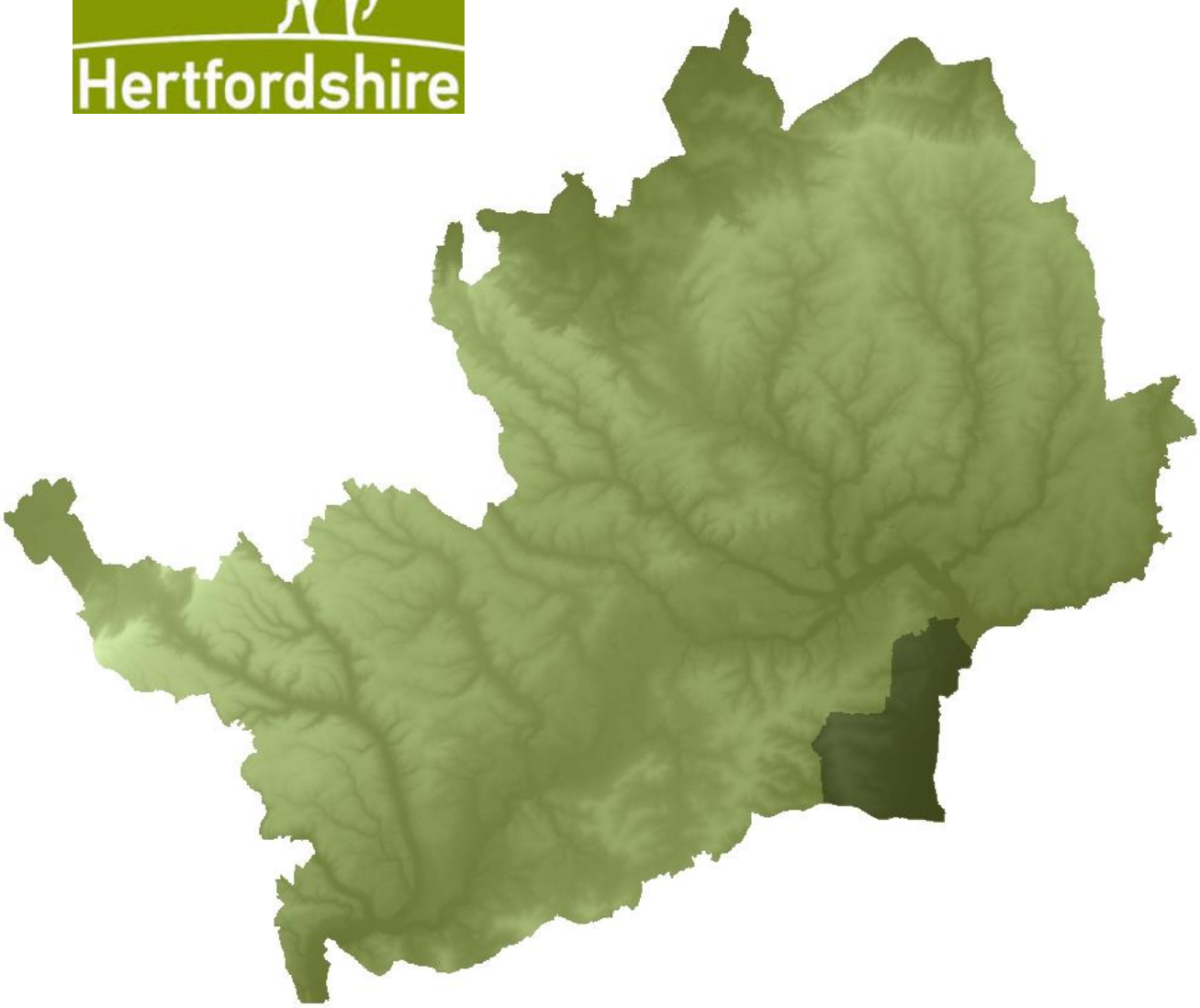

BROXBOURNE BOROUGH SURFACE WATER MANAGEMENT PLAN

FINAL REPORT

REPORT N^{O} 70009115 – B_SWMP – 0-1 2017-03-16

BROXBOURNE BOROUGH SURFACE WATER MANAGEMENT PLAN

FINAL REPORT

Hertfordshire County Council

Final

Project no: 70009115
Date: March 2017

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KEY DEFINITIONS

Surface water flooding (Pluvial Flooding)	**In the context of a Surface Water Management Plan, Defra's SWMP Technical Guidance[1] defines surface water flooding as flooding from sewers, drains, groundwater, and runoff from land, small watercourses and ditches that occurs as a result of heavy rainfall.**
Groundwater flooding	**Surface water flooding due to groundwater occurs when the water held underground rises to a level where it breaks the surface in areas away from usual above ground channels and drainage pathways, though it can occur when subterranean (underground) rivers rise to above the surface. It is generally a result of exceptional extended periods of heavy rain, but can also occur as a result of reduced abstraction, underground leaks or the displacement of underground flows.**
Overland Flow / Surface Water Runoff	**Water flowing over the ground surface that has not reached a natural or artificial drainage channel.**
Fluvial flooding	**Fluvial flooding occurs when rivers overflow and burst their banks, due to high or intense rainfall which flows into them. In the SWMP only fluvial flooding from Ordinary watercourses is assessed.**
Main River	**Main Rivers are usually larger streams and rivers which have been designated as such by Defra and the Environment Agency. The Environment Agency has powers to undertake works on any stretch of Main River and is responsible for flood risk management activities.**
Ordinary watercourse	**Ordinary watercourses are deemed to be all rivers and streams and all ditches, drains, cuts, culverts, dikes, sluices, sewers (other than public sewers vested with utilities) and passages, through which water flows that are not classified as Main River by the Environment Agency.[2]**

