a low point along the natural course of the culverted King George Drain. Daylighting of the watercourse was considered (Option 9) and modelled. Spring Crofts is within very close proximity to the natural route of the watercourse, not allowing for daylighting along the natural course. Daylighting of the culvert would also result in significant disruption to the area and be a highly costly operation. Additionally, maintenance would be required by the riparian owners and the EA as the watercourse is classified as a main river.

Retrofitting of SuDS is widely accepted as a successful method of alleviating flood risk derived from surface water (Option 10). SuDS could be constructed along Bournehall Avenue and Farm Way (e.g. swales) to slow and reduce the excess surface water running along the roads which contributes to the flood volumes around Homefield Road. However, the volumes associated with this highway flow path are significantly low when compared to the flow path through the recreation ground (see Figure 5-3). Consequently, SuDS have not been taken forward as the impact on flooding will be minimal and will not have a notable impact upon the area at risk.

The options chosen as the preferred methods for the hotspot are:

- Option 4 – Property flood resilience;
- Option 5 – Storage of flood waters within Moatfield Recreation Ground;
- Option 7 – Surface Water Management Zone.

It is unlikely that one option alone would not provide protection for the affected properties and the options above should be combined for an effective response to the flood risk.

5.3 Hotspot HBC6 – Bushey

This hotspot is focused upon the area of Bushey which includes Moatfield Road, Spring Cross, Vale Road, Hayden Road and Homefield Road. Flowing northwest through the hotspot, is the Waterfields Way Ditch which begins as an ordinary watercourse and flows as open channel before being culverted. To represent the whole catchment, the model extends to the source of the ordinary watercourse. Survey was also conducted as recommended. In the centre of the hotspot, there is an area of greenfield land, which includes Attenborough Fields. In the west, the area is highly developed, with densely populated residential streets.

5.3.1 Assessment of flood mechanisms – Source-Pathway-Receptor

Within this hotspot two dominant flow paths have been identified. Figure 5-7 shows the predicted surface water flood risk, as output from the detailed modelling. The primary flow path originates in the southeast and flows in a westerly direction. It is associated with Waterfields Way Ditch (flowing through Attenborough Fields) which becomes culverted at Haydon Road. Along Haydon Road, there is an area of flooding which is predicted to occur within the 1 in 30-year event. Surface water flow paths are also present along the A411 (London Road) which meet at a low point which is at the junction with Haydon Road. Here, the water flows down Haydon Road and contributes to the area of flooding around Brick Kiln Lane.

In the northeast of the hotspot, there is a second flow path which originates in the fields beyond Grange Road. The flow path is shown to intersect several residential roads (namely Heathfield Road, Woodlands Road and Belmont Road) before it accumulates along Aldenham Road. Discussions with HCC and HBC have suggested that the modelling over-estimates this flooding, and real evidence of this flow path is unclear.

