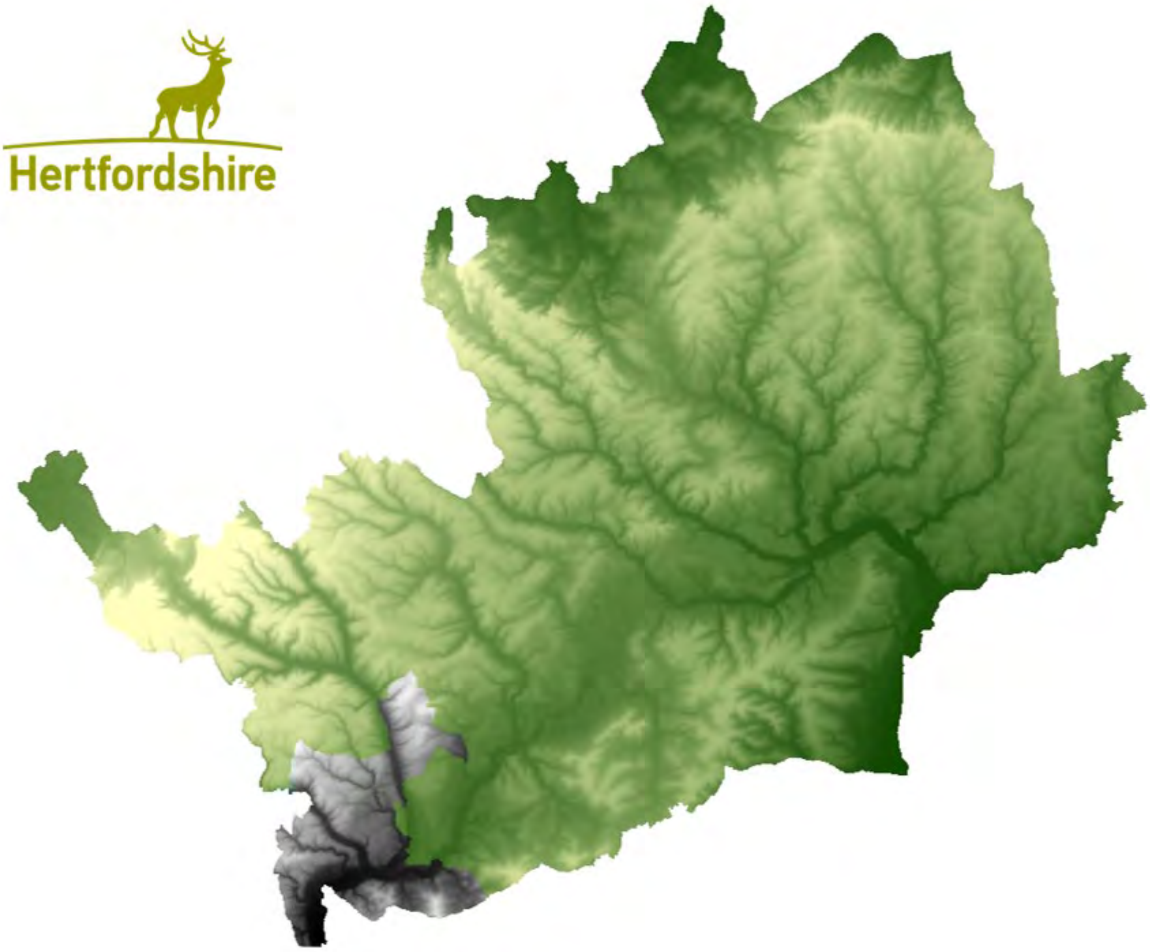

Three Rivers District Surface Water Management Plan

Final Report

March 2021

Hertfordshire County Council

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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 Three Rivers District SWMP has been prepared alongside parallel studies including Hertsmere, 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; Three Rivers District 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 district to identify key surface water flood risk hotspots, which is then further analysed through detailed catchment scale assessments of the hotspots.

Three Rivers is an administrative district in Hertfordshire, England. It is a mix of urban and rural areas that are within the boundary of the Metropolitan Green Belt. Towns in the district include Rickmansworth, Chorleywood, Abbots Langley and South Oxhey. Several main rivers flow through the district including the River Chess, the River Gade and the River Colne, as well as several other ordinary watercourses. In addition to the fluvial flood sources, the county is as risk of surface water flooding, which is the dominant risk to all 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 Three Rivers, 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:

- TRDC1 – Batchworth;
- TRDC2a – Eastbury;
- TRDC2b – South Oxhey;
- TRDC4 – Chorleywood;
- TRDC9 – Prestwick Road, Brookdene Avenue, and Raglan Gardens.

Using the outputs from the detailed modelling, potential strategies 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
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
TRDC ....Three Rivers District Council
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 Three Rivers District.

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 Three Rivers District is in the south west of Hertfordshire, to the north-west of London. The district is fairly urbanised with the main settlements of Rickmansworth, Chorleywood, Abbots Langley and South Oxhey. The north-west of the district remains relatively rural and in total the district covers an area of approximately 88.8km^2.

The district derives its name from the three rivers that run through it; the River Chess in the west of the district, the River Gade in the north-east and the River Colne in the south-east. The rivers converge in the town of Rickmansworth in the south of the district and then continue flowing south, as the River Colne, to join the River Thames. The topography, of the district, shown in Figure 1-1 indicates that the areas that are located around river valleys such as Rickmansworth are at a low elevation relative to their surrounding area.

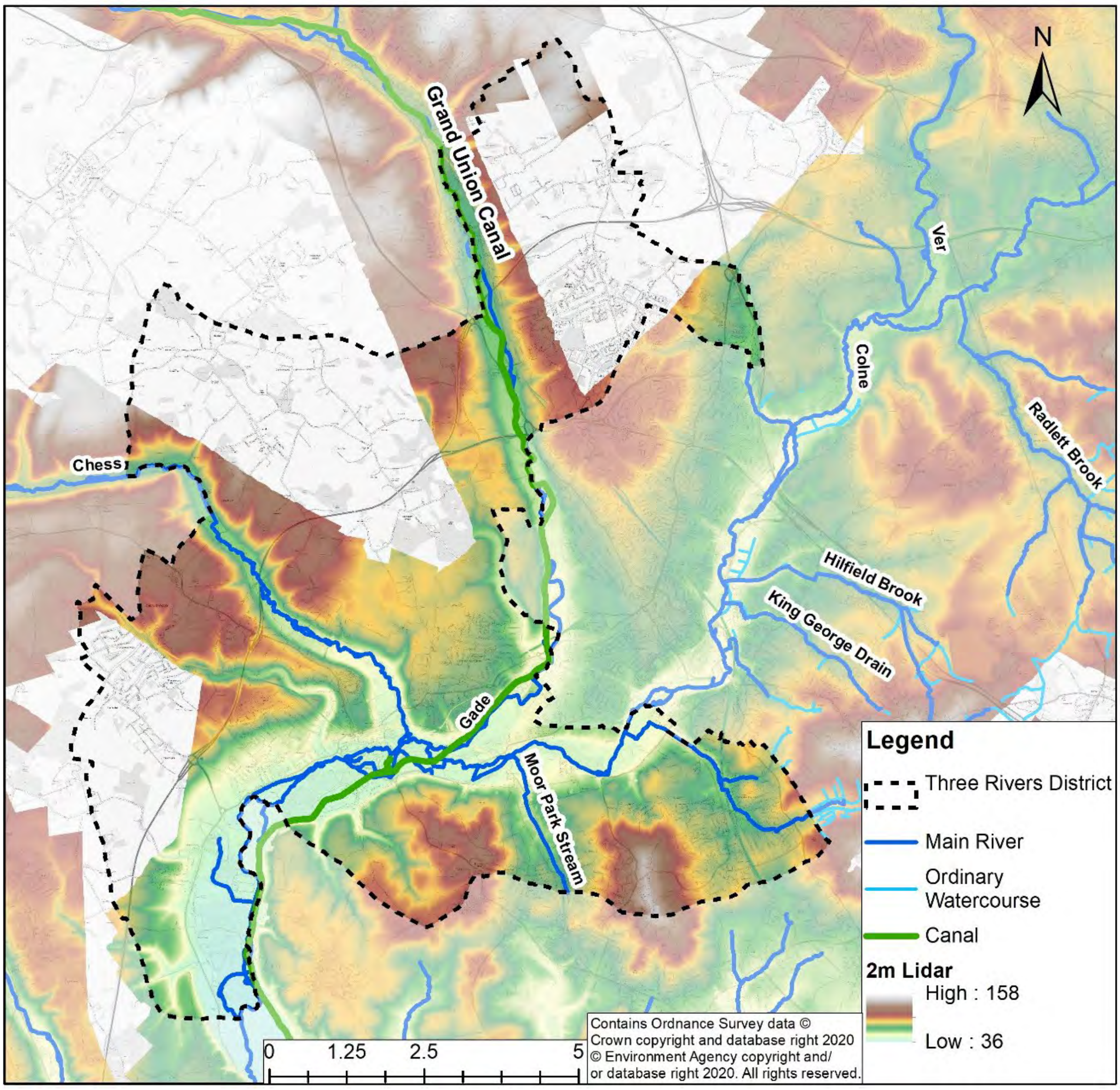


Figure 1-1: Location plan of the SWMP study area and topography of Three Rivers District

1.2.1 Geology

The underlying geology of the Three Rivers District is predominately chalk bedrock, which is highly permeable, and is denoted by the Environment Agency as a Principal Aquifer due to its high water-bearing potential for water supply. Areas of the north east of the district, such as around Abbots Langley, to the north-east and south-west of Chorleywood, and in the south-east of the district are underlain by Lambeth Group geology, which is reasonably permeable and is denoted as a Secondary Aquifer and could have water-bearing potential on a local scale. The far south-east of the district is underlain by low permeability London Clay which acts to prevent the flow of groundwater and is therefore not classified as an aquifer.

The superficial deposits that exist on top of the bedrock include Alluvium along the river paths, and Sand and Gravel which is scattered across most of the district and is reasonably permeable. A simplified map of the bedrock and superficial geology of the district is shown Figure 1-2.

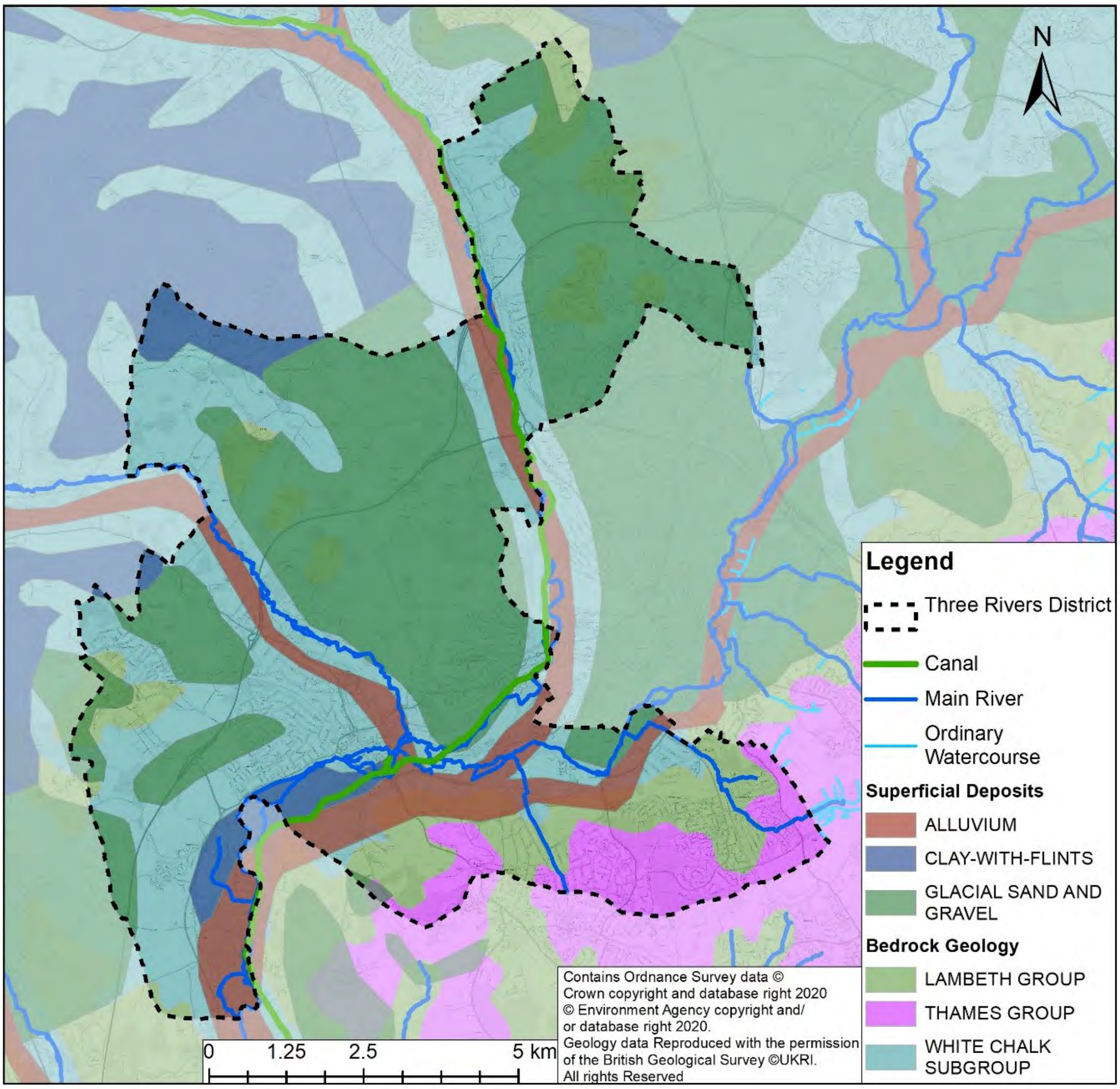


Figure 1-2: Bedrock and superficial geology underling Three Rivers District

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 are addressed in the Catchment Flood Management Plan and Flood Risk Management Plan, and other local more detailed studies. However, interactions between the watercourse and the local drainage network and surface water flows may impact on the surface water flood risk in certain areas.

There are three watercourses that have been classified by the Environment Agency as Main River that run through the Three Rivers District as shown in Figure 1-3, the River Chess in the west of the district, the River Colne in the south-east and the River Gade in the north-east. The confluence of the three rivers is in the town of Rickmansworth in the south of the district and they then continue flowing south as the River Colne a tributary of the River Thames.

The River Gade which runs along the north-east of the district is a chalk stream that flows south to south easterly through the Chilterns. The geology of the Gade watercourses are groundwater fed chalk "bournes" which are dry in the upper reaches in the summer. The River Colne flows from northeast to southwest from approximately 75m AOD near Hatfield, through Watford, to approximately 45m AOD at Rickmansworth. The main tributaries along the reach are the Ver, the Mimmshall Brook and the Ellen Brook which both flow to the east of the Upper Colne. The River Chess is fed by groundwater that is held in the chalk aquifer of the Chiltern Hills.

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 or a public sewer. Hertfordshire County Council (HCC) as a LLFA, has permissive powers to regulate works on ordinary watercourses within Hertfordshire.

There are several unnamed ordinary watercourses that run through the Three Rivers District, shown in Figure 1-3.

Canals

The Grand Union Canal, built in the 19th century for the purpose of commercial transport, passes through the district between Croxley Green and Mill End alongside the Gade. It then continues in a southerly direction, eventually into London

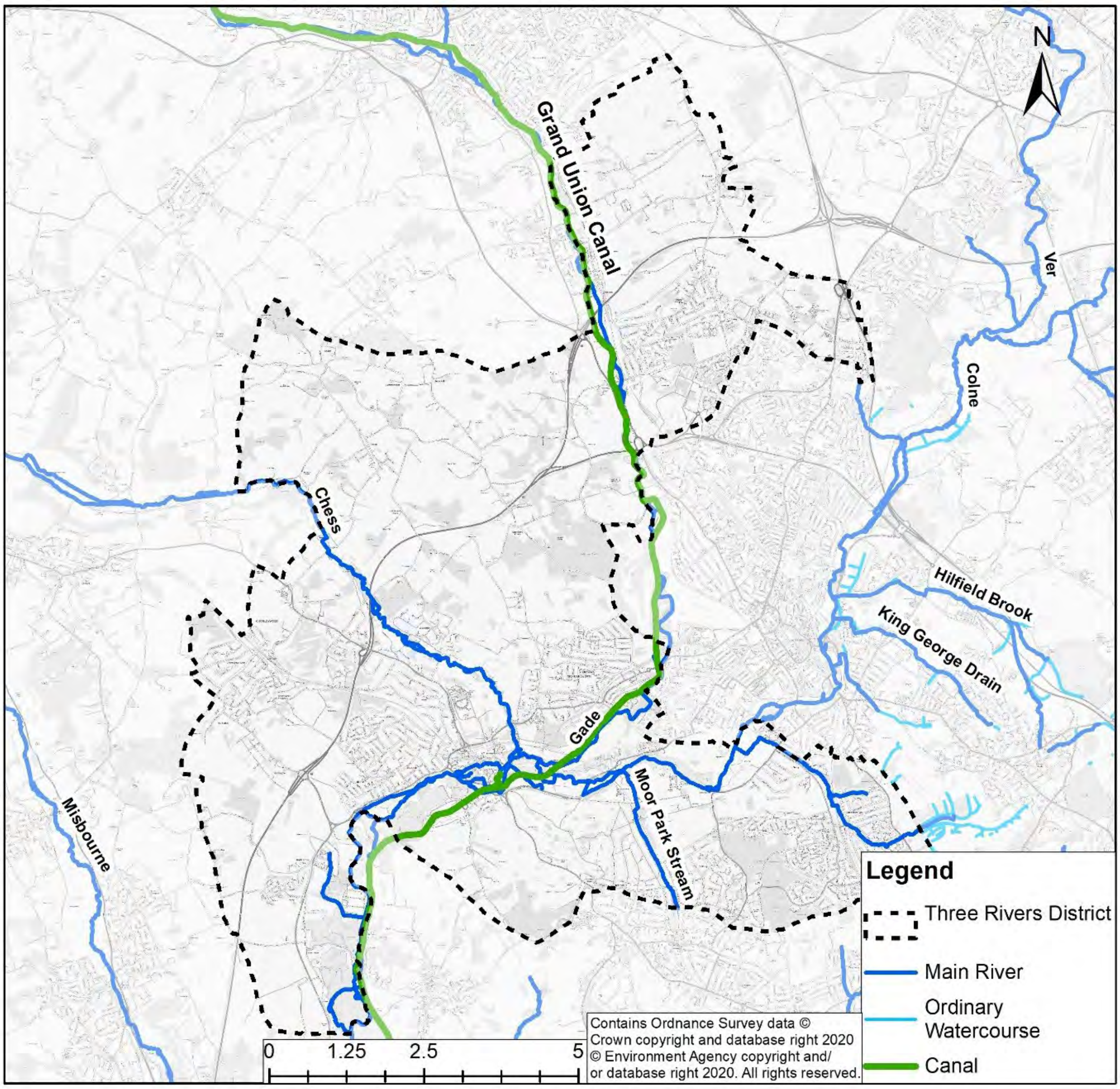


Figure 1-3: Location of Main Rivers and ordinary watercourses in Three Rivers District

1.2.3 Sewers

Sewers describe infrastructure, generally below ground, for the conveyance of wastewater. Sewers are categorised by the type of wastewater removed. The categories 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, also (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 Three Rivers. 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 district.