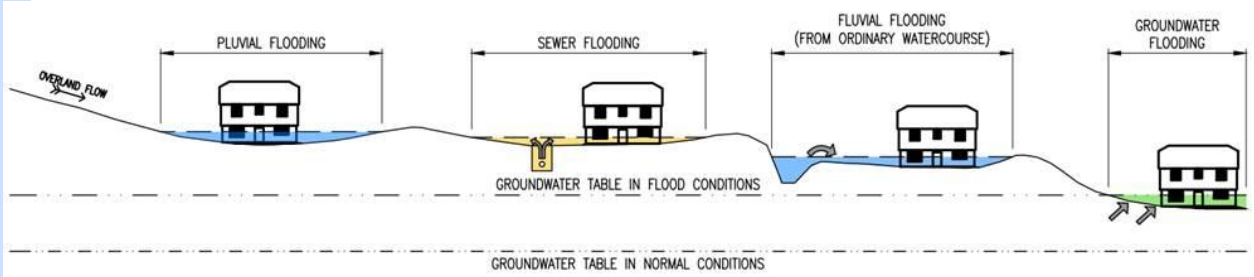


Figure 1: A diagrammatic summary of the key definitions

[1] Surface Water Management Plan Technical Guidance, Defra (March 2010) (Source: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69342/pb13546-swmp-guidance-100319.pdf)

[2] Hertfordshire County Council's definition of Ordinary watercourses (Source: https://www.hertfordshire.gov.uk/services/recycling-waste-and-environment/water/ordinary-watercourses/ordinary-watercourses.aspx)

1 EXECUTIVE SUMMARY

1.1 BACKGROUND

WSP | Parsons Brinckerhoff has completed a Surface Water Management Plan (SWMP) for the Borough of Broxbourne on behalf of Hertfordshire County Council, as Lead Local Flood Authority. The study has been undertaken in consultation with key stakeholders. The stakeholders worked together to understand the causes and effects of surface water flooding and agree the most cost effective processes of managing surface water flood risk for the long term. The process of working together is designed to encourage the development of innovative solutions and practices as well as identifying funding streams to assist in the delivery of the outcomes of the SWMP.

The Defra SWMP Technical Guidance (2010) suggests that a SWMP study will not be required in all locations but rather where areas are "considered to be at greatest risk of surface water flooding or where partnership working is considered essential to both understand and address surface water flooding concerns". The need for a SWMP for the Borough of Broxbourne was identified within the Local Flood Risk Management Strategy (LFRMS) for Hertfordshire.

The Surface Water Management Plan is to be a living document that should be reviewed approximately every five years, to ensure the implementation of the agreed actions is correct and that any new issues are addressed. A review may be required following any new flood event, when new flood data becomes available, or new modelling techniques are developed, and when there is a change of policy in the catchment.

1.2 IDENTIFICATION OF HOTSPOTS

The first part of the risk assessment phase of the Broxbourne Borough SWMP was the strategic and intermediate assessments. The principle purpose of these assessments was to identify broad locations which were considered to be vulnerable to surface water flooding. This was undertaken using the best information available, including some GIS analytical techniques, and historical information.

The Risk of Flooding from Surface Water Maps (RoFfSW) (previously referred to as the updated Flood Map for Surface Water, uFMfSW) are considered to be the best available Hertfordshire-wide representation of potential surface water flood risk. Historical flooding incidents were then used as supporting evidence when looking at the Risk of Flooding from Surface Water Maps, in order to determine areas to focus on in this SWMP. This included the Section 19 Flood Investigation Reports produced under the Flood and Water Management Act 2010.

Local knowledge was used to pinpoint instances of surface water flooding. However, only broad areas were identified (by the Local Planning Authorities and the Environment Agency) as having experienced known incidents of surface water flooding. These included areas identified as being potential development sites and areas which have had Section 19 Investigations already undertaken.

A Desk-Based analysis was conducted to assess the flood risk to receptors within the Borough of Broxbourne. From this, 19 hotspots (areas perceived and identified locally as being at greatest risk of surface water flooding) were analysed using GIS Multi-Criteria Analysis (MCA) to prioritise the hotspots most at risk of flooding within the Borough of Broxbourne. A stakeholder meeting was then held in February 2015, followed by site visits to confirm the findings.

As a result, five of the hotspots were then assessed for suitability of modelling, which resulted in the final five SWMP Modelled Hotspots:

- Hotspot 9 Rye House/North Hoddesdon

- Hotspot 52 Cheshunt
- Hotspot 55 Cozens Lane East, Wormley
- Hotspot 62 Rosedale North/Flamstead End
- Hotspot 63 Rosedale South/Flamstead End

1.3 DETAILED PHASE OF SWMP

The detailed phase of the SWMP focussed on the five SWMP Modelled Hotspots identified above. The detailed modelling involved the construction of individual hotspot models to assess the baseline flood mechanisms, pathways and extents. This included:

- Collection and review of available digital terrain models (DTM) (e.g. LiDAR) for the area;
- Topographic surveys to supplement the DTM where necessary;
- Collation and review of below ground infrastructure;
- Consideration of land use; and
- Specific items where further consideration was required. This included for example an additional site investigation of sewer capacity for a specific area within a hotspot.

The models were 1D-2D linked ESTRY-TUFLOW models to represent the below ground infrastructure (1D) and above ground flowpaths (2D), with direct rainfall applied across the model domain. This produced flood extents, depths, velocities and hazard ratings for events ranging from the 1 in 5 year (20% annual exceedance probability) event up to the 1 in 1,000 year (0.1% annual exceedance probability) event.

Following the hydraulic modelling, a review of the modelled flood extents was undertaken. From this review the types of mitigation measures which could be implemented for each hotspot were identified with the aim to reduce the impacts and damage associated with flooding.

The table below summarises the findings for each hotspot, including details on the mitigation and proposed recommendations to be taken forward.