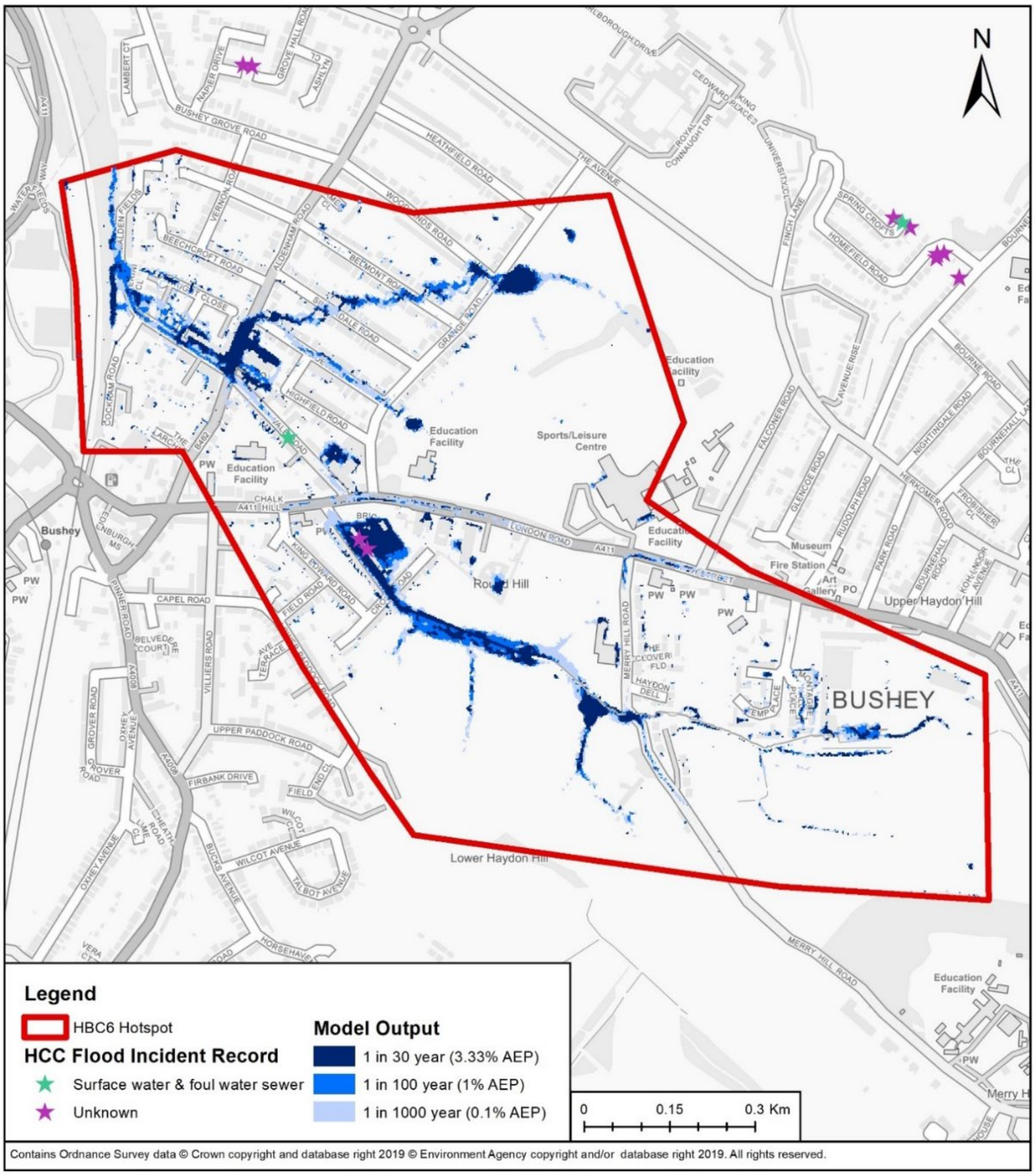

Figure 5-6: Detailed model outputs for HBC6

Table 5-3 shows the number of properties shown to be at risk within the EA RoFSW mapping and within the detailed flood modelling, respectively. Generally, the surface water flooding aligns between the RoFSW mapping and the modelled outputs, with the dominant flow paths appearing. The main difference between the two outputs is the small areas of localised flooding that are included within the detailed modelling. These areas of ponding mostly occur against buildings (in the detailed modelling) and therefore result in larger numbers being shown to be at risk of flooding, particularly at lower return periods. It should be noted that any ponding areas smaller than 25m^2 were excluded when counting the properties at risk of flooding.

Table 5-3: HBC6 Properties at risk from surface water

Number of residential properties at risk	1 in 20 year	1 in 30 year	1 in 75 year	1 in 100 year	1 in 200 year	1 in 1000 year
RoFfSW	N/A	117	N/1	301	N/A	316
HBC6 detailed modelling	165	182	217	222	241	262
Number of non-residential properties at risk	**1 in 20 year**	**1 in 30 year**	**1 in 75 year**	**1 in 100 year**	**1 in 200 year**	**1 in 1000 year**
RoFfSW	N/Q	17	N/Q	29	N/Q	49
HBC6 detailed modelling	25	27	35	37	38	47

5.3.2 HBC6 Mitigation Options Considered

The detailed modelling was used to understand the flood mechanisms that impact the at-risk areas within the hotspot and as part of the longlisting process, several methods were considered to alleviate the flood risk within the hotspot. These options are summarised in Table 5-4 and further information about the options considered and the locations for options is included in Appendix F and Appendix G respectively.