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 district.

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%[1] under the new range of allowances published by the Environment Agency.

This will increase the likelihood and frequency of surface water flooding, with the greatest impact likely to be experienced in impermeable urban areas such as in Rickmansworth. Fluvial flood risk linked to the River Gade, River Chess and River Colne will increase with the impact of climate change, which is likely to impact the fluvial flood risk exposed to Three Rivers District, and flooding from surface water drainage systems restricted by 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,

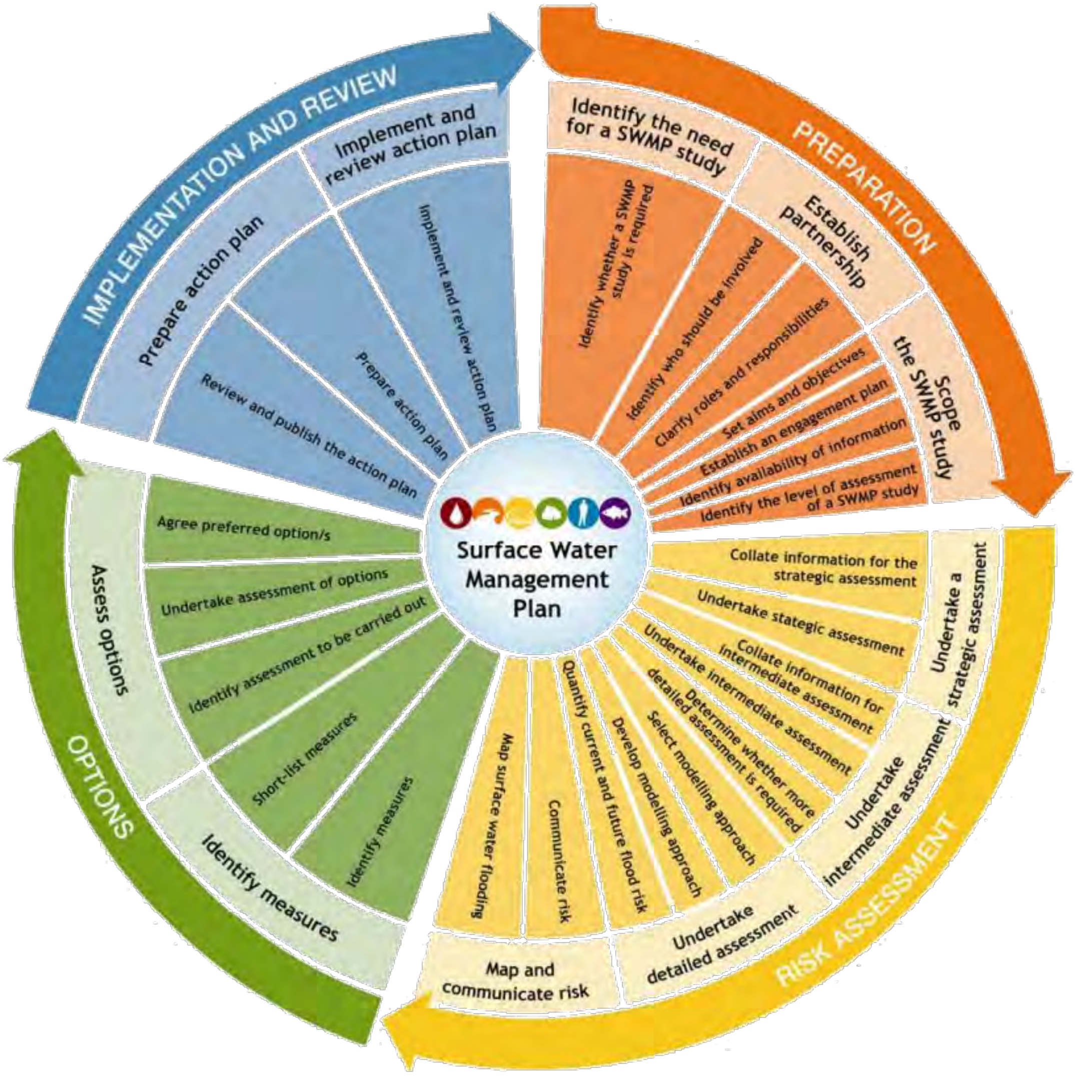
1 Environment Agency (2016) Flood Risk Assessments: climate change allowances. Available at: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

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 district and 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[2], which follows a four-stage "wheel" of preparation, risk assessment, options and implementation shown in Figure 1-4.



2 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.

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:

- **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 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[3], 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 Hertsmere, Stevenage 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 understanding 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 flood risk. Organisations managing flood risk in Three Rivers include:

- Hertfordshire County Council;
- Three Rivers District Council;
- Thames Water; and
- The Environment Agency.

The district 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

[3] 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

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.

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

2.2.2 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 district or borough 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:** 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:** 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:

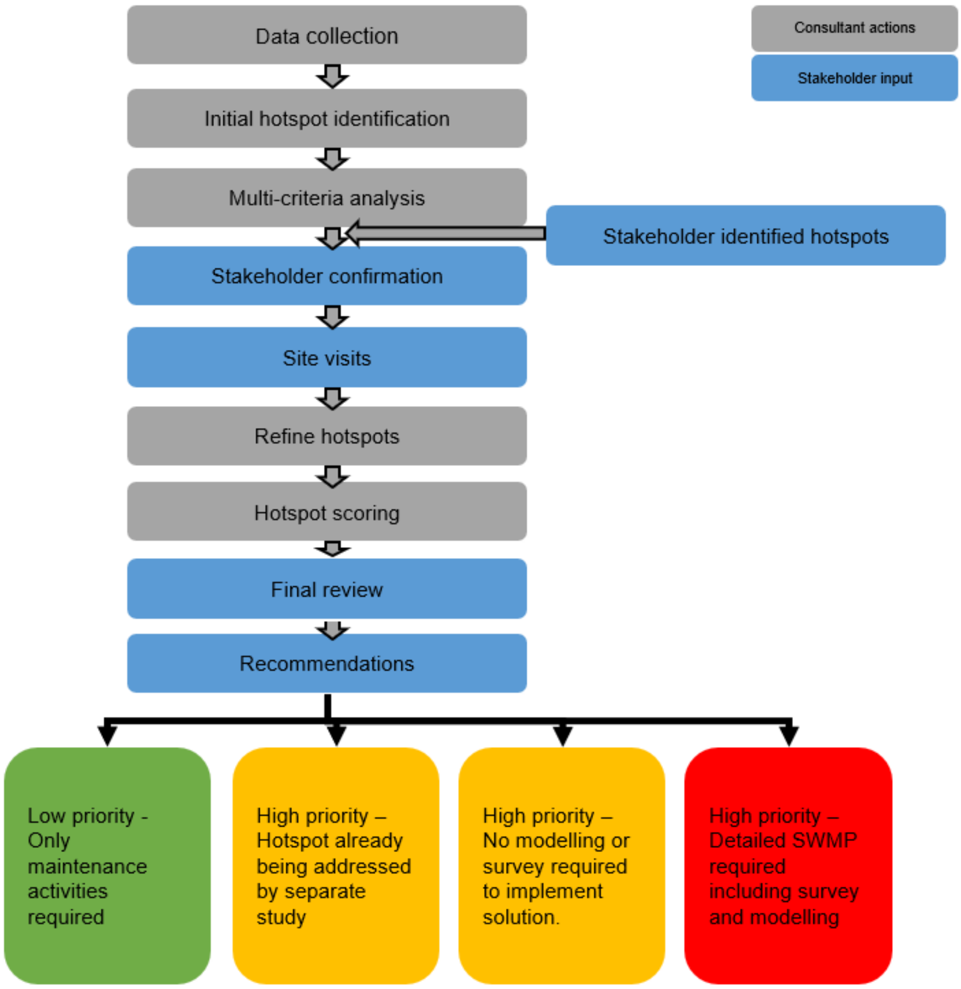


Figure 3-1: Hotspot selection process flow chart

3.3 Data collection

Relevant data was collected and analysed for Three Rivers, from Three Rivers District Council (TRDC), 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
Three Rivers District Council	Evidence of flood history
Three Rivers District 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, in order 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 reported and/or modelled flood risk to homes, 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 flood history register, along with accompanying Section 19 flood investigation[4] 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 the data, it was 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.

[4] 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#

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 10 draft hotspots were identified within TRDC. Hotspots were given unique identification codes, for example TRDC1, as shown in Table 3-2 and Figure 3-2 below.

Table 3-2: Three Rivers draft hotspots

Hotspot Reference	Location
TRDC1	Batchworth
TRDC2	Eastbury
TRDC3	Nanscot and Oxhey Wood
TRDC4	Chorleywood
TRDC5	South Oxley
TRDC6	Gosforth Lane
TRDC7	Little Furze Field
TRDC8	Oxhey Brook
TRDC9	Prestwick Road, Brookdene Avenue and Raglan Gardens
TRDC10	Moor Wood

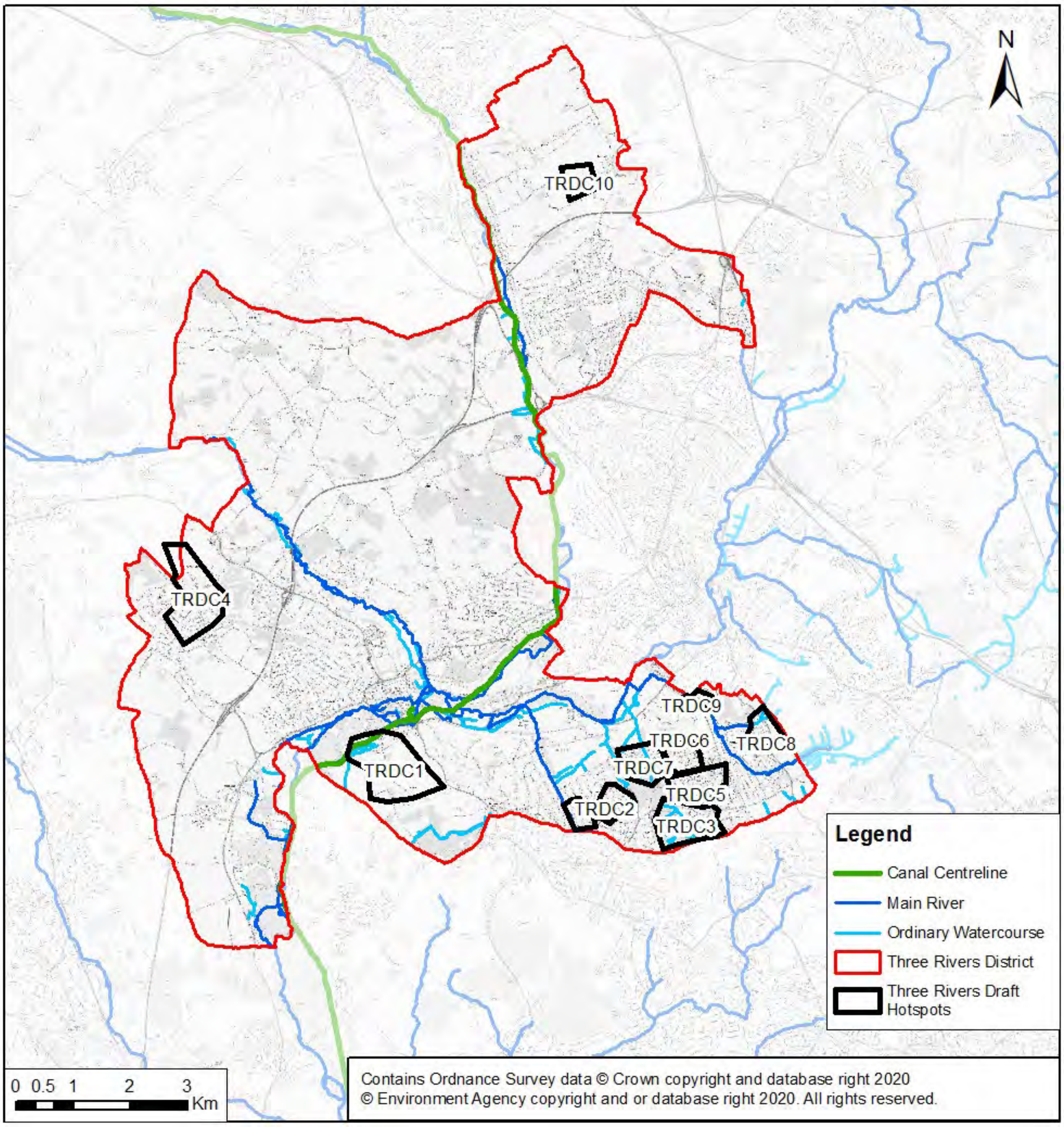


Figure 3-2: Three River Draft hotspots

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 in order 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 each of the Local Planning Authorities. 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. 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, TRDC, EA and TWUL for review. Subsequently, a one-day site visit was carried out to visit all the draft hotspots within the district. The site visits were attended by representatives of JBA, HCC, TRDC and the EA. The site visits provided an opportunity to discuss the various RMA's experience 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 TRDC reduced from 10 to 6, as hotspots TRDC3, TRDC5, TRDC6 and TRDC7 were combined into TRDC2, forming a single large hotspot covering the Oxhey area. Minor alterations to some of the other hotspot boundaries were made and taken forward to the final assessment. 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 Three Rivers, TRDC2 is covered by the EA's Moor Park Stream model as well as a detailed TWUL surface water model that has been made available for this study, and TRDC9 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 district is displayed in Figure 3-3.

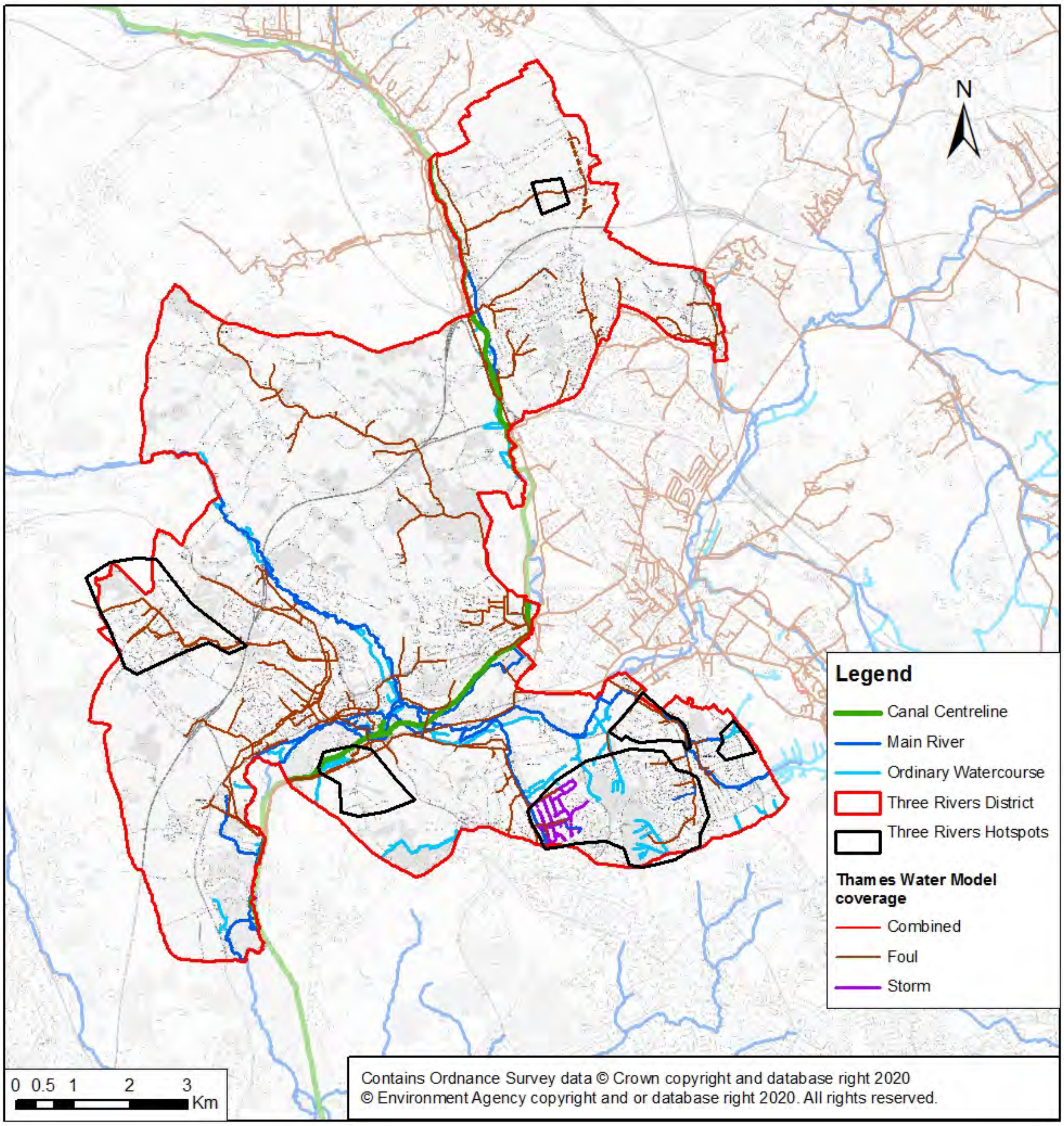


Figure 3-3: Map displaying TWUL model coverage for Three Rivers

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 as 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 the 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 (%)
TRDC1	10	40	10	60
TRDC2*	40	40	20	100
TRDC4	40	20	10	70
TRDC8	20	20	10	50
TRDC9	10	10	0	20

TRDC10	0	20	0	20

* Following a stakeholder review hotspots TRDC3, TRDC5, TRDC6 and TRDC7 were combined with TRDC2

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.