LOCATION	SUMMARY OF FLOOD RISK	PROPOSED MITIGATION MEASURES	RECOMMENDATIONS
Hotspot 9 - Rye House/North Hoddesdon	Ponding is predicted along Beyers Prospect, Ware Road and Bridle Way; around some properties to the south of The Drive but mainly constrained to Ditchfield Road, Tregelles Road, Thurfood Road and properties to the south of Rye Park. Flooding in the area to the west of the underpass in Bridley Way South. Flood hazard rating for areas of high flood depths are classed as danger for most, coinciding with the flowpaths along Ware Road, Bridle Way and Tregelles Road.	Property Level Protection (PLP) is recommended as the main mitigation for properties predicted to be affected by flooding in this hotpots: • Ware Road (properties on the east side). • Area to the south of Bridle Way South. • Area between The Drive and Tovey Avenue. • Area between Thurgood Road, Middlefield Road and Fairfield Road. • The Post Office and properties located in the junction between Middlefield Road and Stanstead Road. • Properties located in Essex Road, to the south of Rye Park.	Property Level Protection (PLP) is one method that can be used to make properties more resilient to flooding. However, by its nature it will only protect properties upon which it is installed, implemented and actively managed. A constraint of the funding process is that if PLP measures are funded through Local Levy or FCERM GiA then these properties cannot be used to justify further alleviation measures, which could benefit a wider area. The alternative measures focus mainly on providing attenuation and utilising the roads as preferential flowpaths in order to reduce uncontrolled flowpaths between properties.

LOCATION	SUMMARY OF FLOOD RISK	PROPOSED MITIGATION MEASURES	RECOMMENDATIONS
Hotspot 52 - Cheshunt	Flooding is predicted between The Mead and Church Lane. The main flowpath extends from west to east through properties between the High Street and the recreation ground. Flood hazard rating identifies an area of danger for most on the highway between The Mead and Church Lane. There are also areas of danger for some along the flowpath that flows from east to west.	• Property Level Protection (PLP) on the properties located to the east of High Street. • Installation of a swale along the side of Church Lane to convey flows from Church Lane and a depression to connect to either the drainage system or the New River. • Infill the existing wall at the back entrance to the courtyards located to the south of Kilsmore Lane.	Investigation into measures to keep the preferential flowpath on the High Street (e.g. speedbumps, reprofiling levels). This is expected to reduce the flood risk downstream and therefore the need for Property Level Protection to the east of the High Street. Reprofiling or installation of a speedbump at the junction of the High Street with Gew's Corner and Hanbury Close should be investigated. • Investigation into the potential for attenuation in the recreation grounds located in Penton Drive. • A site visit, potentially combined with further investigation to determine the preferential flowpath and need for Property Level Protection (PLP) in Prospect Road.
Hotspot 55 - Cozens Lane East, Wormley	Flooding is predicted along estate roads associated with ponding against the railway. The flood hazard rating is danger for most in most areas predicted to flood, notably Lammasmead and Cozens Lane East.	Mitigation options are focused on increasing the capacity of the existing culverts running under the railway and installing additional culverts, in order to reduce ponding against the railway. Extensive consultation with Network Rail should be undertaken in order to determine the viability of this option. Alternatively, PLP could be implemented to protect the properties affected by ponding if the upgrading of culverts is not viable.	• These measures focus mainly on keeping a preferential flowpath along the roads that will spill into a swale that will convey flows into the culverts running under the railway. • Potential attenuation areas have been identified to reduce flooding downstream. • Investigation into the flowpath between properties in High Road Wormley, High Road Broxbourne and High Road Turnford to the east.
Hotspot 62 & 63 - Rosedale (North and South) / Flamstead End	Flooding is predicted along Andrew's Lane and across to the underpasses on Rosedale Way, flooding is also predicted associated with the pond north of Goff's Lane across the road into the recreation ground. Flooding is also shown by the B198. Ponding to the south of Rosedale Way and Westmeade Close. Flood hazard varies across the hotspot with some areas of danger for most.	• Keep preferential flowpath along Rosedale Way (e.g. by road reprofiling or using speedbumps) and installation of a high capacity drain and culvert to convey the flow to Rags Brook. • Ditch along Rosedale Way to convey flows from Granby Park Road to Rags Brook. • PLP in the properties to the south of the recreation grounds (south of Goff's Lane). • PLP in the properties to the south of Rosedale Way and Westmeade Close.	• Topographical survey to confirm whether the flowpath splits at the pedestrian crossing and potentially a need for a wall to cut off the flowpath from Goff's Lane to Cussons Close. • Investigate measures to keep the preferential flowpath along Rosedale Way. This may remove the need for PLP to the south of Rosedale Way and Westmeade Close. • Ensure that the preferential flowpath along Rosedale Way spills into the drain downstream and reprofile the drain. • Investigate potential attenuation (e.g. pond) on the playing fields, which would reduce the need for Property Level Protection (PLP) in the properties downstream of the recreation grounds. • Ensure the attenuation area to the west of Lieutenant Ellis Way (B198) operates and is controlled as modelled.

An economic viability assessment of the potential benefits of each option compared to an indicative cost estimate was undertaken. This assessment was undertaken to ensure that HCC could prioritise future work to focus on measures which not only would reduce flood risk but also would have the potential to secure funding to facilitate their construction. A summary of the economic assessment for each site is provided in the table below.

HOTSPOT	MITIGATION OPTION	PRESENT VALUE DAMAGES [£]	PRESENT VALUE BENEFITS [£]	PRESENT VALUE COSTS [£]	BC RATIO
9 - Rye House, Hoddesdon	Baseline	60,651,000	/	/	/
	100yr SOP	50,277,000	10,424,000	3,101,000	3.4
52 - Cheshunt	Baseline	38,578,000	/	/	/
	30yr SOP	36,550,000	2,028,000	800,000	2.5
55 - Cozens Lane East, Wormley	Baseline	47,059,000	/	/	/
	100yr SOP	22,109,000	24,951,000	4,592,000	5.4
62 - Rosedale (North) / Flamstead End	Baseline	12,521,000	/	/	/
	30yr SOP	11,932,000	588,748	115,000	5.1
63 - Rosedale (South) / Flamstead End	Baseline	31,905,000	/	/	/
	30yr SOP	29,952,000	1,953,000	752,000	2.6

The economic assessment finds all potential mitigation schemes are considered sufficiently viable to be submitted to the Environment Agency for inclusion on their Medium Term Plan (MTP) and further assessments undertaken to refine the schemes to a level suitable for a formal funding application (Outline Business Case). It is advised that HCC work with key stakeholders to secure additional third party funds to improve the overall funding scores and to ensure the schemes have sufficient funding for delivery. Alternatively, smaller more localised schemes could be considered as part of HCC and their partners' operational and capital workstreams.