Table 5-4: Summary of options for HBC6

Option Number	Option Type	Description	Areas Applicable	Shortlisted?
Option 1	Allocation of Land within Local Planning	Land designation based upon at-risk areas	Not applicable within hotspot	×
Option 2	Flow restriction from new development	Recommending greenfield runoff rates for new developments within hotspot	Hotspot-wide application	×
Option 3	Natural Flood Management (NFM)	Utilisation of natural methods to reduce flood risk downstream	Attenborough Fields	×
Option 4	Property Flood Resilience	Protection to individual properties	Brick Kiln Close	✓
Option 5	Storage of flood waters	Construction of a flood bund within Attenborough Fields to detain flows	Attenborough Fields	✓
Option 6	Storage of flood waters	Construction of a flood bund beyond Grange Road to detain flows	Fields beyond Grange Road	×
Option 7	Attenuation basin	Excavation of attenuation basins to increase storage within Attenborough Fields	Attenborough Fields	×
Option 8	Upsizing of sewers	Increased sewer capacity to reduce volumes remaining on the surface	Aldenham Road	×
Option 9	Retrofitting of SuDS	Disconnection of surface water from public sewer via SuDS	Grass area between London Road and Haydon Road	✓
Option 10	Highway management of surface water	Increased conveyance and temporary storage of water within the highway	Merry Hill Road	×

The detailed modelling was used to understand the source flows that impact upon the at-risk areas. As part of the longlisting process, several methods were considered to alleviate the flood risk within the hotspot. The properties that have experienced flooding due to surface water along Haydon Road are located within a topographically low point, and so are at high risk of surface water ponding. It is unlikely that one action alone will prevent these properties from future flood risk, and a combination of methods will be required.

Option 1 and Option 2 consider possible measure that HBC in their role as the LPA could put into place with the support of HCC. Option 1 considered the potential for using the allocation of land at higher risk of surface water flooding for less vulnerable users as part of the Local Plan process. For example, where land at higher surface water flood risk becomes available for redevelopment consider allocating as recreational space or for water compatible development. The model results highlight the importance of runoff generated within the hotspot on local flood risk therefore to address this Option 2 considered whether a hotspot-wide policy to limit any additional flows from new development could be implemented. It is noted that, while some small-scale urban creep may occur, at the time of writing there are no known largescale developments within the hotspot where this policy is most likely to be beneficial. Therefore, it is considered that this option will provide no overall enhancement to the hotspot if it were to be shortlisted.

The dominant source of flood risk within the hotspot is associated with the flow path moving in a north-westerly direction through Attenborough Fields associate with the ordinary watercourse. This flow path is associated with the flooding along Haydon Road, where previous flood incidents have been reported. Attenborough Fields is owned and managed by HCC in partnership with the Friends of Attenborough Fields as an open amenity area and provides an ideal area for managing some of the flow from the upper catchment. Option 3 considered NFM techniques in this area to slow down and store the flow. For example, leaky dams along the existing channel within the fields. This option would provide the opportunity for volunteer led construction and maintenance as part of the on-going management of the fields, however the volumes of the flow would likely exceed the capability of these methods and therefore the option is unlikely to provide noticeable benefits downstream without the inclusion of additional measures.

Option 4 considered the installation of Property Flood Resilience (PFR) measures to reduce the impact of flooding on key properties. PFR can include active measures such as demountable defences on driveways or doorway, or passive measures such as installing flood-proof doors or raising or covering flood entry points like airbricks. PFR is most effective where flood depths are less than 0.6m and may therefore not be suitable all properties in Haydon Road where modelled flood depths can exceed this level but could compliment other options in this area and provide benefits in other at-risk areas of the hotspot.

Option 5 considered the construction of a bund at the western edge of Attenborough Fields, that would run parallel with Cross Road. Figure 5-7 shows how this was incorporated into model to represent the blockage of the flow. It is noted that a bund would result in little environmental degradation or amenity loss, but equally would provide no enhancement. The costs of constructing a bund to this scale would be high and would require consideration against the benefit provided. However, when included within the detailed modelling, this option resulted in the greatest reduction to downstream flood risk. During a period of high rainfall, the bund would likely cause the fields to become flooded, and consideration whether it would be possible to discharge the stored water via infiltration or whether positive discharge of the stored water via the existing drainage network at a controlled rate would be required. As with Option 3 any planned works in Attenborough Fields would require consultation between HCC and the Friends of Attenborough Fields, who manage the area in partnership.

It should be noted that the inclusion of the bund within the model is to demonstrate the potential benefit of the flow path being obstructed, and it may be preferable that a series of bunds and/or storage areas are utilised to accommodate the flood volumes.