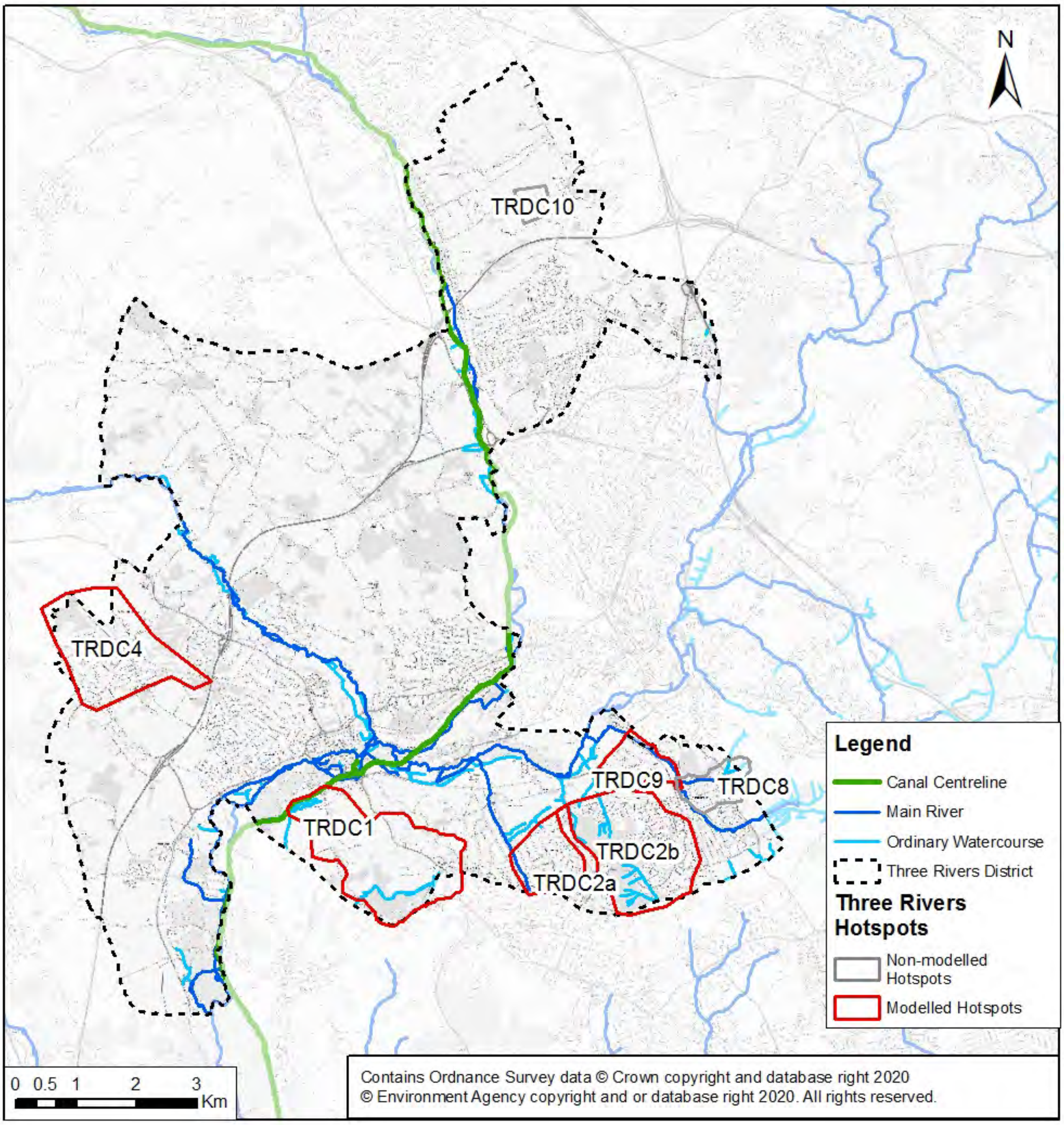


Figure 3-4: Map of modelled hotspots for Three Rivers District

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
TRDC1 – Batchworth	It is recommended that this hotspot is taken forward as a modelling hotspot. There is potential opportunity to hold the surface water flow upstream or to the west.	✓		
TRDC2 - Oxhey Drive, Eastbury, Nanscot and Oxhey Wood, South Oxley, Gosforth Lane and Little Furze Field	The recommended way forward for this hotspot is to model it as one big hotspot alongside TRDC3, TRDC5, TRDC6 and TRDC7 as a result of the flood mechanisms being interrelated. This hotspot boundary has now been redrawn to include TRDC3, TRDC5, TRDC6 and TRDC7. The size of this hotspot is considerable larger than others that have been selected to be modelled, however it captures the main flow paths in the catchment which will be represented accurately despite being given the more dispersed nature of them. There is potential to split this hotspot around Northwood/Eastbury at Batchworth Lane if required, with the road being the	✓		

Hotspot code	Recommended way forward	Decision Significant risk identified and further modelling required	Decision Non-modelled hotspot	Decision No further actions
	rough boundary of the divide.			
TRDC4 - Chorleywood	After the site visit, it was agreed that the boundary of the hotspot was to be extended. There is sufficient modelled and reported flooding to warrant modelling and survey. It is likely that interventions will be placed at upstream rural areas.	✓		
TRDC8 - Oxhey Brook	It is recommended that this hotspot is taken forward to the modelling phase and assesses both the detention and attenuation capacity in the surrounding rural area. Groundwater flood risk needs to be taken into consideration when modelling this hotspot and making an assessment of the options.	✓		
TRDC9 - Prestwick Road, Brookdene Avenue and	It is recommended that this hotspot is taken forward as a small targeted modelling area. There is potential for SuDS e.g. tree pits along Oaklands Avenue by Raglan Gardens.	✓		

Hotspot code	Recommended way forward	Decision Significant risk identified and further modelling required	Decision Non-modelled hotspot	Decision No further actions
Raglan Gardens				
TRDC10 - Moor Wood	This hotspot has been identified as one that is of lower priority. However, the hotspot has potential for some natural flood management due to the amount of available green space which could help control the flow upstream. Thus, a small-scale hydrology and site investigation study would identify what measures could be put in place. Potential future modelling of this hotspot could be justified as it would improve the RoFfSW map as the current surface water flow path doesn't seem to follow the topography of the road. The flood incident record of the hotspot area is low which is why this hotspot has been recommended as being taken forward as a non-modelled hotspot.		✓	

In summary, within Three Rivers District, five hotspots are recommended for a detailed SWMP investigation and one hotspot is recommended to go forward as a non-modelled hotspot.

3.10 Hotspot selection workshop

A hotspot selection workshop was carried out on 16 January 2018, attended by representatives of HCC, TRDC, EA and TWUL. The workshop recommended that hotspot TRDC2 was split into 2 separate hotspots, TRDC2a - Eastbury TRDC2b – South Oxhey. The split followed the high ground between the two hotspots and considered the natural split in flow from west to east. The workshop confirmed the other recommendations for 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

TWUL have made GIS information of the sewer network available to support the study. In addition, a detailed surface water model of the Eastbury area has previously been developed by TWUL and this has been shared to support the investigations in Hotspot TRDC2a.

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 and an estimate 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 Three Rivers District 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 Three Rivers District 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, 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 metrics 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, none of the properties were assigned a property value nor were 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.

4.7.5 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

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 TRDC1 – Batchworth

This hotspot includes the areas around the Stockers Farm Road, Harefield Road and Heron Close which have reporting flooding in the past. To assist the model development, a survey was undertaken of the watercourses in the north of the hotspot and sewer network as advised. The model boundary was extended south beyond the original hotspot to include the topographic catchment and represent the rural flows in the area. This increased the amount of greenspace included within the hotspot.

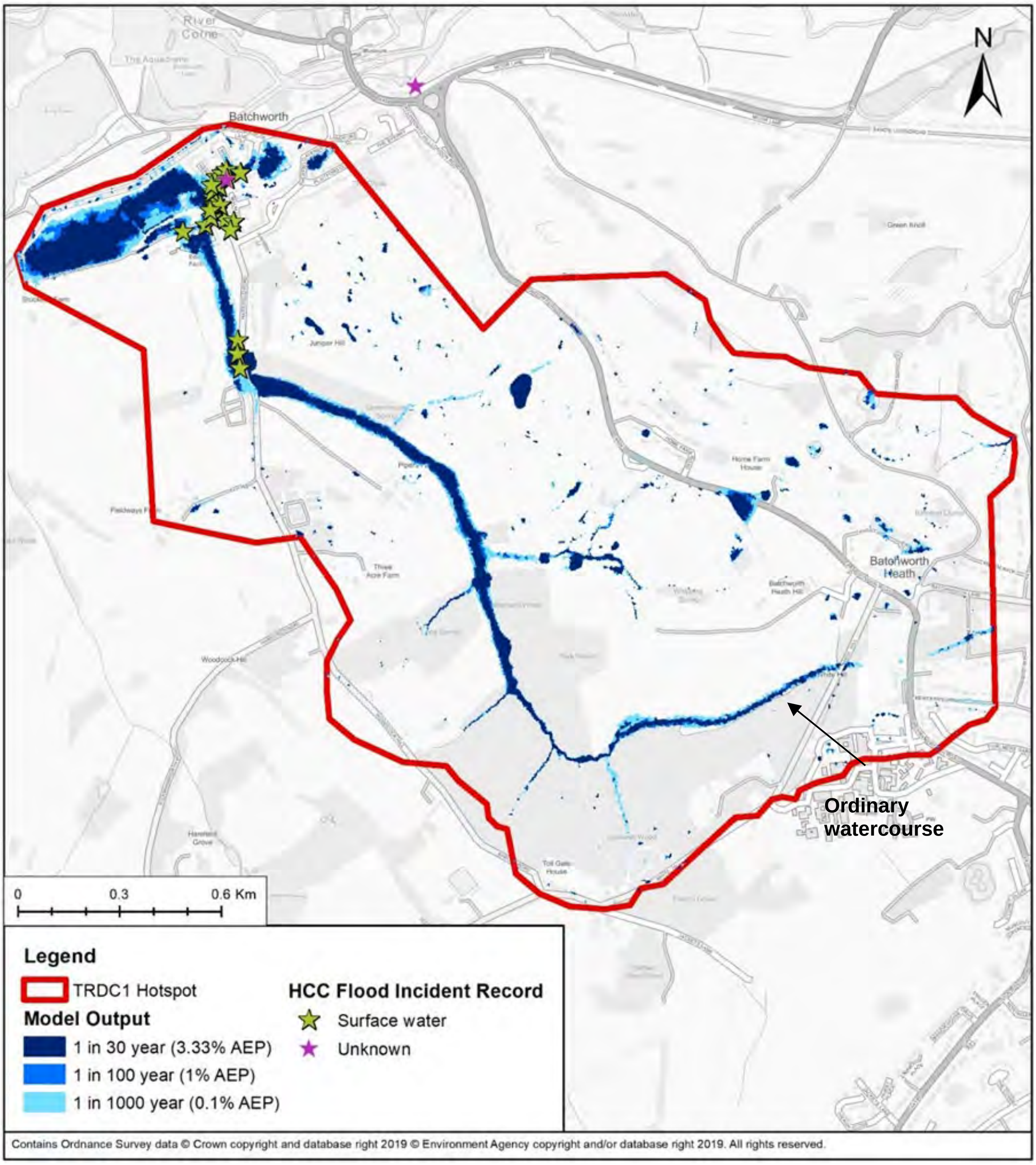


Figure 5-1: Detailed model outputs for TRDC1 – Batchworth

5.2.1 Assessment of flood mechanisms - Source-Pathway-Receptor

The primary source of flooding in TRDC1 is surface water which is driven by the natural topography. The main flow path originates in the south east of the hotspot (see Figure 5-1), near White Hill where the flow path is associated with the ordinary watercourse. The watercourse is not mapped beyond the woodland area, but the flow path continues over the fields before being culverted below Harefield Road. There is a large area of ponding in the north of the hotspot associated with the drainage ditches adjacent to the Grand Union Canal. In the north-east of the hotspot there have been numerous reported flood incidents, however the flooding in this area is disconnected from the main flow path, but is most likely to result from local runoff which ponds in the low-lying areas.

The modelled flood results, shown in Figure 5-1 and Appendix E, correspond with previous flood events that have been recorded in the hotspot including 19 incidents of external flooding to properties in February 2014, which was attributed to failed culverts allowing water to flow down Harefield Road and a second flood event on Harefield Road in September 2016.

During the site visit in November 2017, discussions with HCC about Stockers Farm Road confirmed that there is a culvert under the road, which has been included within the hotspot modelling based on existing survey information. During previous surface water flooding events it has been noted that surface water flows north along Stockers Farm Road and then accumulated in the low-lying areas along Harefield Road.

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

Table 5-1 shows a comparison of the number of properties at risk in the EA RoFSW mapping and based on the detailed flood modelling, respectively. The RoFSW flood extents largely align with the updated detailed modelling, with the dominant south-north flow path being represented. For the 1 in 30- and 100-year events, the numbers of properties expected to flood are also relatively similar. The largest difference lies with the 1 in 1000-year event, with the RoFSW mapping suggesting nearly double the amount of properties predicted to flood in the detailed modelling. The difference lies in the north where the area of ponding is much larger in the RoFSW mapping. Additionally, there are small lateral flow paths that intersect buildings within farms.

Table 5-1: TRDC1 Properties at risk from surface water flooding

(a) Number of residential properties at risk

Flood risk	1 in 20 year	1 in 30 year	1 in 75 year	1 in 100 year	1 in 200 year	1 in 1,000 year
RoFSW	N/A	29	N/A	45	N/A	140

TRCD1 detailed modelling	42	46	53	53	61	77

(b) Number of non-residential properties at risk

Flood risk	1 in 20 year	1 in 30 year	1 in 75 year	1 in 100 year	1 in 200 year	1 in 1,000 year
RoFSW	N/A	3	N/A	8	N/A	34
TRDC1 detailed modelling	5	7	10	10	12	17

5.2.2 TRDC1 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 TRDC1

Option Number	Option Type	Description	Areas Applicable	Shortlisted?
Option 1	Upstream management through natural flood management (NFM)	Use of natural methods in the upstream area of the hotspot to slow flows downstream	Upstream rural areas of catchment	✓
Option 2	Embankments	Construction of embankments along Harefield Road to obstruct flow path	East of Harefield Road	✘
Option 3	Increased culvert size	Enlarging the culvert below Harefield Road to increase conveyance and capacity	Harefield Road	✘
Option 4	Retrofitting of SuDS	Disconnect direct runoff from existing roofs and roads from public sewers and route it via SuDS before re-connecting to public sewers.	North of the hotspot around Harefield Road, Heron Close and Sherfield Avenue	✓
Option 5	Property flood resilience	Protection of individual properties	North of the hotspot around Harefield Road and Heron Close Heron Close and properties close to the junction between Stockers Farm Road and Harefield Road	✓

The dominant source of flood risk appears to be associated with the flow path originating in the south, thus the options are focussed upon slowing and reducing this flow path.

Option 1 (see Table 5-2 and Appendix G) considered upstream management with a focus on the use of Natural Flood Management (NFM) techniques. Along the Ordinary Watercourse itself, construction of leaky dams is suggested to slow down the flows, these could be designed alongside additional temporary storage, that the leaky dams could activate during high flows. The areas of storage within the woodland could be designed as dry basins or ponds (online or offline). Costs for both construction and future maintenance is low, and they would also work with the existing woodland environment with no environmental degradation.

Downstream of the woodland, the flow path is no longer defined as an ordinary watercourse but continues as an overland flow path. NFM and land management options could also be implemented here to further reduce the flows reaching downstream. A potential method would include the construction of bunds perpendicular to the flow path to provide local storage, which would result in areas of ponding during times of high flow. It must be ensured that this does not result in additional flood risk elsewhere. An outlet from the storage area would be required to drain any flood water. Costs associated with the bund and detention basin construction are moderate and would depend upon the ultimate size of the scheme and agreement of the existing landowners. Future maintenance would involve checks of the bund structure and any siltation of the detention basin and outlet. Bund construction is recommended upstream of the farm building area and so would be located within an area of farmland, requiring discussions with the landowners. However, if the water were to be significantly reduced upstream of the farm, it would limit flood risk to several other parcels of land.

An alternative NFM method, to purpose-built flow obstructions, would involve utilising the field boundaries through the planting and management of hedgerows, across slope, would slow down the water through the temporary storage of water and increased infiltration. The creation of hedgerows would also present further agricultural benefits including habitat creation for birds and insects, natural weather barriers for livestock, limiting runoff including fertilisers and pesticides and reducing soil erosion by increased protection of crops, that may be considered in the future. In comparison to a bund, smaller volumes of water would be temporarily stored, however, the land-take required is significantly lower. During the initial phases of hedgerow creation, the maintenance required is high to ensure that any competitive weeds are controlled and do not hinder the growth of the hedges.

Option 2 considered the construction of an enlarged bund along the eastern side of Harefield Road, which runs from south to north through the hotspot. This option is intended to store water within the field and woodland area to the east of the road to reduce the flows downstream to reduce the volume of water that enters to lower lying areas of the hotspot. Initial testing of the option indicates that due to the relatively steep nature of the catchment, the bund would need to be significantly higher than at present to provide a notable benefit downstream. It was therefore not recommended for the shortlist.

Option 3 (see Table 5-2 and Appendix G) considered the upgrades to the culvert below Harefield Road to the north of the Woodcock Hill Cemetery which channels the flow from the upper catchment. During the site visit it was not possible to locate the culvert, and its current condition is unknown. However, it is suggested that an increase to culvert capacity would improve flows through the culvert and consequently alleviate flooding around Harefield Road as a result of overtopping onto the highway and adjacent properties. It is advised that further investigations are made to understand the current standard to assess whether improvements are required. Consideration of the impact of the culvert standard upon the upstream flow path is required, and the effectiveness of any potential improvements.

The detailed modelling showed that the flood risk around the residential area in the north east is largely associated with locally sourced runoff. Figure 5-2 shows that the flooding here is not associated with the flow from the south but is instead ponding in low areas resulting from locally derived runoff and surcharging of the local drainage network.

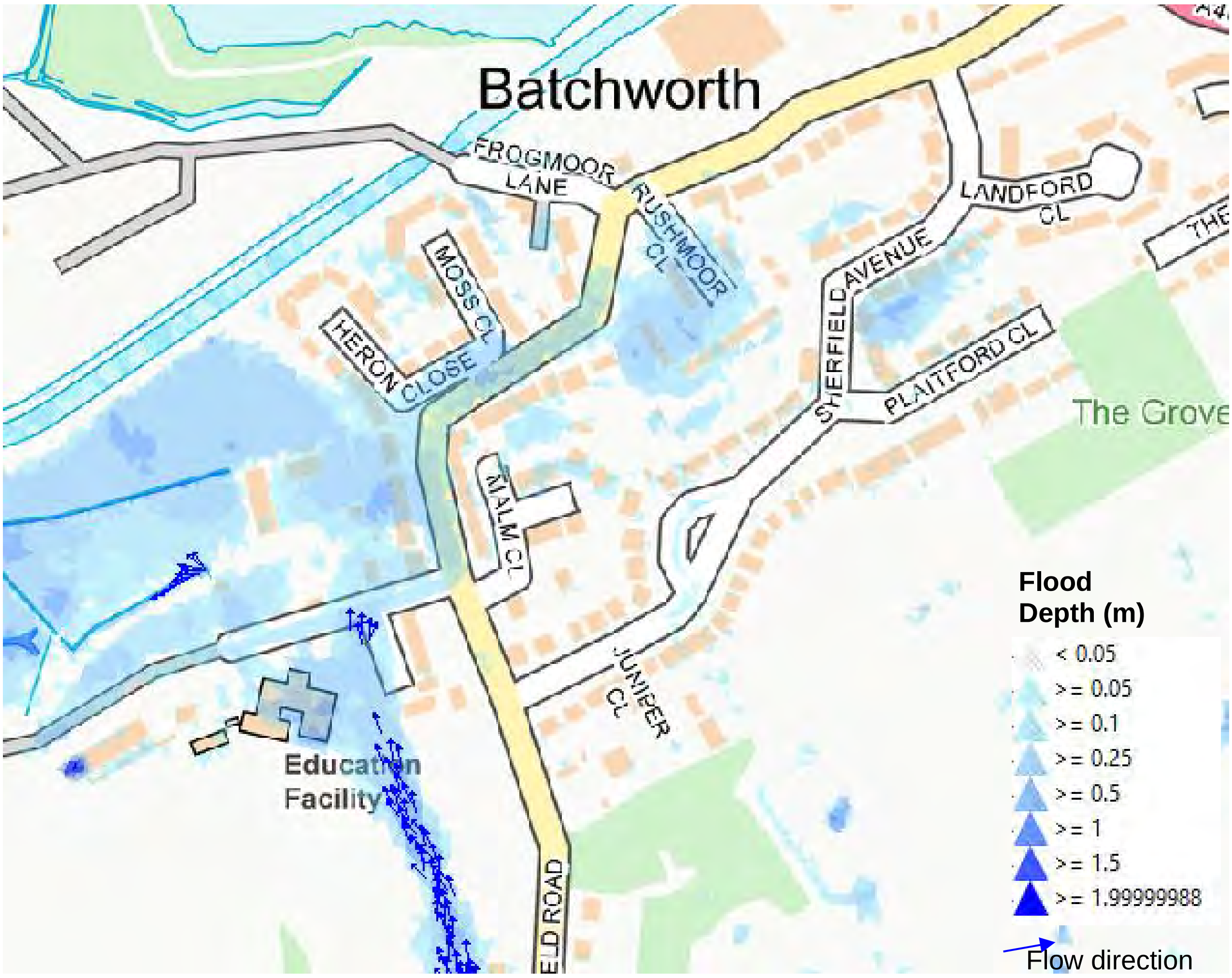


Figure 5-2: TRDC1 - Localised flooding in north of the hotspot

Option 4 considered the potential to retrofit SuDS into this area to store surface water and manage runoff from the highway. This option is most suited to areas of locally sourced runoff, where source control measures and techniques that manage flows at the surface such as swales, infiltration basins or raingardens could be considered. A number of areas of existing public greenspace, shown in Figure 5-3, were identified around Harefield Road and Heron Close as well as at the junction between Rushmore Close and Harefield Road and at Sherfield Avenue that have potential for the retrofitting of SuDS to provide temporary storage of water during intense rainfall.