In addition to the five SWMP Modelled Hotspots, seven of the Non-Modelled hotspots were allocated recommendations and actions, as shown in the table on the following page.

HOTSPOT NUMBER	LOCATION	RECOMMENDATIONS AND ACTIONS
Hotspot 49	Crossbrook Street, Cheshunt	Investigation of any culverts under the railway. Increased maintenance of these culverts could reduce the flood risk in the area around Limes Road where existing flooding incidents have been reported.
Hotspot 50	Waltham Cross (south)	Ensure suitable highway drainage infrastructure is in place. Work with property owners to recommend PLP where appropriate.
Hotspot 56	Broxbourne town	Review exceedance routes for overland flows near to the New River, with the aim of avoiding areas of substantial ponding. Review maintenance regimes in the critical areas.
Hotspot 65	Longfield Lane, Cheshunt	Increased maintenance of the ditch running alongside Longfield Lane may alleviate some flood risk in the area.
Hotspot 69	Little Grove Avenue, Cheshunt	Possible inclusion of a cut-off drain to the west of Cony Close may reduce the flood risk to the residential area.
Hotspot 71	Greta Groves, Goff's Oak, Waltham Cross	HCC LLFA staff to undertake a site investigation to ensure that flowpaths exist through the residential area or recommend changes to divert water to a preferential flowpath. A review of the highway drainage should also be undertaken.
Additional Stakeholder Selection	Hell Wood	If any development in the Hell Wood area was to take place, it is recommended that this include some flood storage, with the aim to reduce the flood risk to the area around Thomas Rochford Way.

1.4 HABITATS REGULATION ASSESSMENT (HRA)

There are important designated sites (Sites of Special Scientific Interest (SSSI) and Special Areas of Conservation (SAC)) along the River Lea/Lee corridor within and in close proximity to the Borough of Broxbourne. To ensure that the implementation phases of the SWMP will not lead to adverse impacts within these sites, a Habitats Regulation Assessment (HRA) has been undertaken in conjunction with this study. This demonstrates that the SWMP will not lead to adverse impacts on the designated sites.

1.5 ACTION PLAN

An Action Plan (provided in Appendix G) has been developed to cover the measures identified and recommended as part of the SWMP. The Action Plan identifies the process that would need to be undertaken for each element that would require capital funds to facilitate its implementation.

2 INTRODUCTION

2.1 BACKGROUND

The Borough of Broxbourne suffered flooding in February 2014 and more recently in June 2016. There was also significant flooding across Hertfordshire during both events. Historically, flooding has been associated with fluvial sources.; however more recent events have seen both fluvial, pluvial and combined causes.

The overall SWMP process is set out in Section 2.4.

This document specifically deals with surface water flooding. However, where there is potential interaction between fluvial flows and surface water flooding it outlines the potential impacts.

This report has been developed using the 'Surface Water Management Plan Technical Guidance' published by the Department for Environment, Food and Rural Affairs (Defra) in March 2010. Since the publication of this document the Environment Agency has published the Risk of Flooding from Surface Water (RoFfSW) map. The information contained within this dataset means that the full Strategic and Intermediate Phases as detailed in the guidance are no longer necessary.

2.2 STUDY AREA

The Borough of Broxbourne is a non-metropolitan local authority in Hertfordshire, England. The borough includes the towns of Broxbourne, Cheshunt and Hoddesdon. Figure 2 illustrates the location of the Borough of Broxbourne within Hertfordshire. The area of the borough is 51.4km^2.