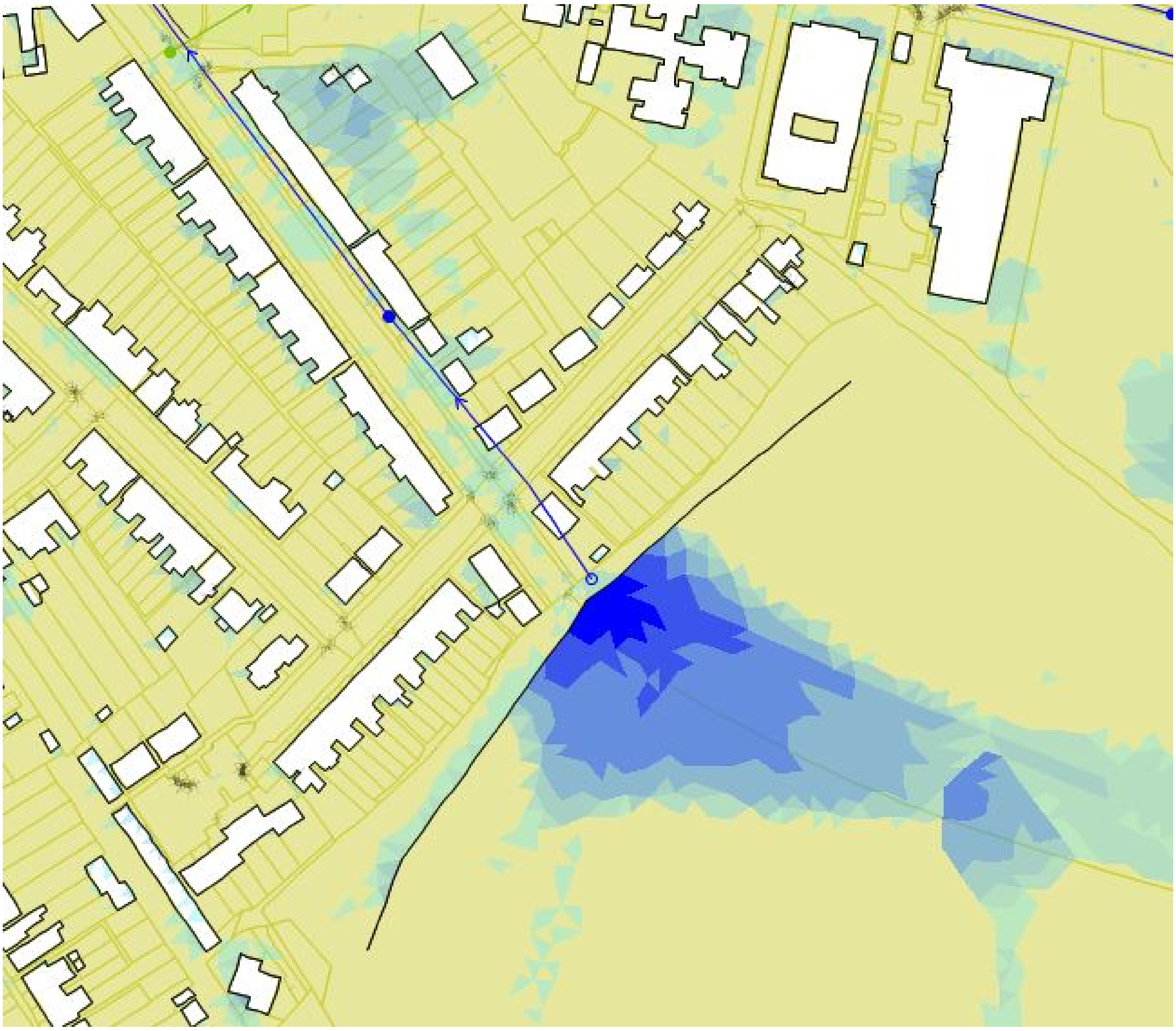

Figure 5-7: Model representation of a bund within Attenborough Fields

Option 6 considered the construction of a flood wall or embankment to obstruct the flow path moving west from fields adjacent to Grange Road in the north of the hotspot. The modelling indicates that this flow path contributes to ponding in the centre of the hotspot around the junction between Three Valleys Way and Aldenham Road, however it is believed that the modelling over-emphasizes the true impact of this flow path. Initial modelling of this option indicates that adding the obstruction does significantly reduce the flow path volumes. Despite this, at Aldenham Road where flood incidents have been recorded, there is little impact upon flood depths. This option has not been considered for further investigation.