The available greenspaces are generally small and would be best suited to smaller scale SuDS techniques such as rain gardens or tree pits. These features have a lower individual storage capacity than larger scale options like an attenuation basin, but by including a series of such features within the existing verge or along the highway a significant volume could be stored. These features also provide additional benefits such as improving the visual appeal of the area and providing greater biodiversity through habitat creation in the area.

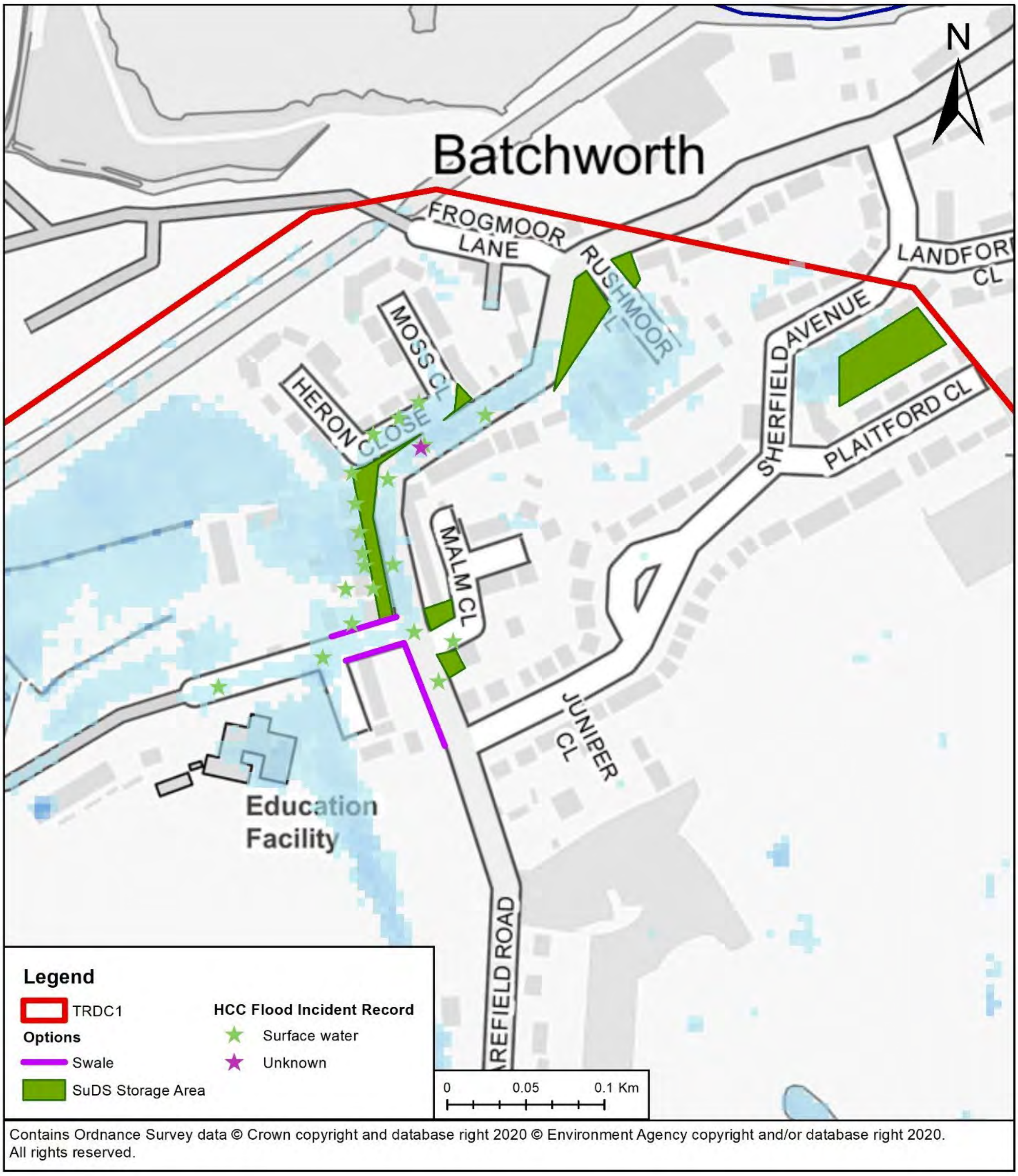


Figure 5-3: TRDC1 SuDS retrofit opportunity locations

Due to low-lying nature of this area it is likely that infiltration will be limited, therefore discharge from the features would be via the existing highway drainage network to replace gullies in key locations. To ensure efficiency, maintenance would be required to manage the vegetation, clear out any litter and ensure the inlets and outlets remain clear as part of the regular maintenance of the existing greenspaces.

Option 5 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 would therefore be suitable for locations such as Heron Close and properties close to the junction between Stockers Farm Road and Harefield Road which have recorded the most incident of flooding in the recent flood events.

5.2.3 Shortlisted options

From the options discussed above (and in Appendix F) the preferred options for the hotspot are:

- Option 1 – Upstream management of surface water;
- Option 4 – Retrofitting of SuDS;
- Option 5 – Property flood resilience.

It is unlikely that any one option will solve flood risk across the hotspot. The area is large with several flows contributing to the risk, and so a combination of actions will be required to ensure successful risk reduction.

5.3 Hotspot TRDC2a – Eastbury

The Eastbury Hotspot was identified to take forward for more detailed modelling due to the variety of potential flow and flooding mechanisms and previous flood history. The modelling in the hotspot has built on the existing TWUL model in this area to improve the understanding of the surface water flood risk across the area and the associated surface water flood events.

5.3.1 Assessment of flood mechanisms - Source-Pathway-Receptor

Within this hotspot area several flow paths that have been identified, as shown in Figure 5-4. The primary flow path, which is responsible for most of the reported incidents, runs parallel with Batchworth Lane along the lower ground to the south. The flow path intercepts several side roads resulting in numerous properties predicted to be at risk of flooding. The flow originates in the higher areas to the east of the hotspot and drains west toward the Moor Park Stream which runs adjacent to the railway at the western boundary of the hotspot. Limited sewer network detail is available for the Ministry of Defence area to the east of the hotspot and therefore in line with the existing TWUL model, it has been assumed that flows from this area drain to the west to three main manholes.

The main mechanism of the flood risk is as a result of overland flow resulting from runoff that fails to enter the local drainage network rather than surcharging of manholes. However, the detailed modelling does highlight several flooded manholes along Batchworth Lane and Grosvenor Road due to exceeding capacity in events greater than a 1 in 30-year return period.

Analysis of property counts shows increased values at higher return periods where the extended surface water flow path is predicted to intersect properties on Grosvenor Road, Batchworth Lane and St Mary's Avenue.

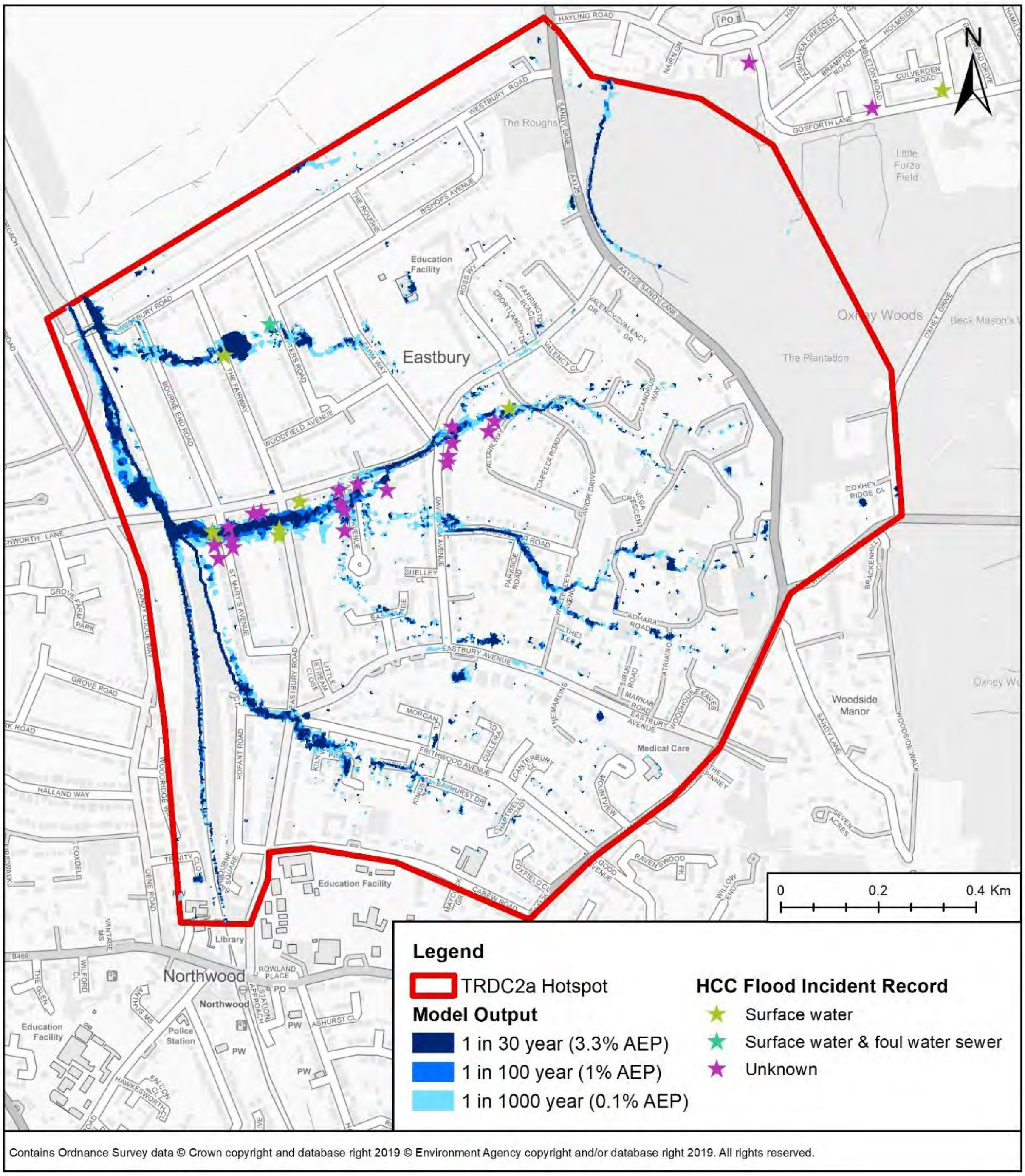


Figure 5-4: Detailed model outputs for TRDC2a

Table 5-3 shows a comparison of the number of properties to be at risk of surface water flooding in the EA RoFSW mapping and the detailed flood modelling for TRDC2a. In general, the key surface water flow paths aligns well between the RoFSW mapping and the modelled outputs; however the detailed modelling extents are generally smaller than the RoFSW which results in a lower number of properties shown to be at risk as reflected in Table 5-3. The detailed modelling is at increased resolution and more representative of the existing landscape, and so likely to provide a more accurate representation of flood risk.

Table 5-3: TRDC2a Properties at risk from surface water flooding

(a) Number of residential properties at risk

Flood risk	1 in 20 year	1 in 30 year	1 in 75 year	1 in 100 year	1 in 200 year	1 in 1,000 year
RoFSW	N/A	158	N/A	274	N/A	651
TRDC2a detailed modelling	142	170	207	213	N/A	303

(b) Number of non-residential properties at risk

Flood risk	1 in 20 year	1 in 30 year	1 in 75 year	1 in 100 year	1 in 200 year	1 in 1,000 year
RoFSW	N/A	15	N/A	33	N/A	86
TRDC2a detailed modelling	19	21	25	25	N/A	46

The modelled flood risk areas generally align well with the recorded flood history in the hotspot, which includes torrential rain that caused flash flooding on 23/06/2016 in the Northwood area, resulting in the local surface water drainage becoming overwhelmed. A significant number of properties were affected by a mix of internal and external flooding along St Mary's Avenue, Batchworth Lane, Eastbury Road, Ardross Avenue, Davenham Avenue and Altair Way. The flooding on St Mary's Avenue was reported to be up to 0.6m deep outside of properties and 0.25m deep inside some properties. Sewerage was also reported to enter several properties. Observations from the site visit on 30/11/2017 along St Mary's Avenue confirmed that the area lies within a natural low point in the topography and may therefore be susceptible to accumulation of runoff.

Discussions with residents living along St Mary's Avenue and Eastbury Road noted that surface water was present along the back gardens of the properties, suggesting a cross-slope flow path. However, these flow paths are not replicated in the detailed modelling and it is therefore possible that there is an alternative source of flooding in this location such as soakaways which have been overwhelmed by the event in question. It is recommended that there is further geotechnical investigations area undertaken in this area to help understand the potential source of this flooding and address the issue previously experienced.

5.3.2 TRDC2a 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 mitigation options for TRDC2a

Option Number	Option Type	Description	Areas Applicable	Shortlisted?
Option 1	Investigation of buried watercourse	Identification of potential buried watercourse below The Fairway gardens	Gardens behind The Fairway	×
Option 2	Attenuation basins	Excavation of attenuation basins to provide storage of overland flows	Ross Way; Land west of St Mary's Avenue adjacent to railway	✓
Option 3	Increased temporary storage / conveyance in highway	Increased capacity within the highway through increased kerb height to limit volumes reaching the pavement	Batchworth Lane	×
Option 4	Retrofitting of SuDS	Disconnection of surface water from public sewers via SuDS	Avior Drive, Altair Way, Orion Way Ardross Avenue, Eastbury Road, St Mary's Avenue	✓
Option 5	Connection to sewer network	Connection of flow path, parallel to Batchworth Lane, to the sewer network to reduce volumes on the surface	Batchworth Lane	×
Option 6	Property Flood Resilience	Protection to individual properties	Avior Drive, Altair Way, Orion Way Ardross Avenue, Eastbury Road, St Mary's Avenue, Batchworth Lane	✓

Option 1 considered the potential to provide additional drainage along the flow path identified in the north of the hotspot between Farm Way and Bourne End Road to manage the surface flows and help reduce ponding along The Fairway as shown in Figure 5-4 and Appendix G. Following discussions with TWUL it is believed that the flood risk in this area follows the path of a buried watercourse, however very limited detail was available on the possible course and status of any drainage infrastructure beyond a connection in Bourne End Road. The number of flood incidents associated with this flow path are limited, which suggests that the modelling may overestimate the risk in this area and therefore this option has not been taken forward for further consideration.

In order to manage the volume of surface water, particularly along the main flow path associated with Batchworth Lane, Option 2 (see Table 5-2 and Appendix G) considered the installation of attenuation areas in areas of existing open space within the in hotspot, particularly in the field between Ross Way and Farm Way. This is the largest public open space within the catchment and offers the potential to provide multiple benefits. The main issue with this location is that it is not directly connected to the main flow path and therefore it would be vital to carefully consider how to make best use of any storage created in the location as well as how stored water was discharged.

In addition to the potential attenuation area in the upper catchment the woodland adjacent to the railway embankment at the west of the hotspot (see Appendix G for further detail) was also considered for potential storage. Rather than storing water from the east, storage in this location could provide additional capacity in the Moor Park Stream and therefore allow for improved discharge from the surface water drainage network that connects to the ditch. NFM techniques could also be employed along the watercourse to manage the flows, which are largely derived from drainage of the urban area to the south. Maintenance of any storage and structures within the watercourse would require the agreement of residents and consent from the EA as a Main River. Discussions may also be required with TFL as the watercourse runs through private property in this area and the site is close to the railway line. From a visual perspective this option would have very limited impacts on the residents as the scheme being localised to the existing woodland area. However, maintaining the state of the current woodland would be crucial to ensure that there is no environmental degradation. It is considered that this option has the potential to provide limited localised benefits. Due to steep nature of the drainage network in the hotspot the potential reduction in water levels in the channel would have a limited effect on the water levels in the pipe system.

The modelling identified that surface flows, particularly in the upper catchment are generally associated with the highway. Option 3 therefore considered the potential use of raised curbs and to convey flows within the highway, particularly Batchworth Lane, and provide temporary storage inside roads such as Ardross Avenue and Eastbury Road extreme events. This option would also require upgrades to the highway drainage system to remove the water following the event. Due to the vehicle access requirements along Batchworth Lane and lack of connectivity with the Moor Park Stream at the downstream end of the road this option was not deemed suitable.

Option 4 considered the retrofitting of SuDS within the hotspot to capture surface water runoff, particularly in the upper catchment, shown in Figure 5-5 before it flows west towards Batchworth Lane and the properties that have been impacted in the past in Ardross Avenue and St Mary's Avenue. Several grassy areas have been identified that could be adopted for the temporary storage of water during high flows as shown in Figure 5-6 and Appendix G. In the larger area's excavation could be used to form infiltration/detention basins in a similar way to the attenuation area suggested in Option 2. For the use of infiltration basins, it would be essential that ground infiltration testing is carried out to understand infiltration capacity which is dependent upon on the underlying geology.

Overflow from any SuDS feature is an important consideration and flows should either be routed to a further storage area, or a pipe that connects the water into the sewer system. For detention basins, a pipe to connect to the sewer system would be required. The cost of excavations is moderate and dependent upon the size of the required basin and the connections to drainage required. However, the cost of maintenance is low and only requires clearance of the basin and connecting pipes to ensure that there is no loss of capacity and/or blockage.