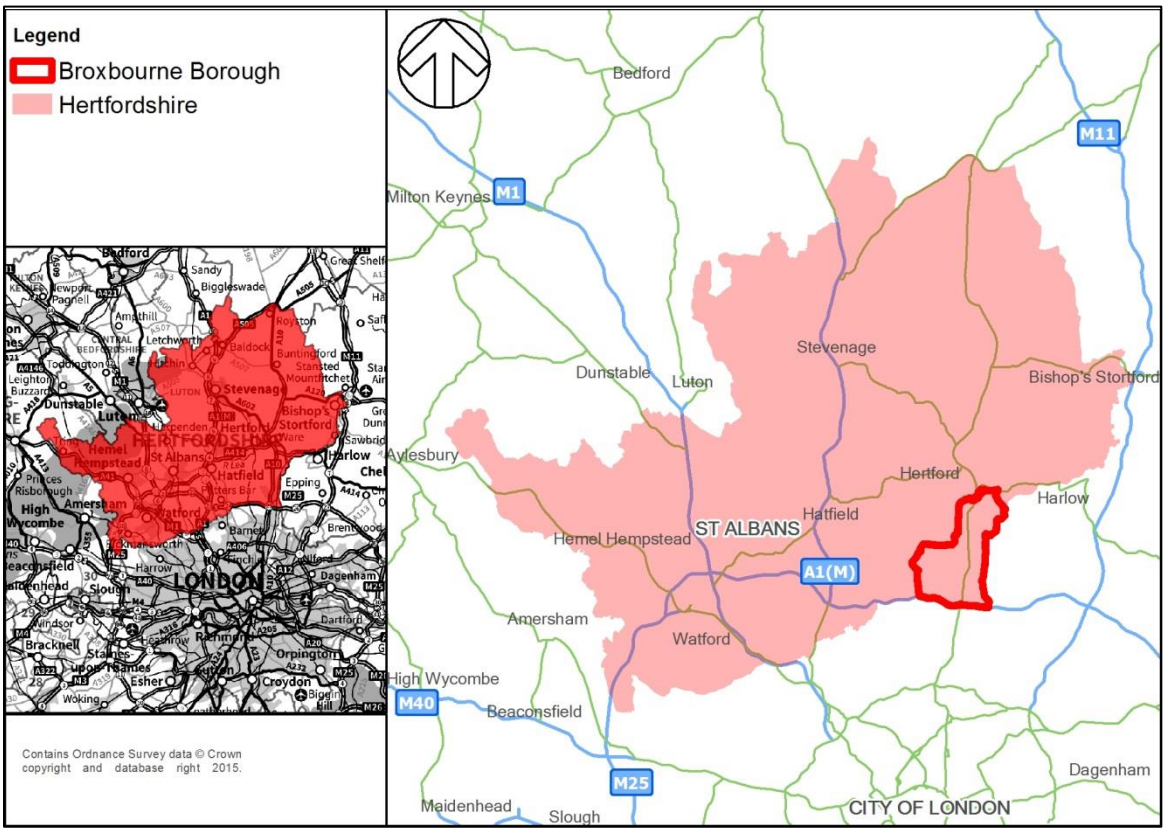


Figure 2: The Borough of Broxbourne Location Plan

There are three river catchments within the Borough of Broxbourne, shown in Figure 3; the Lea Navigation, the Small River Lee, and the Turkey Brook and Cuffley Brook catchments. The River Lea/Lee (Lea is the natural river channel; Lee is the man-made canalised channel, known as the Lee navigation), rises near Luton in Bedfordshire and flows across Hertfordshire. The River Lea becomes braided at the confluence with the River Stort to the north east of the borough. From there the river flows in a southerly direction towards the River Thames, along the eastern boundary of the borough. The River Lea has a number of tributaries, which flow through the Borough of Broxbourne in an easterly direction. These tributaries include:

- The Woollen Brook and River Lynch fall generally in a south easterly direction through Hoddesdon in the north of the borough. The rivers fall into the River Lee Navigation and eventually into the River Thames.
- Turnford Brook rises to the north of Shambrook Road and flows in an easterly direction under the A10 before flowing south, then east through Turnford. The river then flows under the West Anglia Main Line Railway and discharges into the River Lee.
- Rags Brook begins to the south of Bloomfield Road and flows in an easterly direction through Flamstead End. Rags Brook flows to the south of the Brookfield Centre and underneath the A10 before discharging into Turnford Brook adjacent to St Clement Church.
- College Brook begins to the south of Goff's School and flows easterly through Cheshunt until it discharges into the River Lee.
- Theobalds Brook rises to the south of Goff's Oak and flows in a south easterly direction, around Theobalds Grove station and discharges into the River Lee.
- Spitalbrook and Wormleybury Brook are additional watercourse that run through the Borough of Broxbourne.

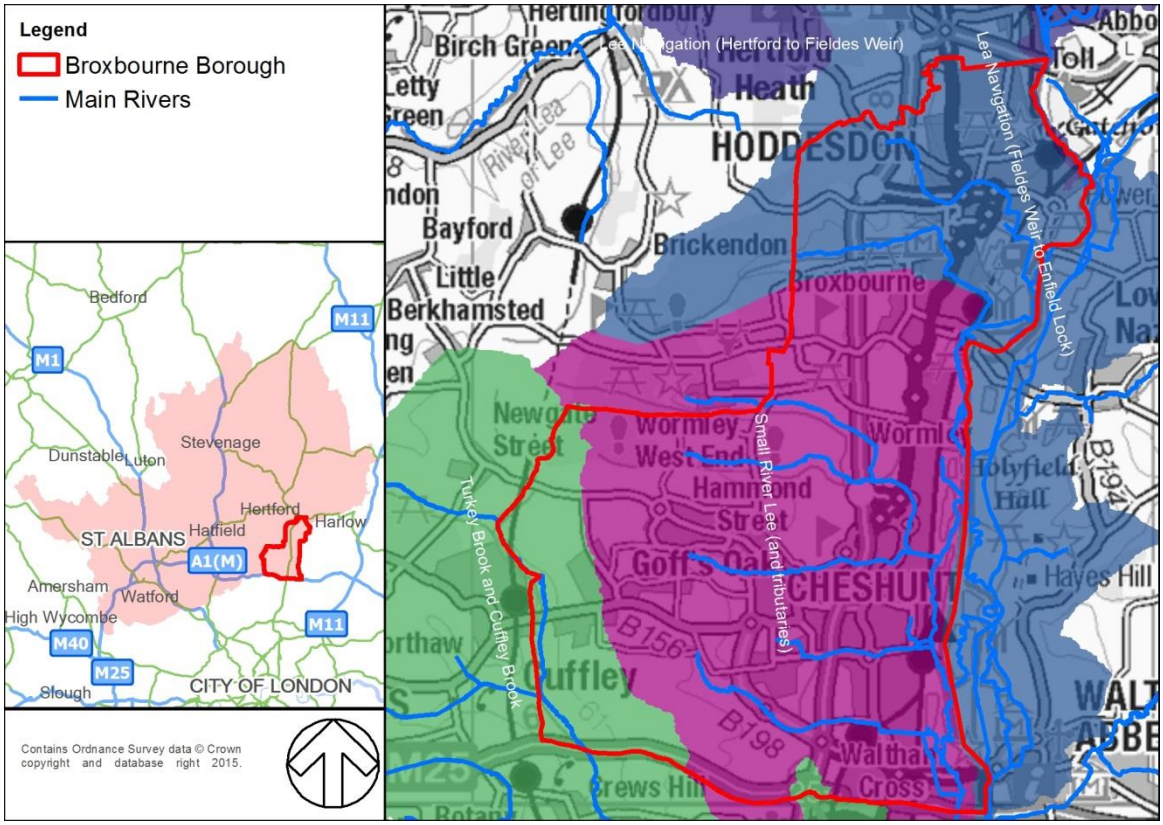


Figure 3: River Catchments within the Borough of Broxbourne

The British Geological Survey (BGS) mapping indicates that the Borough of Broxbourne is underlain predominantly by London Clay deposits shown by Figure 4. Lewes Nodular Chalk

Formation underlays a relatively small area to the north east of the Borough with Lambeth Group featuring as border with the remaining London Clay Formation, which underlays the majority of the Borough of Broxbourne.

In general, clay catchments are considered to be impermeable with large proportions of the rain falling on the ground unable to infiltrate resulting in significant surface water runoff from undeveloped land in addition to man-made impermeable surfaces.

The majority of the bedrock underlying the borough is classified as a “Principal Aquifer.” These are rock layers that have high intergranular and/or fracture permeability. As a result, the aquifers can provide a high level of water storage. They may support water supply and/or river baseflow on a strategic scale.