Option 7 considered an alternative to Option 5 by providing additional storage within the east of Attenborough Fields, where an existing pond area connects to the ordinary watercourse. Excavation of detention basins would potentially provide environmental enhancement, but it was also considered that these would require future maintenance and the impact upon existing recreational use of the fields would need assessing. When considering the volumes associated with the flow path, the detention areas would have to be significant to have any notable impact.

Modelling the bund within Attenborough Fields (Option 5) showed that surface water was also flowing onto Haydon Road from London Road. Figure 5-8 illustrates this additional flow with any water from Attenborough Fields obstructed. The modelling clearly represents the routing of the flow into Brick Kiln Lane. In comparison to the dominant path flow from the south through Attenborough Fields, the volumes were low but still resulted in ponding around properties that had reported previous flooding. To capture the flow from London Road Option 9 considered the creation of a SuDS feature, such as a rain garden or storage area within the grassy area at the junction between Haydon Road and London Road. The flows from London Road would require routing into the storage space, such as lowering of the pavement to allow water into the space or the installation of in kerb drainage to route flows directly into the storage feature.

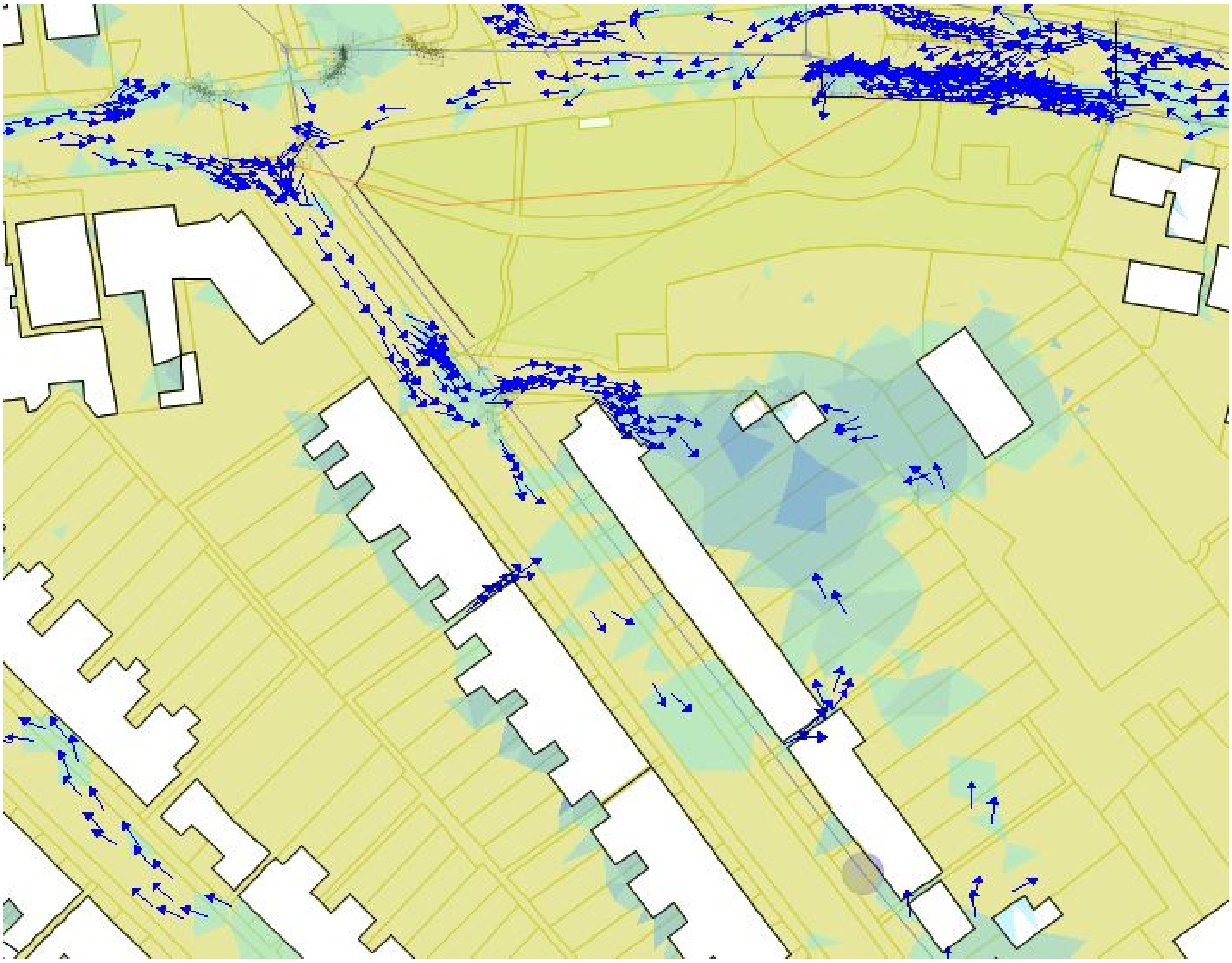

Figure 5-8: Flows to Brick Kiln Lane from London Road

Option 10 considered the potential to reduce the flows entering Attenborough Fields by increasing conveyance and temporary storage within Merry Hill Road. Methods to slow or reduce the flows in this location would restrict the volumes requiring further management in the fields and therefore potential reduce risk downstream. This option was considered to have limited viability and was therefore not taken forward for further investigation.

5.3.3 Shortlisted options

The options considered the most preferential for the hotspot are:

- Option 4 – Property flood resilience;
- Option 5 – Flood bund within Attenborough Fields;
- Option 9 – Retrofitting of SuDS.

It is unlikely that one option alone would not provide protection for the affected properties and the options above should be combined for an effective response to the flood risk.

6 SWMP Action Plan

This section sets a plan for managing the flood risk identified in this SWMP. The action plan uses the information collated during the SWMP process to recommend measures to reduce or mitigate the flood risk in the Hertsmere Borough. The actions are dependent on the identified flood mechanisms.