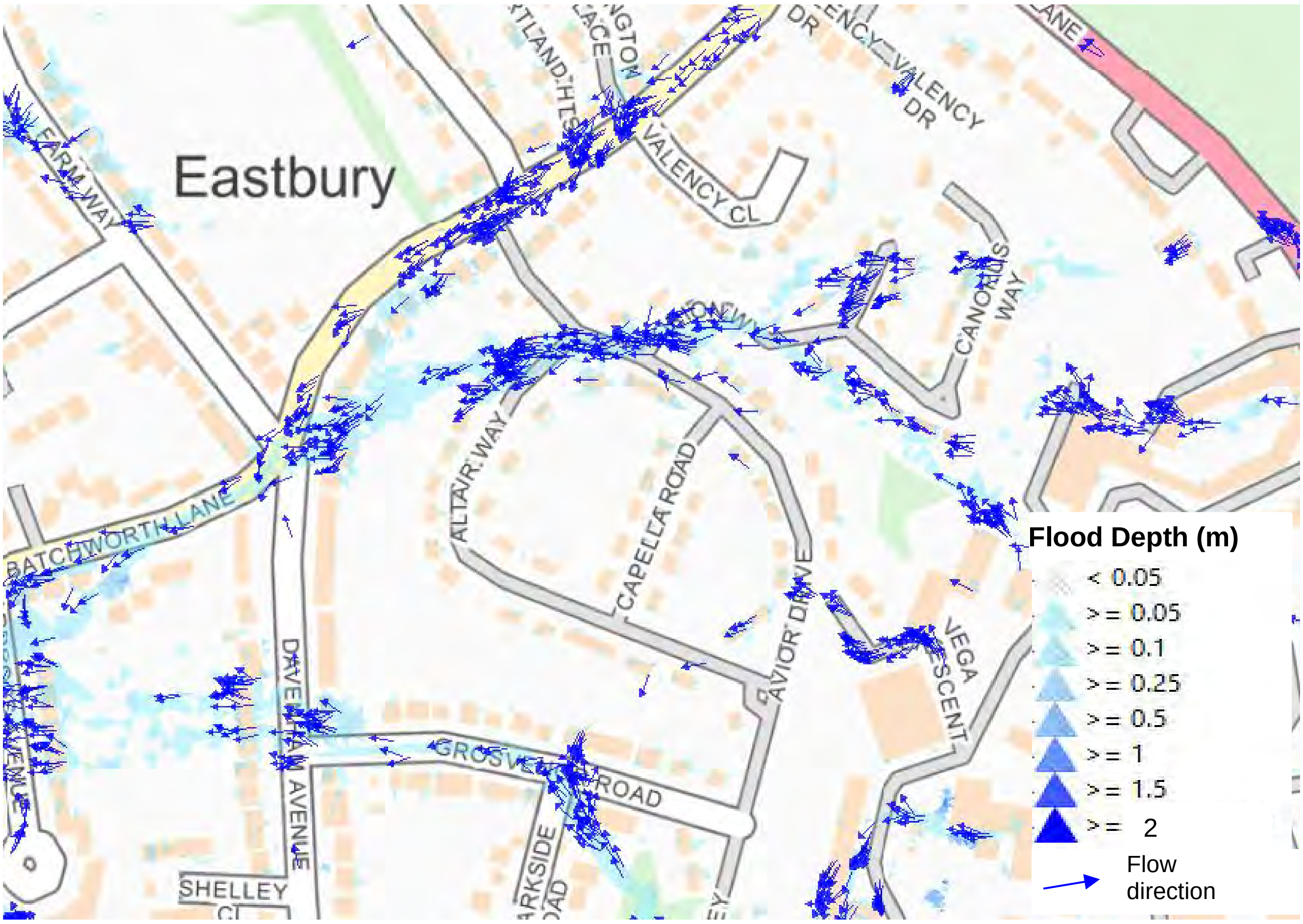


Figure 5-5: TRDC2a Flows originating from Avior Drive and surrounding areas

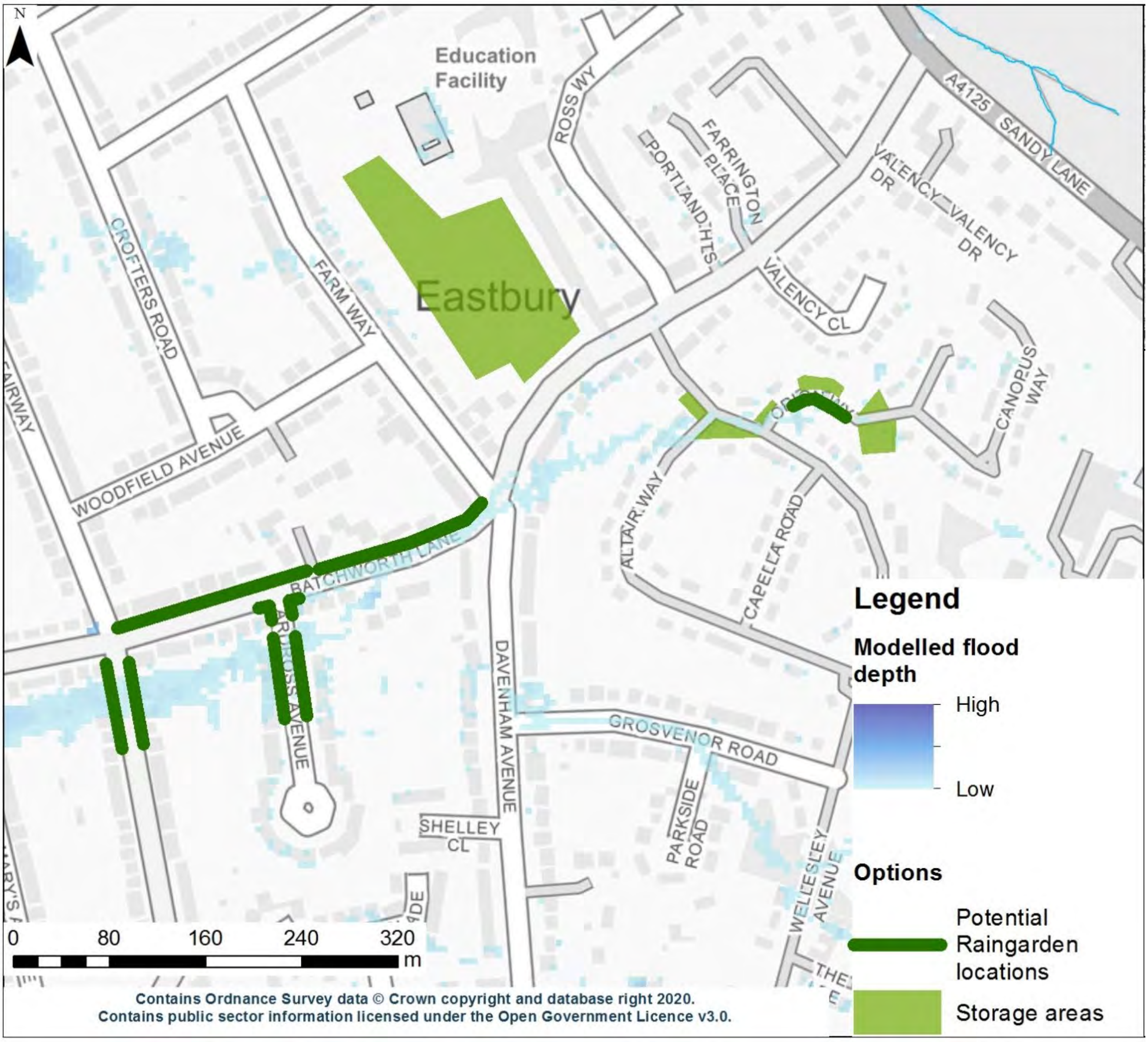


Figure 5-6: TRDC2a SuDS retrofit opportunity locations

Where space is limited, as is the case in much of the hotspot, smaller scale SuDS techniques such as rain gardens or tree pits as shown in Figure 5-7, could be considered. Individually, these have a much lower storage capacity than an attenuation basin, but by including a series of such features within the exiting verge or along within the highway a significant volume could be stored. The installation of such features can also provide additional benefits such as improving the visual appeal of the area and providing greater biodiversity through habitat creation in the area.

Where the underlying geology allows it, it may be possible to dispose of runoff collected in the rain gardens via infiltration, alternatively they could be connected into the highway drainage network to replace gullies in key locations. To ensure efficiency, maintenance would be required to manage the vegetation, clear out any litter and ensure the inlet/outlet remain clear.

Figure 5-7: Example of rain gardens in a residential street (CIRIA, 2018[5])

An alternative option for managing the flow path is considered in Option 5 (see Table 5-4 and Appendix G) and involves additional connections to the sewer network. The modelling suggests that the nearby network has some additional capacity, but surcharging is occurring downstream and any additional water would likely exacerbate this issue. Connection to the sewer network would be a very costly operation with significant disruption with road closures whilst the laying of pipes is carried out. This scheme would also require the consent of TWUL. It is also advised that where possible options should provide additional benefits such as amenity or environmental and this would not be the case with this option.

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[5] Greener Grangetown, Courtesy of CIRIA accessed at https://www.susdrain.org/resources/images.html

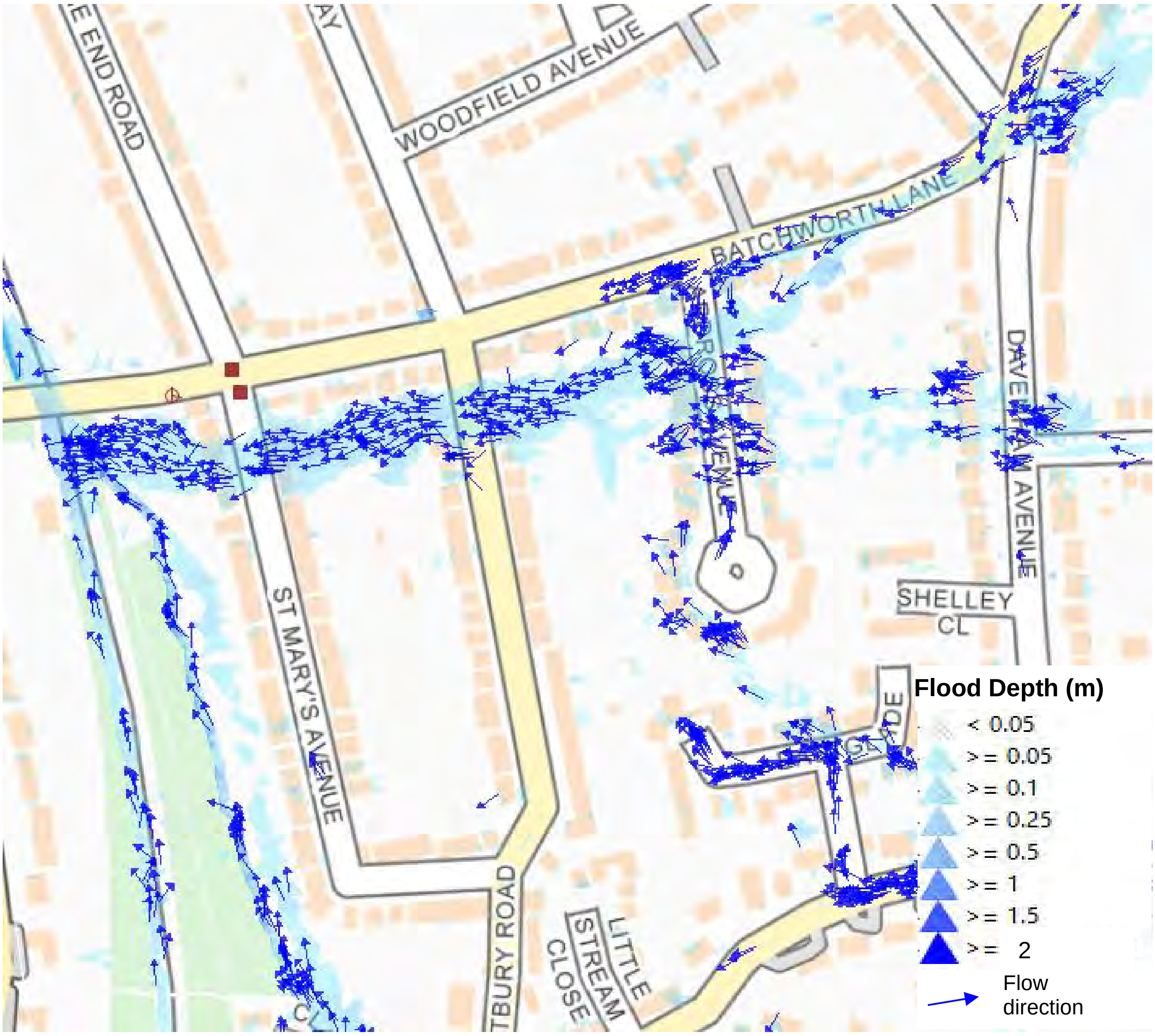

Figure 5-8: Flow path intercepting Ardross Avenue, Eastbury Road and St Mary's Avenue

Option 6 considered the installation of Property Flood Resilience or 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 would therefore be suitable for several locations along Ardross Avenue, Eastbury Road and St Mary's Avenue which have recorded the most incident of flooding in the recent flood events.

5.3.3 Shortlisted options:

From the options discussed above (and in Appendix F) the preferred options for the hotspot are:

- Option 2 – Attenuation areas;

- Option 4 – Retrofitting of SuDS;
- Option 6 – Property flood resilience.

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.

5.4 Hotspot TRDC2b – South Oxhey

This hotspot is largely divided between woodland in the upper western area and urbanised area to the north and east as shown in Figure 5-9. The hotspot required the detailed surface water network to be incorporated, to fully understand flood mechanisms present.

5.4.1 Assessment of flood mechanisms - Source-Pathway-Receptor

Within this hotspot, the majority of the flow paths originate in the higher woodland areas to the west (see Figure 5-9). The Ordinary Watercourses that flow through the woodland are all culverted at the boundary of the residential area, in some cases behind raised embankments where the watercourses enter the pipe network. In normal flow conditions, the culvert should have capacity for the flows. However, in periods of high flow, water may surcharge the culverts and flow through residential areas, following the natural topography. The modelling shows this to occur in the north west of the hotspot where water from two small watercourses intercepts Gosforth Lane and results in property flooding. Similarly, in the south west, the B452 is intercepted by flow paths from the woods in several places, resulting in property flooding along Ashridge and Burnley Close. These flow paths also contribute to the significant highway flooding along the B452.

Alongside the main flow paths and associated areas of flood risk there are other areas of locally derived flood risk that are not directly associated with the ordinary watercourses. For example, flooding beyond Fulford Grove and Hayling Road is locally derived and results from runoff from the greenspace north of the hotspot. Additionally, flooding around the school on Oxhey Drive also appears to be locally sourced (i.e. not associated within a flow path), as there is no clear external flooding source.

There is evidence of limited capacity in the drainage network within some areas of the hotspot, for example manholes are predicted to surcharge in the 1 in 5-year event at the inflow point on Bowring Green. In the 1 in 30-year storm event, the flood risk is greater around Pond Wood Education Facility and flooding from several manholes was identified. Analysis of the modelled flood extents identified high property counts at higher return periods (Figure 5-9) where the extended surface water flow path is predicted to intersect properties on roads such as Prestwick Road and Oxhey Drive.

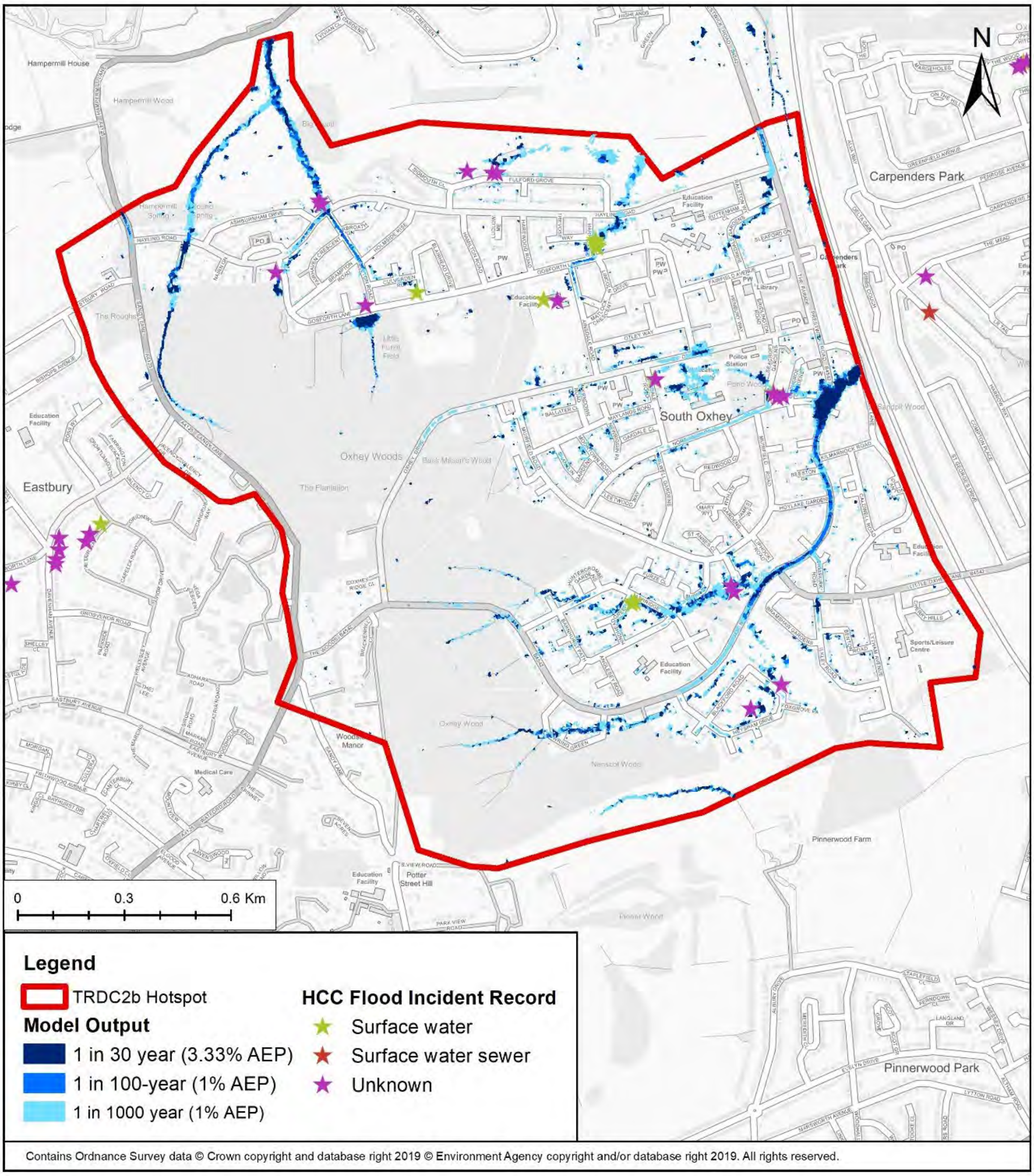

Figure 5-9: Detailed modelling outputs for TRDC2b

Table 5-5 shows a comparison of the number of properties to be at risk of surface water flooding in the EA RoFSW mapping and the detailed flood modelling for TRDC2b. The detailed modelling shows flooding in the same areas as that within the RoFSW mapping. However, the outputs from the detailed modelling suggests that in higher return period events there are lower numbers of properties at risk compared with the RoFSW. The mapping shows that the flow path along Prestwick Road is significantly larger within the RoFSW mapping, intersecting many more properties. Additionally, there are several highways that are shown to flood in the RoFSW data, but not within the detailed modelling.