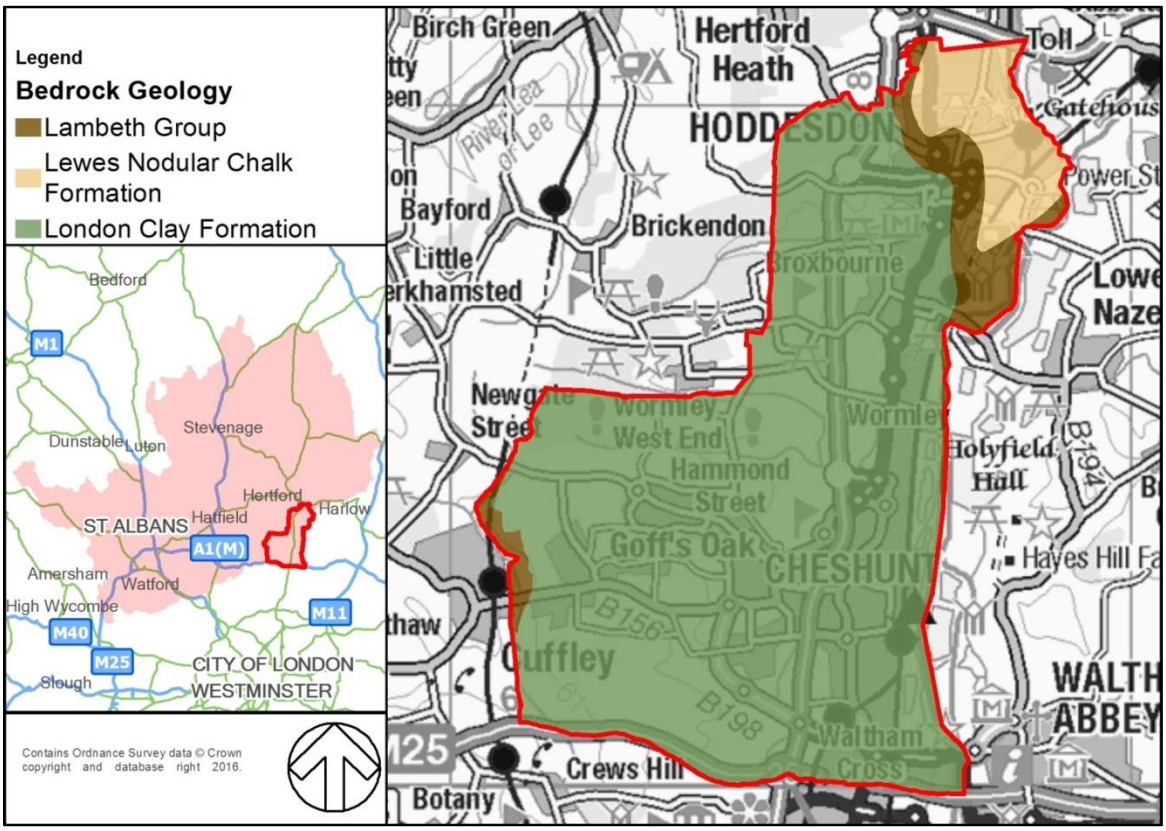


Figure 4: British Geological Survey Map of the Borough of Broxbourne – Bedrock Deposits

Figure 5 shows the superficial deposits overlaying the bedrock. The deposits within Broxbourne are mainly clay and silt with some sand and gravel areas closer to the River Lea. The pattern of deposits is consistent with river terrace deposits of the River Lea.

The sand and gravel based deposits are classed as Secondary A aquifers, capable of supporting water supplies at a local rather than a strategic scale, and in some cases forming an important source of baseflow to rivers. These are generally aquifers formerly classified as minor aquifers. During times of heavy rainfall, water may saturate the underlying soils and as a result cause groundwater to seep out of the ground. Elsewhere, there are localised areas of Secondary Undifferentiated aquifers and areas not classified as aquifers[3].

[3] Definitions adapted from Environment Agency What’s in Your Back Yard website http://apps.environment-agency.gov.uk/wiyby/117020.aspx