6.1 Monitoring the Action Plan

It is proposed that the monitoring and reporting of the implementation of the action plan will be undertaken locally and it is expected that partners will take forward actions independently. The action plan should be reviewed and updated quarterly, and the SWMP steering group should convene as and when appropriate.

6.2 Communicating the Action Plan

The action plan is divided into three components, each of which look at mitigating flood risk at a different scale. The three action components are: the generic plan, the hotspot action plan and the incident specific action plan. The geographic area and purpose of each action plan is explained in Table 7-1.

Table 7-1: List of action plans

Geographic area	Action plan	Purpose
Study area wide	Generic action plan (Section 7.3)	Outline broad scale actions applicable across the study area
Hotspots	Hotspots action plan (Section 7.4)	Recommend strategic actions to manage the flood risk in hotspots
Incident	Incident action plan (Incident specific)	Use information in this SWMP to inform Multi Agency Flood Plans

6.3 Generic Action Plan

Some of the actions derived from this SWMP are applicable across the borough. Actions to mitigate these issues are listed in the generic action plan.

6.3.1 Ongoing Maintenance of the Partnership

To successfully undertake the action plan and continue to improve the management of flood risk in the area, it is important to maintain the links between the risk management authorities involved in the production of the SWMP. The on-going partnership will discuss the implementation of the proposed actions, review opportunities for operational efficiency and to review any legislative changes. It is proposed that the monitoring and reporting on the implementation of the action plan will be undertaken locally.

6.3.2 Planning and Surface Water Drainage

Although flood risk from fluvial flood sources is accounted through the NPPF, surface water and groundwater flood risk issues can be less well represented at the planning stage. For major development, HCC as LLFA review all sources of flood risk to the site and the suitability of surface water drainage proposals. However, the same level of scrutiny is not possible for all minor development.

6.3.3 Asset Maintenance

Frequency of asset maintenance should be informed by the susceptibility of a drainage asset to become blocked and cause a flooding issue. This helps to pre-empt flooding and optimise maintenance by targeting key assets.

However, delivery of proactive maintenance is often informed by the reactive response to a reported flood incident or asset defect Figure 7-1 outlines the typical process operated by RMAs in responding to a reported incident.