Table 5-5: TRDC2b Properties at risk of flooding from surface water

(a) Number of residential properties at risk

Flood risk	1 in 20 year	1 in 30 year	1 in 75 year	1 in 100 year	1 in 200 year	1 in 1,000 year
RoFSW	N/A	347	N/A	720	N/A	1790
TRDC2b detailed modelling	99	435	636	693	849	1218

(b) Number of non-residential properties at risk

Flood risk	1 in 20 year	1 in 30 year	1 in 75 year	1 in 100 year	1 in 200 year	1 in 1,000 year
RoFSW	N/A	11	N/A	23	N/A	28
TRDC2b detailed modelling	6	12	16	17	19	16

The historic flood events support the detailed modelling results. In June 2016, there were numerous flood incidents across the hotspot. There were recorded incidents of surface water flooding on Hindhead Green, and four of unknown origin on Blackford Road and Gleneagles Close. A number of these properties experienced internal flooding. Residents noted that the drainage system around Oxhey Wood could not cope, and drains were overflowing along these roads, contributing to the flooding. Further flood incidents were reported widespread across the hotspot. However, the flood source was often unknown.

5.4.2 TRDC2b 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 5-6 and further information about the options considered and the locations for options is included in Appendix F and Appendix G respectively.

Table 5-6: Summary of mitigation options for TRDC2b

Option Number	Option Type	Description	Areas Applicable	Shortlisted ?
Option 1	Allocation of land within planning	Long term designation of land based upon risk	Not applicable	×
Option 2	Runoff control	Flow restrictions to limit volumes of surface water reaching property	Harrogate Road	×
Option 3	Flow restrictions from new developments	Applying runoff restrictions of greenfield (or lower) to developments	Area-wide application	×
Option 4	Retrofitting of SuDS	Disconnection of surface water from public sewers via SuDS	Ashridge Drive, Burnley Close, Seacroft Gardens	✓
Option 5	Natural flood management (NFM)	Utilisation of natural methods to reduce downstream flood risk	Woodland areas in west of hotspot	✓
Option 6	Property Flood resilience	Protection to individual properties	Seacroft Gardens, Northwick Road	✓
Option 7	Upsizing of sewers	Increased sewer size to increase capacity for surface water	Prestwick Road	×

The modelling highlighted that many of the surface water flow paths originate from the woodland areas in the west of the hotspot where there are multiple small watercourses which become culverted at the woodland boundary. During high flows, the culverts and headwalls may be surpassed, leading to the flow paths entering residential areas as opposed to flowing through the sewer system, as shown in Figure 5-9.

Option 1 and Option 3 considered possible measures that Three Rivers District Council 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 3 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.

Option 2 considered the modelled flood risk along Harrogate Road, which correlated with the recorded flood incidents in this area, and in particular the management of runoff within the highway by installing control measures within the highway to slow and divert flows away from properties. Following discussions with HCC it was considered that structures within the highway solely for the purpose of temporarily retaining water, and flood risk management could have a detrimental effect on the highway and would therefore not be suitable.

As the reported incidents are not concentrated to one area within the hotspot it is unlikely that the implementation of a single capital scheme would not solve the widespread flood risk, therefore Option 4 (Table 5-6) considers the retrofitting of a range of SuDS features across the hotspot to capture flows to limit the impact upon property. Green spaces across the hotspot (see Appendix G) have been identified for the retrofitting of SuDS to increase storage or infiltration (dependent upon the geology). Many of these areas will directly intercept flow paths such as along Hayling Road and Gosforth Lane (Figure 5-10). Prestwick Road Meadows provides an ideal space to both capture flows and store diverted water in times of flood. Through here there is a flow path that originates from Heysham Drive and moves towards Prestwick Road that could be captured and stored. Water could also be diverted from Prestwick Road.

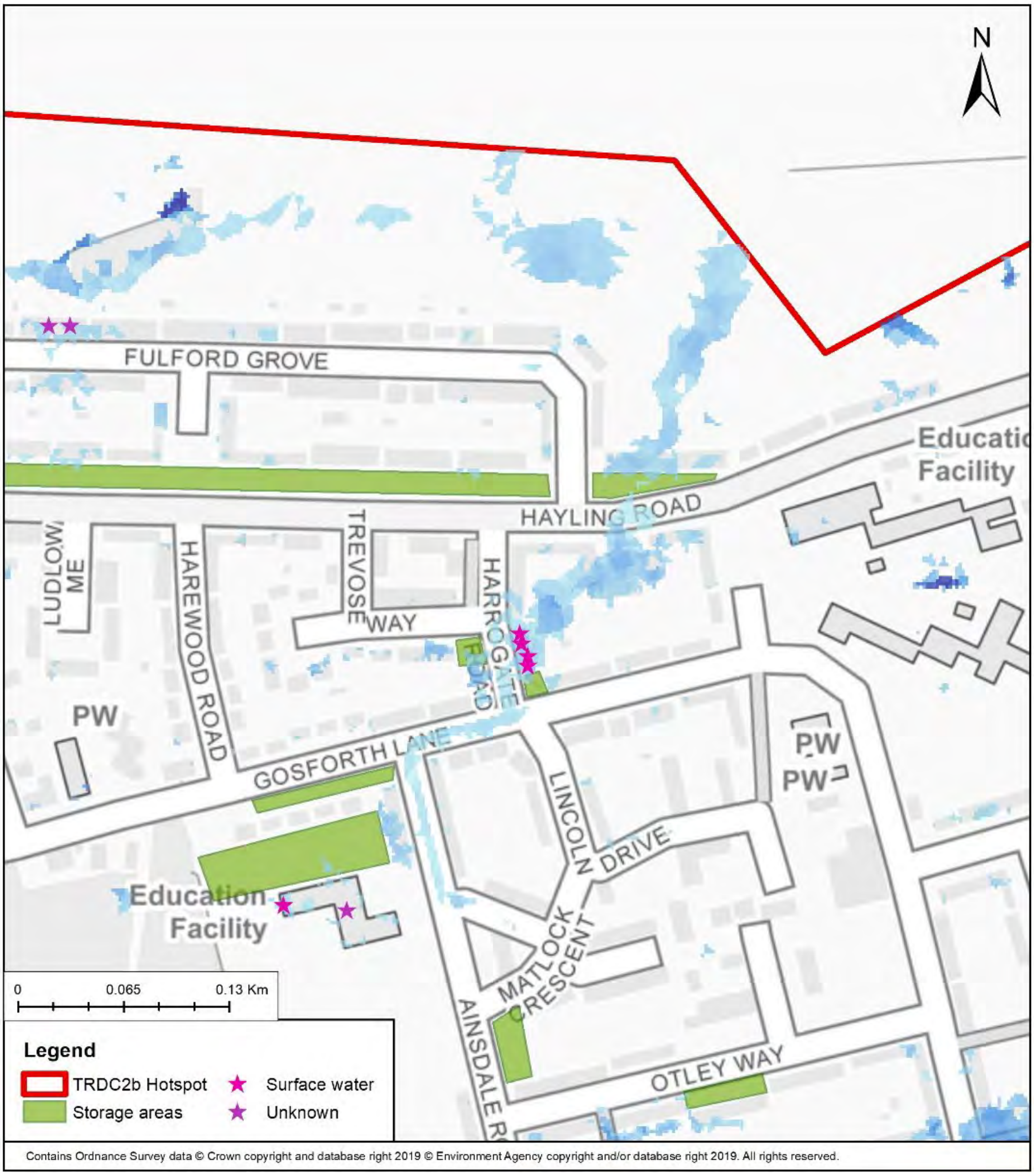

Figure 5-10: TRDC2b SuDS opportunity areas along Hayling Road and Gosforth Lane

Figure 5-11 shows areas along Prestwick Road (in the south west of the hotspot) where there may be the opportunity to construction of swales within the existing grass verges. This would limit the volumes that accumulate in the east. In the smaller areas of existing greenspace across the hotspot, various forms of SuDS could be considered. For example, rain gardens or infiltration basins could be considered. Alternatively, if geology does not permit infiltration, detention basins would be utilised. Across the area, SuDS should be designed to work with the existing environment and enhance the natural environment.

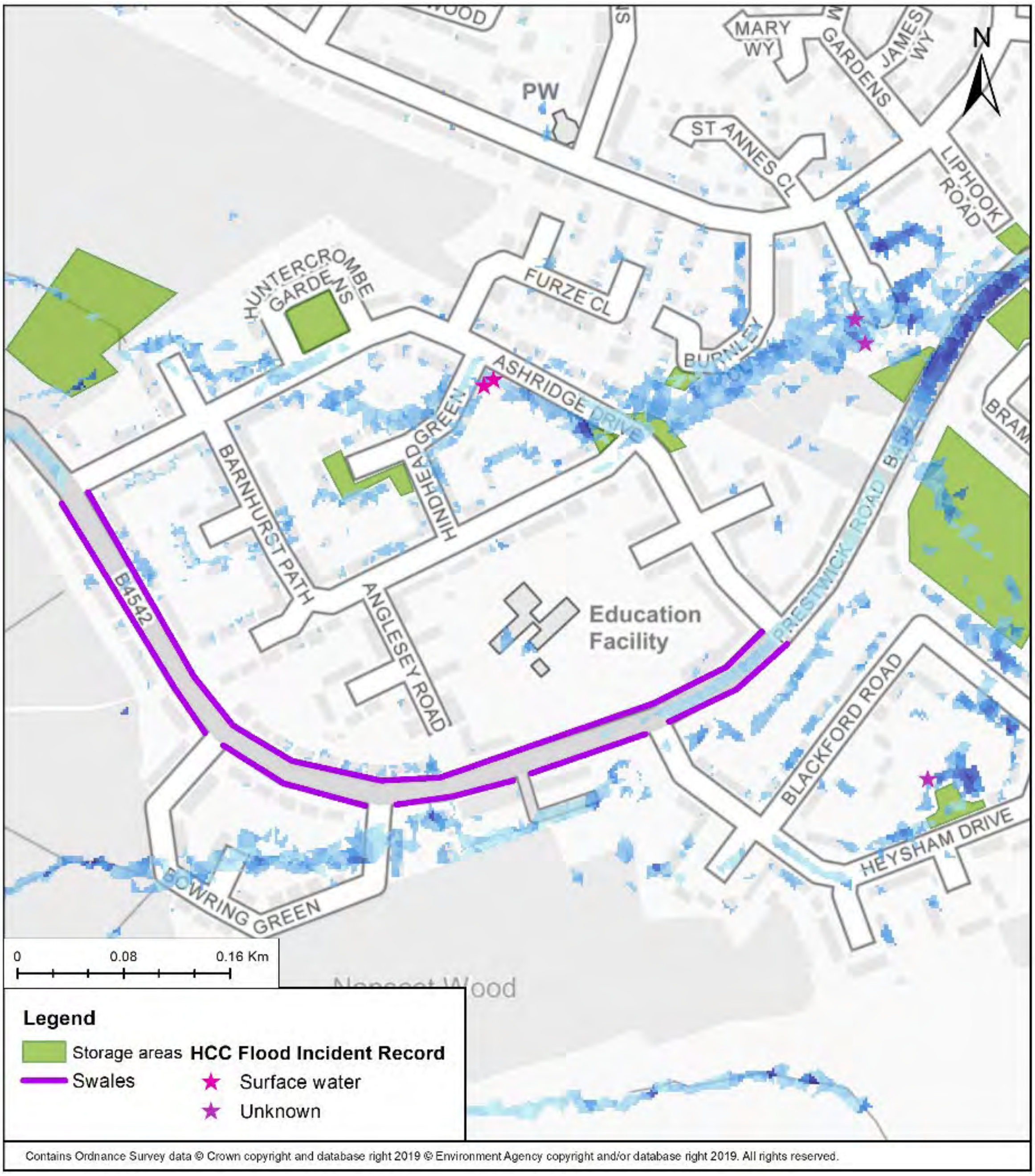

Figure 5-11: TRDC2b SuDS opportunity areas around Prestwick Road

Option 5 (Table 5-6 and Appendix G) considers the implementation of NFM methods within the woodland to limit flows before reaching the culverts and therefore providing increased capacity within the network. Figure 5-12 shows one of the surveyed watercourses in Oxhey Wood. The channel is small and would be suitable for the construction of leaky dams. The partial barrier would result in flood waters spilling out and so excavation of storage areas may also be required. If leaky dams are installed on multiple watercourses within the woodland areas, careful planning would be required to ensure that they do not cause the downstream flood peak to coincide. The construction of leaky dams would have little environmental impact as they are created using tree trunks and the lowest timber is set to allow fish to pass. As the watercourses are within a woodland area, locally sourced wood would also be available. The costs of construction and maintenance is low, with maintenance including checks to ensure stability of the structure and clearance. Schemes like this also provides the opportunity for community engagement and education and the construction could be undertaken by volunteer groups.

Figure 5-12: Surveyed watercourse within Oxhey Woods

Option 6 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 would therefore be suitable for a number of locations across the hotspot included at the Northwick Road and Seacourt Gardens junction and Harrogate Road which have recorded the most incident of flooding in the recent flood events. The modelling showed that there is manhole exceedance occurring along Prestwick Road which contributes to the flood risk. As shown in Figure 5-13, the manhole exceedance occurs in the east of the hotspot where the greatest depths are recorded.

Option 7 (Table 5-6) considers increasing the sewer capacity to accommodate greater volumes of water. Increasing sewer capacity would be a very costly operation requiring large stretches of the highway network to be excavated to allow the new pipes to be laid. Not only would the construction aspect of this be costly, there would also be high costs associated with disruption of road closures. Furthermore, any options that are adopted to tackle flood risk should aim to provide other benefits to the area such as amenity or environmental enhancement. Upgrading the sewer system will provide no other benefits besides a greater network capacity.

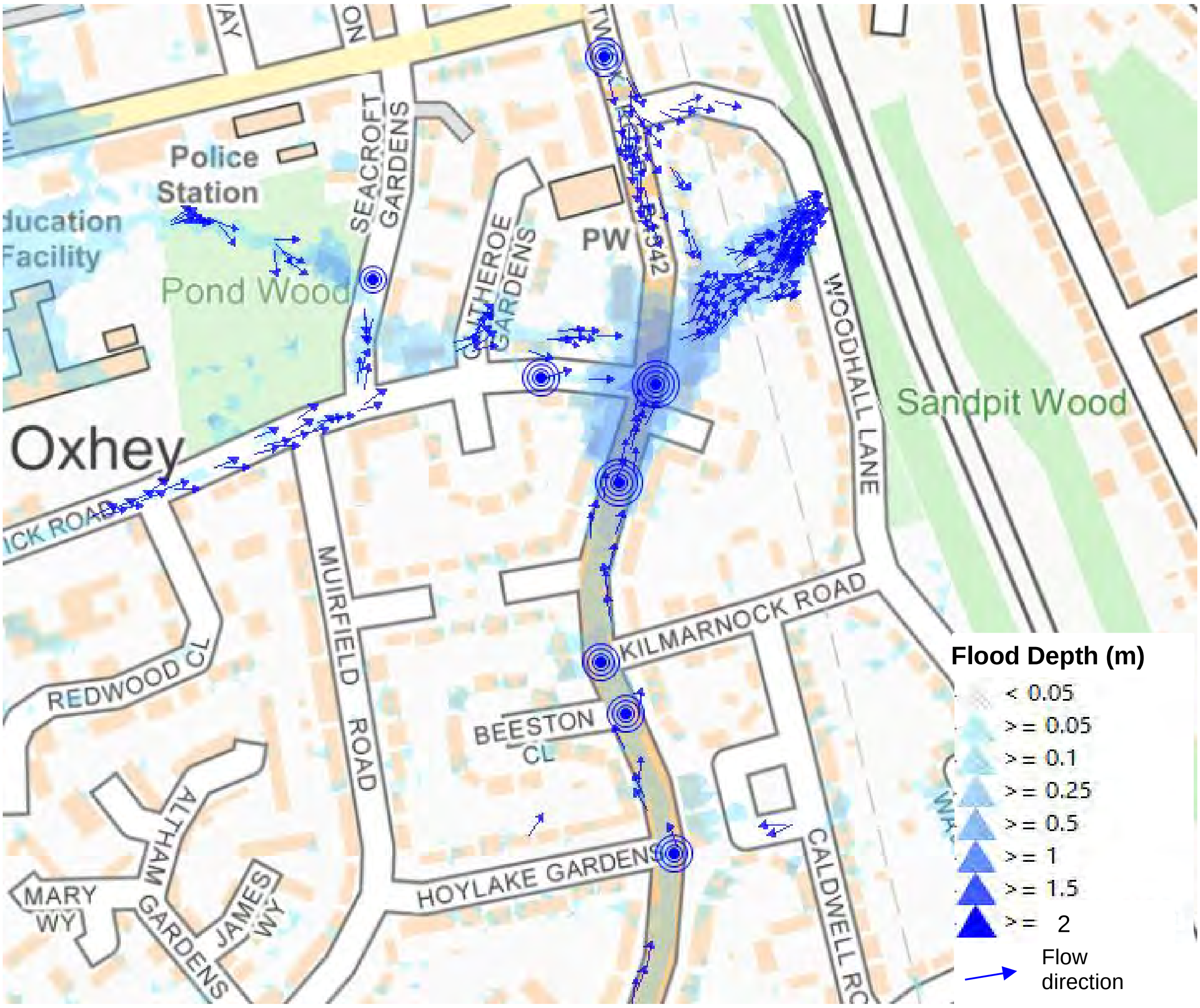

Figure 5-13: Manhole exceedance along Prestwick Road (note: blue circles indicate manholes predicted to surcharge).

5.4.3 Shortlisted options:

From the options discussed above (and in Appendix F) the preferred options for the hotspot are:

- Option 4 – Retrofitting of SuDS
- Option 5 – Natural flood management
- Option 6 – Property flood resilience

It is unlikely that one option alone would provide protection for the affected properties and the options above should be combined for an effective response to the flood risk.

5.5 Hotspot TRDC4 – Chorleywood

This hotspot area in Chorleywood covers Chorleywood West and Chorleywood Bottom as well as the east and west side of the railway line which runs through this catchment. This hotspot was identified under the multicriteria analysis as being warranted to model.