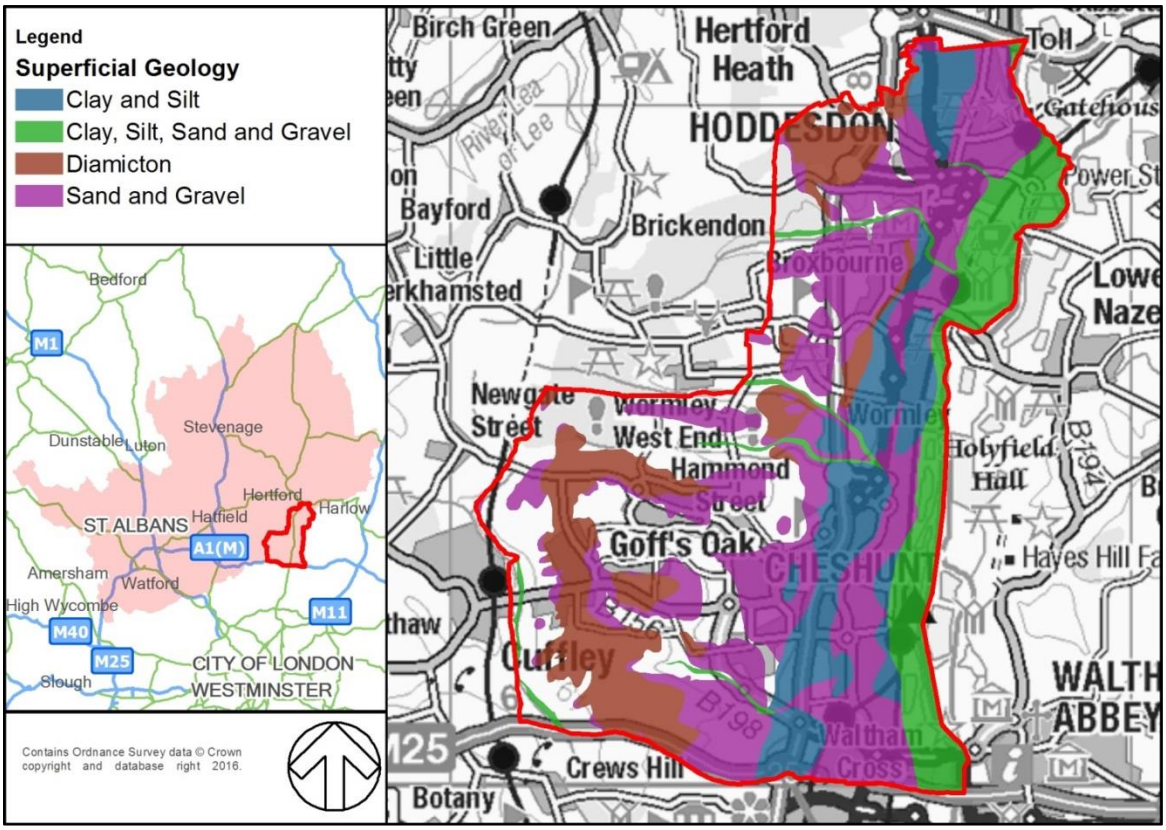


Figure 5: British Geological Survey Map of the Borough of Broxbourne – Superficial Deposits

2.3 SURFACE WATER MANAGEMENT PLANS (SWMP)

A Surface Water Management Plan (SWMP) is a plan which outlines the preferred surface water management strategy in a given location. In this context, surface water flooding describes flooding from sewers, drains, groundwater, and runoff from land, small watercourses and ditches that occur as a result of heavy rainfall. It does not include river (fluvial) flooding except to the extent that river levels impact on surface water flooding.

The study is undertaken in consultation with key stakeholders who are responsible for surface water management and drainage in their area. All parties should work together to understand the causes and effects of surface water flooding and agree the most cost effective processes of managing surface water flood risk for the long term. The process of working together is designed to encourage the development of innovative solutions and practices as well as identifying funding streams to assist in the delivery of the outcomes of the SWMP.

2.4 STAGES OF A SWMP

There are four phases to be completed in order to undertake a SWMP study as illustrated in Figure 6.

The Defra Surface Water Management Plan Technical Guidance (March 2010) sets out a description of the four stages as follows[4]:

- **Preparation** – The first phase of a SWMP study focuses on preparing and scoping the requirements of the study. Once the need for a SWMP study has been identified the LLFA and the key stakeholders should identify how they will work together to deliver the SWMP

[4] Page xvi, Paragraphs i29 to i32.

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, identify any mitigation measures (which could be easily implemented and do not require a large assessment), and scope out any requirements for detailed assessments. 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.

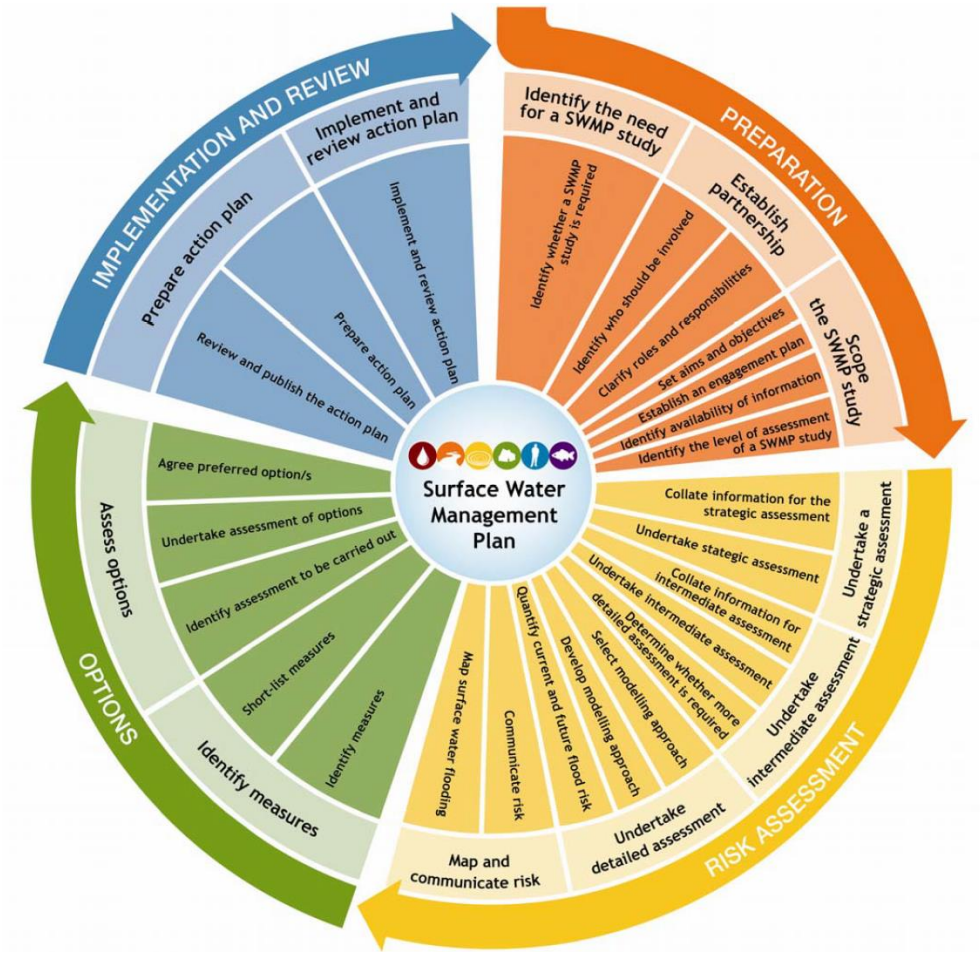


Figure 6: Different Stages of a SWMP study

The Local Flood Risk Management Strategy (LFRMS) for Hertfordshire 2013 – 2016 (published February 2013) identified the need for district scale SWMPs. A strong partnership has already been developed to implement aspects of the Flood and Water Management Act 2010, as well as deliver the St Albans and Watford SWMP update (February 2015), undertaken by WSP | Parsons Brinckerhoff. Given the work undertaken across Hertfordshire to date, it was deemed suitable to combine the Strategic and Intermediate Assessments of the Risk Assessment Phase.