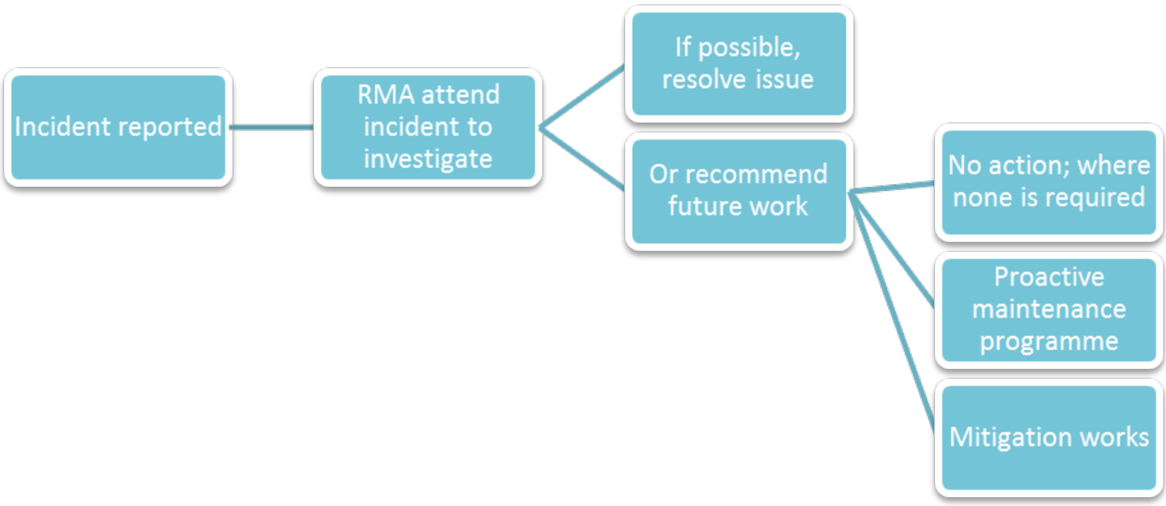

Figure 7-1: Typical process of asset maintenance by RMAs

This approach is largely being adopted by RMAs in Hertsmere Borough, with HCC Highways having identified a series of priority areas for drainage works and gully maintenance across the county, and TWUL maintaining a proactive, rather than reactive, asset management system. As a result, maintenance works should be undertaken before a flood incident occurs due to a blockage or collapse.

Maintenance of private owned assets in Hertsmere Borough such as flat valve outfalls onto one of the main rivers and property downpipes are the responsibility of the landowner although it may not be evident. Co-ordinated awareness raising of asset ownership by the RMAs and providing advice, would help to the secure the future maintenance of these assets.

6.4 Hotspot action plan

For the hotspots identified in Section 3, strategic actions have been recommended to address integrated flood mechanisms operating in these areas. Table 7-2 identifies the recommended actions.

Table 7-2: Hotspot action plan

Hotspot	Actions	Owner
HBC3 – Moatfield Road	Identify methods to limit the volumes of runoff within the area surrounding Herkomer Road and Finch Lane, essentially creating a surface water management area. This could be achieved through improved conveyance and temporary storage within the highway and disconnection of surface water at a property scale from the sewer system e.g. via water butts.	Homeowners, HCC
HBC3 – Moatfield Road	Explore in more detail the possibility of creating a Flood wall / earth bund within Moatfield recreation ground as an obstruction to the dominant flow path.	HCC
HBC3 – Moatfield Road	Property-level protection for buildings which remain at flood risk (mostly are located along Homefield Road and Spring Crofts).	HCC / Homeowners
HBC6- Bushey	Flood wall / earth bund within Attenborough fields to cut off the main flow path to act as a restriction to the main flow path.	HCC
HBC6- Bushey	Investigate the introduction of retrofitting of SuDS – utilising the parcel of greenspace between London Road and Haydon Road as a storage area to limit the depths of flooding at Brick Kiln Lane.	HCC, HCC Highways
HBC6- Bushey	Property level protection	HCC / Homeowners

6.5 Way Forward

Whilst HCC has taken responsibility for leading the Phase 2 of the SWMP, it is recommended that the responsibility for monitoring the progress of the action plan and maintaining the links between the partners would be better served at the local level. The immediate next step should be to agree who will lead the delivery of the action plan and the continuation of the partnership between HCC and HBC.

It is also recommended that the progress of the SWMP to the later, more detailed stages should be focused on the areas where repeated flood incidents have been recorded together with high predicted flood risk. For the Hertsmere Borough SWMP area, further detailed assessment is recommended in some of the hotspot areas, including hotspot areas of Moatfield Road and Bushey. This may include integrated hydraulic modelling to better understand the risk of flooding, and where required could also lead to a flood risk mitigation options appraisal.

Finally, as part of an iterative process of revision, the outputs of the SWMP should be incorporated into future revisions of the Hertfordshire Local Flood Risk Management Strategy.

Appendices

A Project data register

B Stakeholder Communications and Engagement Plan

C Hotspot assessment sheets

D Modelling methodology

E Hotspot flood risk mapping

F Options long-list

G Options mapping

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