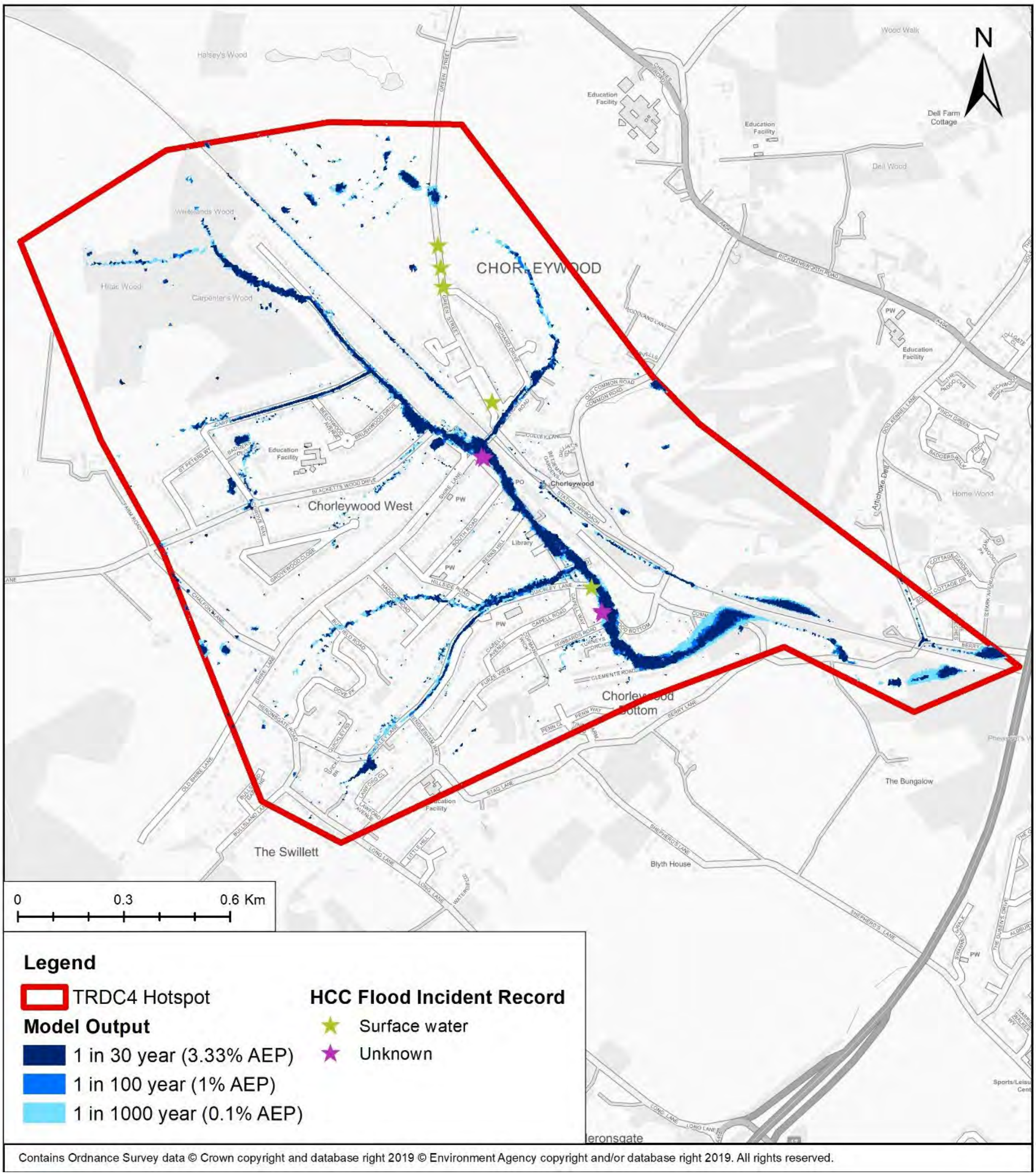

Figure 5-14: Detailed model results for TRDC4

5.5.1 Assessment of flood mechanisms - Source-Pathway-Receptor

Figure 5-14 and Appendix E shows that the main surface water flow path follows Lower Road through from north west to south east. Two other flow paths also join from Chorleywood to the north and the Swillett to the south west. Under the 1 in 30-year event a source of the flooding is from overtopping of surface water manholes such as along Clements Road and Lower Road. The flow paths run along Quickley Lane and Hillside Road and pond in topographic low points, and in gardens of properties. In the 1 in 100-year event increased flooding was predicted on the railway and more houses were at risk, as expected, such as along Whitelands Avenue and by Blacketts Wood Drive. This is reflected in the property counts (Table 5-7), with large areas of ponding during the 1 in 100-year event, and flow paths during the 1 in 1,000-year event.

Table 5-7 shows a comparison of the number of properties to be at risk of surface water flooding in the EA RoFSW mapping and the detailed flood modelling for TRDC4. At the 1 in 100- and 1000-year event, the RoFSW data predicts significantly more properties to flood. When comparing the outputs, the detailed modelling is mostly focused upon the central flow path moving north to south. The RoFSW data is suggesting of many more lateral flows, resulting in more properties being at risk.

Table 5-7: TRDC4 Properties at risk of flooding from surface water

(a) Number of residential properties at risk

Flood risk	1 in 20 year	1 in 30 year	1 in 75 year	1 in 100 year	1 in 200 year	1 in 1,000 year
RoFSW	N/A	247	N/A	418	N/A	807
TRDC4 detailed modelling	270	281	306	314	341	377

(b) Number of non-residential properties at risk

Flood risk	1 in 20 year	1 in 30 year	1 in 75 year	1 in 100 year	1 in 200 year	1 in 1,000 year
RoFSW	N/A	56	N/A	76	N/A	137
TRDC4 detailed modelling	67	68	74	80	79	83

The results are consistent with the historic flood events in the hotspot. Overland flows onto Green Street have been known to lead to frequent and prolonged flooding of the road, such as in 2013 and 2014, with reports of other events between 2002 and 2012. External property flooding due to blocked drains was reported near the junction between Shire Lane and Lower Road in September 2016. Three recorded incidents of flooding on Chorleywood Bottom have been reported due to blocked drains.

5.5.2 TRDC4 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 5-8 and further information about the options considered and the locations for options is included in Appendix F and Appendix G respectively.

Table 5-8: Summary of mitigation options for TRDC4

Option Number	Option Type	Description	Areas Applicable	Shortlisted?
Option 1	Natural flood management (NFM)	Utilisation of natural methods to reduce flood risk downstream	Northern and eastern areas of hotspot	×
Option 2	Control of flow below the railway	Construction of a culvert below the railway to allow flow path through and prevent backing up	Railway embankment near Common Gate Road	×
Option 3	Retrofitting of SuDS	Disconnection of surface water from public sewers via SuDS	Whitelands Avenue, Homefield Road, Orchard Drive	✓
Option 4	Flow routing in the highway	Utilisation of speed bumps to divert flows away from at risk areas and into drainage	Green Street, Whitelands Avenue, Lower Road	×
Option 5	Property flood resilience	Protection to individual properties	Shire Road, London Road, Chorleywood Bottom	✓

In the north and east of the hotspot, there are flow paths through fields and woodland. These areas provide ideal opportunity for the implementation of NFM methods to control the flows that reach residential areas (Option 1). Possible techniques include the construction of bunds, detention basins, offline ponds or cross-slope woodland; all of which typically have low construction and maintenance costs once in place. The flow paths were obstructed in the model to represent the impact of NFM, but it was clear that the flows are not significant to downstream risk. Although NFM is often a preferred method of flood management, it would not be a viable option within this hotspot as there is not a significant benefit following reduction of the flow paths.

Option 2 considered changes to the flow around the railway line in the southeast corner of the hotspot to reduce the ponding represented in the modelling. This option would require significant capital expenditure and it is unlikely that it would provide significant benefit therefore it was not considered for further investigation.

To manage the flow upstream, Option 3 suggests the retrofitting of SuDS (see Figure 5-15). Within the hotspot, there are existing areas of green space that could be adopted for management of surface water. The retrofitting of SuDS within the hotspot is largely located near the highway network. Between Orchard Drive and Homefield Road, it is suggested that the greenspace is adopted to store some of the surface water. Similarly, along Whitelands Avenue (near the area of shops), there are landscaped green spaces already existing within the highway. These could be adapted to store greater volumes of water. Finally, along Shire Road, there is an existing band of wooded area that could capture diverted flows. The retrofitting of SuDS across this area is largely associated with adopting existing green spaces. As result it is not likely to have any environmental enhancement or degradation. These schemes will have little associated future maintenance and is likely to only include grass cutting to ensure no volume loss. Furthermore, there will be little disruption during the excavation of the areas and no detrimental visual impact for the area.

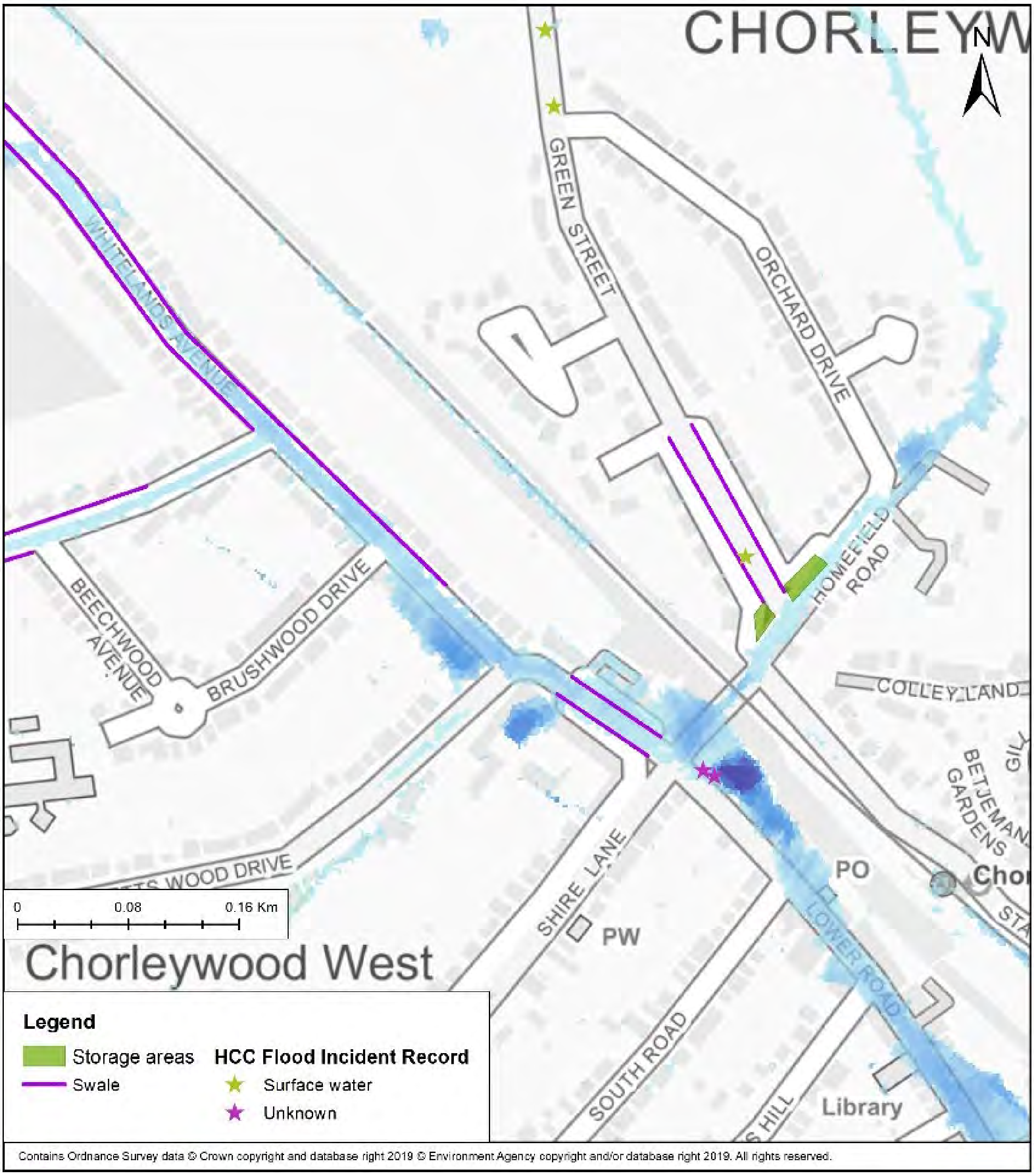

Figure 5-15: TRDC4 SuDS retrofit opportunity areas

At the downstream end of the flow path, in the east of the hotspot, the water is essentially dammed against the railway bridge. This is shown in Figure 5-16. Option 4 (Table 5-8 and Appendix G) proposes a culvert through the railway to manage the flow path. This would prevent backing up of the flood waters, reducing upstream risk. The engineering works associated with the construction of a culvert below the railway bridge would be highly costly and would require the involvement of Network Rail, with potential rail disruption. Management of the water beyond the railway would also be required and would most likely involve connection to the sewer network. It is encouraged that actions are taken to manage the flow path upstream, as opposed to dealing with the water downstream and the addition of a culvert would not provide a solution to flood risk.

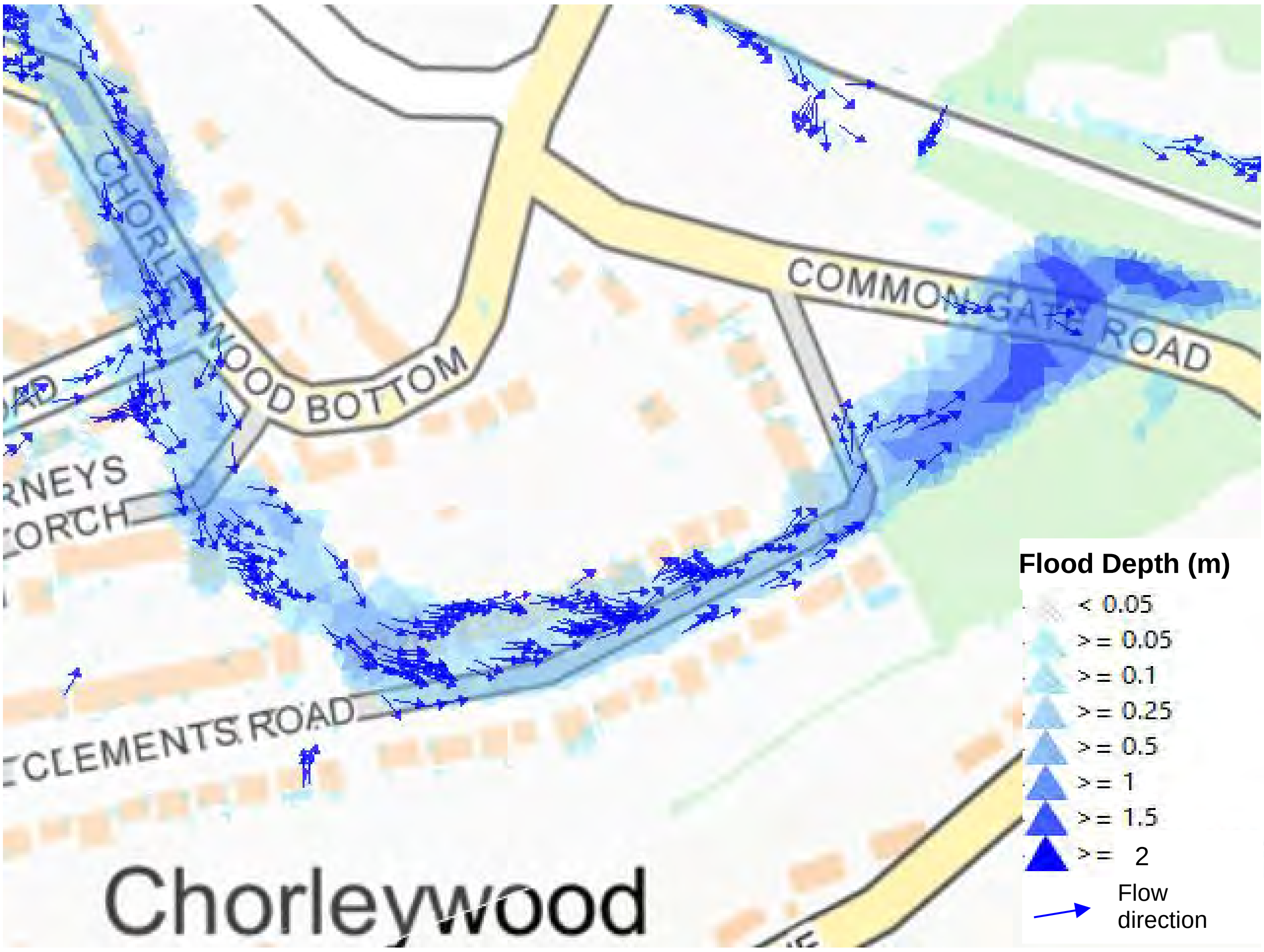

Figure 5-16: Damming of the flow path against the railway bridge

Option 5 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 would therefore be suitable proposed for properties along Chorleywood Bottom which have a history of flooding.

5.5.3 Shortlisted options:

From the options discussed above (and in Appendix F) the preferred options for the hotspot are:

- Option 3 – Retrofitting of SuDS;

- Option 5 – Property flood resilience.

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.

5.6 Hotspot TRDC9 – Prestwick Road, Brookdene Avenue and Raglan Gardens

It was recommended that this hotspot was carried forward to the modelling phase, with potential for SuDS such as tree pits along Oaklands Avenue by Raglan Gardens considered as an early option for managing runoff within the hotspot.

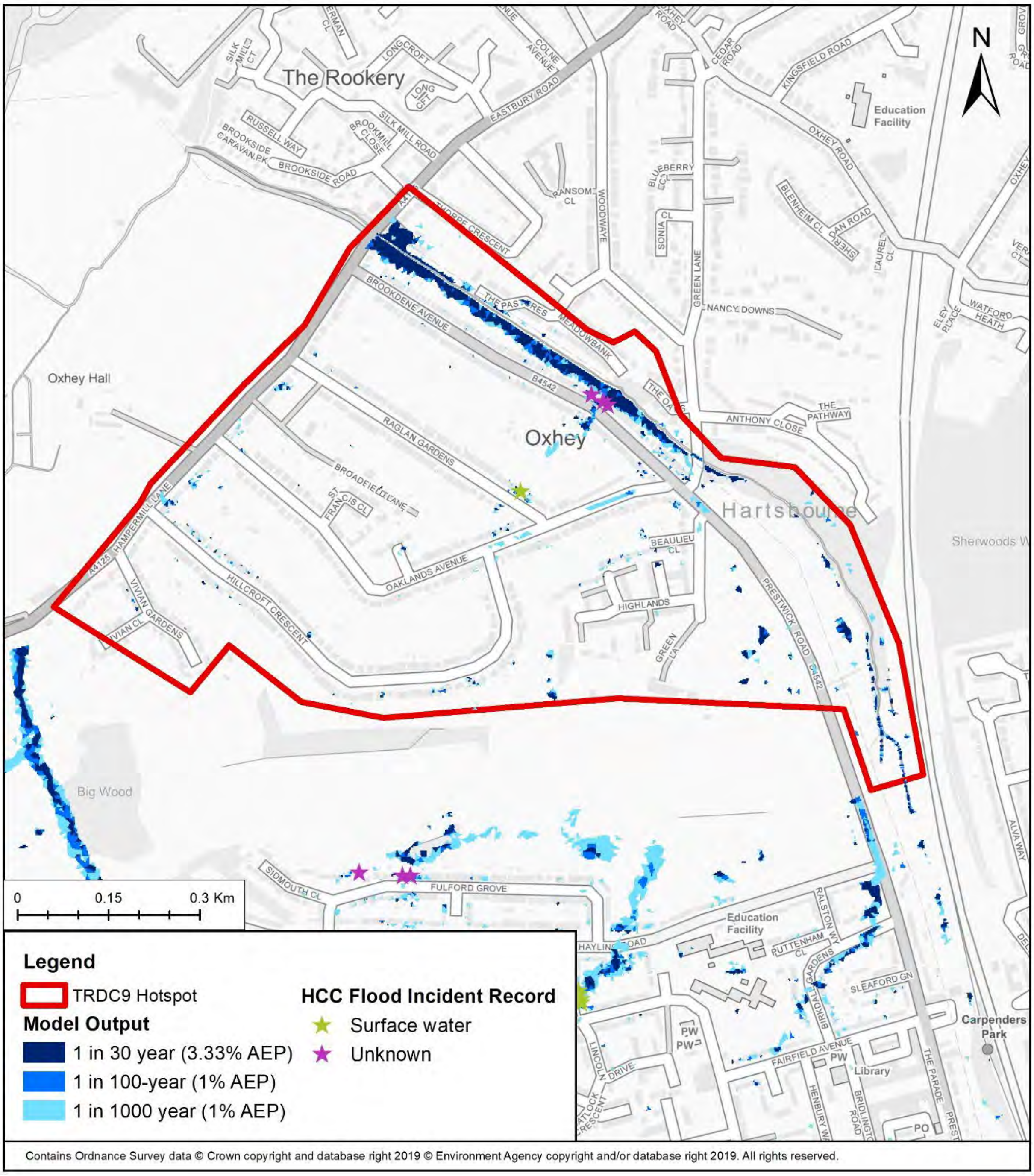

Figure 5-17: Detailed model outputs for TRDC9

5.6.1 Assessment of flood mechanisms - Source-Pathway-Receptor

A significant surface water flow path exists between Raglan Gardens and Brookdene Avenue, through back gardens (see Figure 5-17). It then joins the modelled fluvial flood extent of the Hartsbourne (a Main River) to the north of

Brookdene Avenue (see Figure 5-17). Figure 5-18 shows the slope from Raglan Gardens towards Brookdene Avenue. Other surface water flood risk in the hotspot is concentrated to the highway. There is high predicted flood risk at the junction with Hampermill Lane (A4125). From the site visit walk over, it is likely that the flood risk has been overestimated at the downstream extent of the hotspot boundary, at the junction with Hampermill Lane. This was reinstated at the hotspot selection workshop on 16/01/2018, suggesting that it is overstated along the line of the watercourse. The results for this model suggest that there is a link between the watercourse and surface water network in this model, with the main source of flood risk from the river.

Figure 5-18: Slope in road along Raglan Gardens

During the 1 in 30-year event the model predicts ponding along Hampermill Lane and spills onto the land boundary. In this event, flooding is predicted along the Hartsbourne, which shows overtopping of its banks in a number of locations and the potential to reach back gardens of a few properties. The flood risk within this hotspot is mostly associated with fluvial flooding but this has the potential to influence the surface water flood risk. The modelled flood extent is limited during the 1 in 30-year event, however large areas of ponding form during the 1 in 100-year event, and connect to form flow paths during the 1 in 1,000-year event, as reflected in the numbers of properties identified as at risk in the property counts. Table 5-9 shows a comparison of the number of properties to be at risk of surface water flooding in the EA RoFSW mapping and the detailed flood modelling for TRDC9, and highlights that there is a large difference between the RoFSW flood outputs and those of the detailed modelling. The detailed modelling suggests significantly a lower number of properties predicted to flood. There is a large difference in the flood extent at the Hartsbourne but also smaller lateral flow paths in the west which intersect several residential streets resulting in higher property counts.

Table 5-9: TRDC9 Properties at risk of flooding from surface water

(a) Number of residential properties at risk

Flood risk	1 in 20 year	1 in 30 year	1 in 75 year	1 in 100 year	1 in 200 year	1 in 1,000 year
RoFSW	N/A	29	N/A	87	N/A	279
TRDC9 detailed modelling	2	25	30	37	45	83

(b) Number of non-residential properties at risk

Flood risk	1 in 20 year	1 in 30 year	1 in 75 year	1 in 100 year	1 in 200 year	1 in 1,000 year
RoFSW	N/A	9	N/A	11	N/A	15
TRDC9 detailed modelling	0	7	7	8	9	10

The flow paths and surface water risk identified are in line with recorded flood incidents. Flooding was reported in June 2016 in three properties along Brookdene Avenue. No cause was recorded but following discussions with HCC it is understood that the flooding occurred as a result of surface water in the highway, which is supported by the flow path simulated in the modelling. Internal flooding has been experienced along both Brookdene Avenue and Raglan Gardens. The site visit on 30/11/2017 confirmed that flow paths are likely to occur along Raglan Gardens (due to the topography) and many of the properties have low thresholds.

5.6.2 TRDC9 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 5-10 and further information about the options considered and the locations for options is included in Appendix F and Appendix G respectively.

Table 5-10: Summary of mitigation options for TRDC9

Option Number	Option Type	Description	Areas Applicable	Shortlisted?
Option 1	Catchment management	Increased storage upstream of flows into the Hartsbourne to reduce downstream risk	Catchment-wide policy	✓
Option 2	Retrofitting of SuDS	Disconnection of surface water from public sewer via SuDS	Raglan Gardens, Brookdene Avenue	×
Option 3	Property flood resilience	Protection to individual properties	Brookdene Avenue	✓
Option 4	Increase conveyance and temporary highway storage	Increasing capacity within the highway via increased kerb height to limit water reaching property	Raglan Gardens, Brookdene Avenue	×
Option 5	Disconnection of surface water from sewers	Property-level disconnection of surface water to have a cumulative reduction in volumes reaching sewers	Oaklands Avenue, Raglan Gardens, Brookdene Avenue	✓

Option 1 (see Table 5-10 and Appendix G) considered the potential for catchment management measure to be installed upstream of the hotspot to improve the regulation of fluvial flows and therefore reduce the risk of fluvial flooding in the hotspot. The fluvial flows in this location are largely derived from the urban catchment that is covered by the TRDC2b hotspot and therefore measures in the neighbouring hotspot described in Section 5.4.2 may have benefits in this hotspot as well. This would also have the potential to reduce the constraints on the surface water drainage network that discharge into the main river. As this option relates predominantly to the fluvial risk in the hotspot any interventions would also require liaison with the EA to assess the required steps.

Option 2 considered retrofitting of SuDS into the hotspot with the aim of alleviating the flow path that is responsible for the reported flood incidents along Raglan Gardens and Brookdene Avenue. Along Raglan Gardens, the pavements are relatively wide, which could allow for the construction of rain gardens that would provide interception storage along the flow path and potentially reduce the risk of flooding in key locations. Along Brookdene Avenue, there are already some areas of greenspace which could also be utilized, however while there are opportunities for SuDS techniques, space is limited.

Option 3 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 would therefore be suitable proposed for properties along Brookdene Avenue where flooding is predicted to be 0.15m in a 1 in 75-year event.

To limit any flooding that is associated with the surface water flow path between Raglan Gardens and Brookdene Avenue shown in Figure 5-19, increased storage and conveyance within the highway was considered as Option 4. Increasing the kerb height along Brookdene Avenue would provide an obstruction to the flow path, potentially protecting those properties that have previously experienced flooding. Any options that involves altering the highway will have significant costs associated, with both the construction process and disruption caused through road closures. It should also be noted that increased kerb height will likely only protect during lower return periods, as kerbs may be overtopped in higher order events. Acceptance of this option is likely to be low from the residents as it will result in a raised kerb in front of driveways.

The model results show that there are several manholes along Oaklands Avenue which are overwhelmed as a result of surface water which flows along Raglan Gardens and Brookdene Avenue, which is consistent with previous reported flooding. As the area is well developed there is little available space for on-surface capture of surface water.

Option 5 (see Table 5-10 and Appendix G) considered methods to reduce flows within the drainage network and how inflows to the sewer network could be disconnected where possible. Across the residential area, water capture of roof runoff, through the installation of water butts or planters, could be implemented to limit the volumes of water that reach the sewer system during rainfall events. To be effective, this would require a large-scale adoption of the scheme. This would be a potentially lower cost scheme to implement, however it would require the agreement of the homeowners.

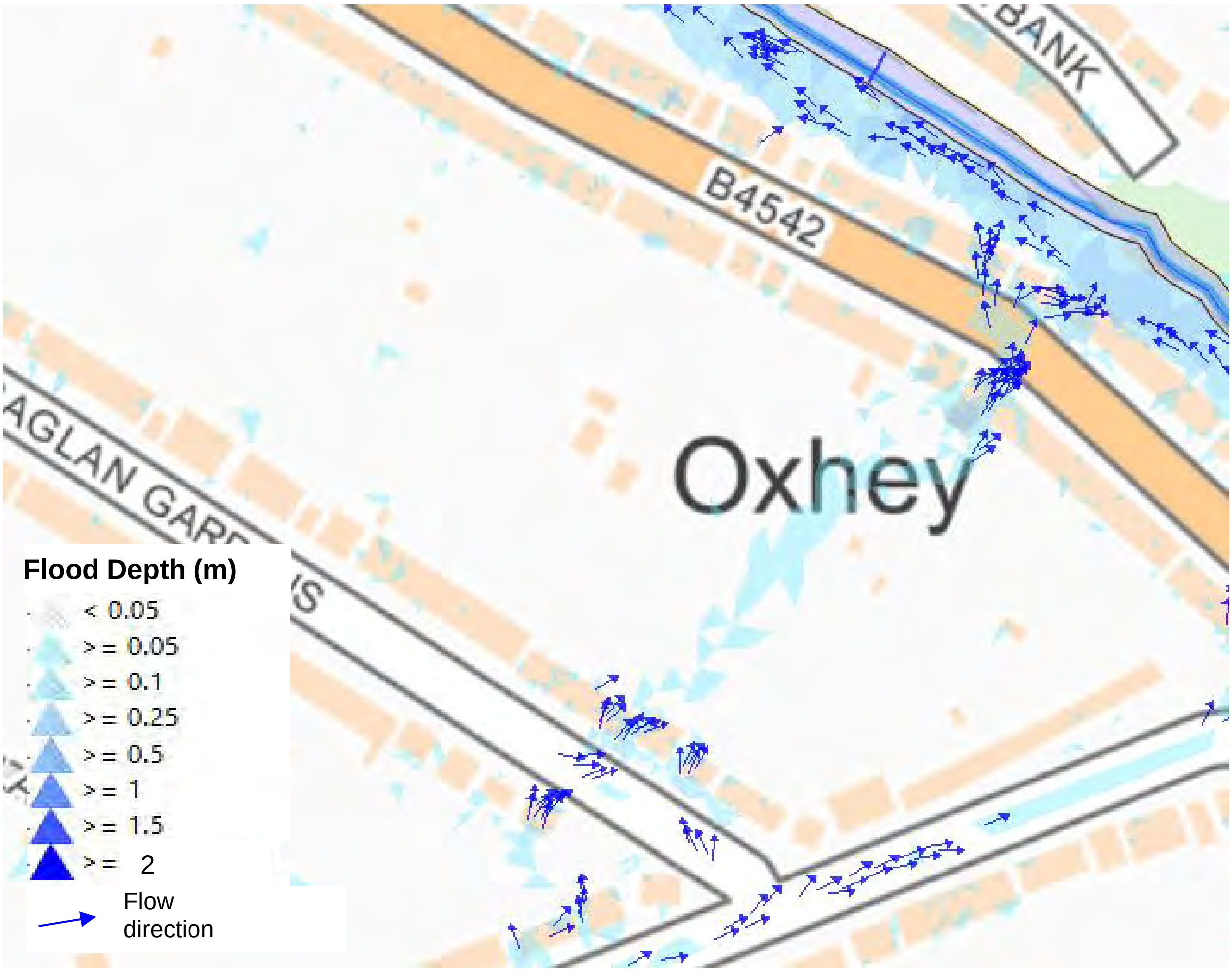

Figure 5-19: Flow path from Raglan Gardens to Brookdene Avenue

5.6.3 Shortlisted options:

From the options discussed above (and in Appendix F) the preferred options for the hotspot are:

- Option 1 – Catchment management;
- Option 3 – Property flood resilience;
- Option 5 – Disconnection of surface water from system.

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 Three Rivers District. 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 6-1.

Table 6-1: List of action plans

Geographic area	Action plan	Purpose
Study area wide	Generic action plan (Section 6.3)	Outline broad scale actions applicable across the study area
Hotspots	Hotspots action plan (Section 6.4)	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

6.4 Generic action plan

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

6.4.1 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.

6.4.2 Planning and surface water drainage

Although flood risk from fluvial 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.

6.4.3 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 6-1 outlines the typical process operated by Risk Management Authorities in responding to a reported incident.

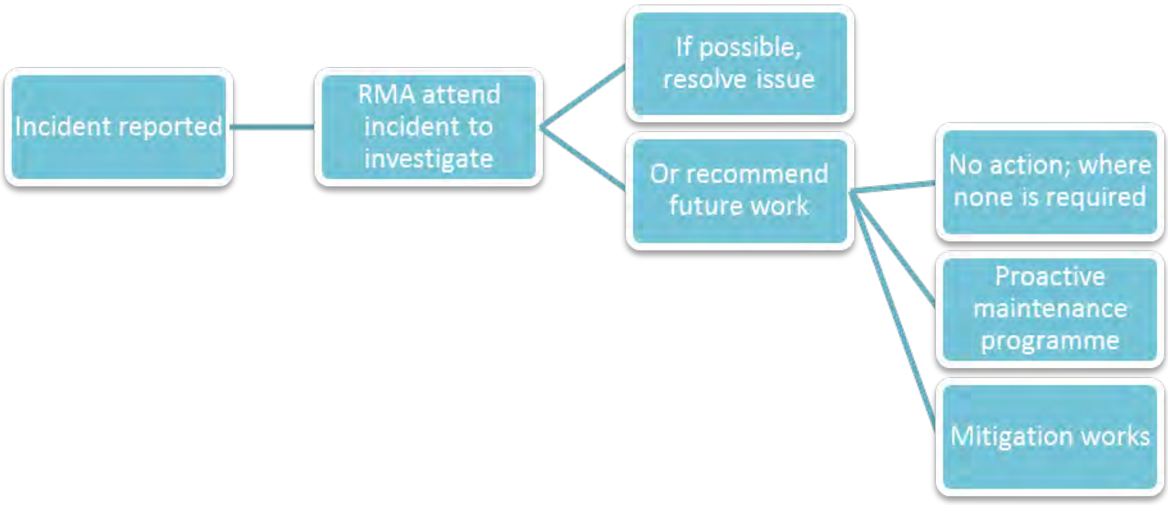

Figure 6-1: Typical process of asset maintenance by RMAs

This approach is largely being adopted by RMAs in Three River District, with HCC Highways having identified a series of priority areas for drainage works and gully maintenance across the county, and Thames Water 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 Three Rivers District, such as flap 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 Risk Management Authorities and providing advice, would help to the secure the future maintenance of these assets.

6.5 Hotspot action plan

For the hotspots strategic actions have been recommended to address integrated flood mechanisms operating in these areas in the table below.

Table 6-2: Hotspot action plan

Hotspot	Actions	Owner
TRDC1- Batchworth	Upstream management of the dominant flow path through the hotspot. Incorporating the management techniques would limit environmental impacts. Overall, to reduce flood risk downstream of the culvert, volumes need reducing upstream. Investigate the introduction of retrofitting SuDS within the Harefield Road area to capture and slow the overland flows that result in property flooding. Utilisation of existing small green spaces to incorporate these areas.	HCC HCC, HCC Highways
TRDC2a– Eastbury	Explore in more detail the possibility of creating an attenuation area within the existing wooded area around the railway embankment to capture surface water flows and flood flows from the Moor Park Stream. Retrofitting of SuDS across the hotspot. There are several green areas in the upper area of the hotspot that could be used to limit the flow path that originates here. Moving south in the hotspot, there are green areas along Batchworth Lane and its side roads (Ardross Avenue and Eastbury Lane) which could be adopted as SuDS spaces.	HCC, TRDC HCC
TRDC2b– South Oxhey	Hotspot-wide implementation of SuDS (retrofitting) where redevelopment allows to mitigate the flows from the several flow paths. Key areas to consider include; Hayling Road and Gosforth Lane, and Prestwick Road. The hotspot should be treated as an ‘at-risk’ area, and surface water managed across the area. Management of the small ordinary watercourses in the upstream areas of woodland. Actions to reduce and slow the volumes of water before it becomes culverted would act to alleviate the downstream flood risk.	HCC, HCC Highways HCC

Hotspot	Actions	Owner
TRDC4–Chorleywood	Retrofitting of SuDS across the hotspot to target surface water flow paths originating on the highway. The main roads contributing to this flooding are Shire Road, Whitelands Avenue and Homefield Road. The implementation of SuDS along these roads (there is opportunity for swales along all) would limit the combined flood risk when these routes meet.	HCC, HCC Highways
TRDC9–Prestwick Road	Disconnection of surface water from the sewer system to alleviate pressure and reduce the risk of manhole. Increased highway capacity along Raglan Road and Oakland Gardens to restrict the flow path from reaching properties. Management of flows from the upper catchment to regulate the fluvial flood risk, particularly from the urban areas in TRDC2b This is likely to require coordination with the EA	HCC TWUL HCC Highways EA / HCC

6.6 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 Three Rivers District.

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 Three Rivers District SWMP area, further detailed assessment is recommended in some of the hotspot areas, including hotspot areas of Batchworth, Eastbury, South Oxhey and Chorleywood. 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

1. Three Rivers District Council SWMPForPublishingAccessibility10112021

A Project data register

A large table of the Project Data Register, used to list all the data source layers for GIS work on the modelling.

This is not uploaded to the website, due to accessibility issues.

If you require access, please email the FRM team to request a digital copy is sent to you. Our email address is: FloodandWaterManagement@hertfordshire.gov.uk

The reference for this document is: TRDC SWMP Appendix A

B Stakeholder Communications and Engagement Plan

A plan setting out communications between HCC and JBA consulting.

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If you require access, please email the FRM team to request a digital copy is sent to you. Our email address is: FloodandWaterManagement@hertfordshire.gov.uk

The reference for this document is: TRDC SWMP Appendix B

C Hotspot assessment sheets

Maps and data for the hotspots for modelling purposes.

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The reference for this document is: TRDC SWMP Appendix C

D Modelling methodology

Detail on the modelling methodology used in production of data for the SWMP.

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The reference for this document is: TRDC SWMP Appendix D

E Hotspot flood risk mapping

Flood risk maps showing predicted flood depths for various events for each of the locations.

F Options long-list

Table for the long list of options for each location. Information from this table is included in the maps of Appendix G.

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The reference for this document is: TRDC SWMP Appendix F

G Options mapping

Maps for the long and short list of options for each location.

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The reference for this document is: TRDC SWMP Appendix G.

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