3 WIDER POLICY AND LEGISLATIVE CONTEXT

3.1 POLICY AND LEGISLATIVE HISTORY

There has been a sequence of legislative and policy frameworks which cover flood risk developed by central government over the course of the last 15 years. The following information details a chronology of when this policy was developed, published and the main changes it brought about.

→ Land Drainage Act (1991)

The Land Drainage Act brought together legislation relating to IDB's and local authorities previously in the Land Drainage Act 1976 concerning inland and sea defence matters. This was amended by the Land Drainage Act 1994 and the key elements are duties on the enhancement of the environment, restoration and improvement of ditches, provision of funding and compulsory purchase of land.

→ Planning Policy Guidance Note 25 (PPG25): Development and Flood Risk (2001)

PPG25 set out the government's guidance to local authorities and others on planning policy associated with flood risk. This document was replaced in 2006 by the introduction of PPS25.

→ Planning Policy Statement 25 (PPS25): Development and Flood Risk (2006)

PPS25 set out the government's policy on development and flood risk following a review of the PPG25 document. Its aim was to ensure that flood risk was taken into account at all stages in the planning process to avoid inappropriate development. Key methodologies promoted within the document were as follows:

- Defining four Flood Zones for fluvial or coastal flooding based on the Annual Exceedance Probability (AEP) of an event occurring.
- Requiring the preparation of Regional Flood Risk Appraisals (RFRAs) or Strategic Flood Risk Assessments (SFRAs).
- Development of the Sequential and Exception Tests which guides development away from areas most at risk of flooding; only permitting development in flood risk areas where it is appropriate.

→ A Practice Guide was issued in 2008 and offers guidance on how to implement the policies within PPS25.

In PPS25 SWMPs were referred to as tools to manage surface water flood risk on a local basis by improving and optimising coordination between relevant stakeholders. The guidance issued alongside PPS25 advised that planners at the strategic and development control levels should use SWMPs to inform their Core Strategy documents, such as the SFRA. The core strategy policies would have the SWMP as evidence to support any policies on flooding and surface water drainage. This document was superseded in 2012 when it was incorporated into the National Planning Policy Framework (NPPF).

→ The Pitt Review: Learning Lessons from the 2007 Floods (2008)

The Pitt Review was undertaken following the summer 2007 flooding and looked at the causes and response to the flood events across the UK. The review found inadequacies in terms of who was responsible for different types of flood risk and how that flood risk was communicated to emergency services and the wider community when required. The review made 92 recommendations, particularly aimed at driving closer collaboration between government agencies and improved information on where there is risk of flooding.

Recommendation 18 of the Pitt Review states that Surface Water Management Plans (SWMPs) "should provide the basis for managing all local flood risk. SWMPs will build on or

inform Strategic Flood Risk Assessments (SFRAs) and provide the vehicle for local organisations to develop a shared understanding of local flood risk, including setting out priorities for action, maintenance needs and links into local development frameworks and emergency plans."

- Flood Risk Regulations (FRR) (2009)

  The Flood Risk Regulations (FRR) transposed the EU Floods Directive into law in England and Wales. Under the FRR the Environment Agency (EA) and Lead Local Flood Authorities (LLFAs) had to prepare preliminary flood risk assessments (PFRAs). Completed by LLFAs, these PFRAs are published by the Environment Agency. There is also a duty on LLFAs with an agreed Flood Risk Area to publish flood hazard and flood risk maps for all sources of flooding and flood risk management plans. These flood risk management plans should set objectives for flood risk management and outline measures for achieving these objectives.

- Flood and Water Management Act (FWMA) (2010)

  The FWMA (2010) was first proposed as the legislative vehicle to implement the European Floods Directive, however due to delays in the bill, it was not implemented within the timeframe set out by the Floods Directive, hence the FRRs implemented the Floods Directive and the FWMA was delayed until 2010.

  The FWMA provided the legislative basis for a number of recommendations in the Pitt Review. In October 2010, Section 9 of the FWMA came into force requiring all LLFAs in England to develop, maintain, review, update as well as apply and monitor the application of a strategy for local flood risk in their area. This is known as a Local Flood Risk Management Strategy (LFRMS).

- National Planning Policy Framework (NPPF) (2012)

  The NPPF was published in 2012 and simplified all the disparate Planning Policy Statements into one coherent framework to underpin the planning system. PPS25 was updated and included in the NPPF in *Section 10: Meeting the challenge of climate change, flooding and coastal change.*

  Planning Practice Guidance was published alongside the NPPF and the section of the Guidance for flood risk provides additional details on the approach for strategic level studies. The NPPF does reiterate the importance of the Strategic Flood Risk Assessment (SFRA) in setting local planning policy.

  NPPF does not explicitly mention SWMPs but highlights the importance of assessing flood risk from all sources including surface water. A SWMP can be undertaken either proactively to inform future SFRAs or reactively as a result of an SFRA study.

  On 24th March 2015, the Government laid a statutory instrument making the Lead Local Flood Authority a statutory consultee in planning for all major development in relation to the management of surface water drainage from 15th April 2015. The NPPF and associated Planning Practice Guidance were updated to reflect these changes.

3.2 LEAD LOCAL FLOOD AUTHORITY (LLFA)

Hertfordshire County Council, as the Lead Local Flood Authority for Hertfordshire, has the role of managing flood risk from surface water and groundwater and is a statutory consultee in planning for all major development in relation to the management of surface water drainage.

As LLFA the county council has a range of duties which includes:

- Preparing reports and plans to meet the requirements of the Flood Risk Regulations 2009 (FRR).
- Carrying out investigations of flooding where appropriate and publishing reports.
- Keeping a public register and associated record of structures and features which have a significant effect on local flood risk.

- Designation of structures and features where appropriate.
- Regulation of Ordinary watercourses outside of areas covered by Internal Drainage Boards (IDBs).

In accordance with the Flood and Water Management Act (2010), LLFAs are required to co-ordinate and lead local flood risk management activities by preparing and implementing a Local Flood Risk Management Strategy (LFRMS). HCC has already prepared a Local Flood Risk Management Strategy, and is currently progressing through 10 district/borough based Surface Water Management Plans (SWMPs) throughout Hertfordshire, to gain a better understanding of local flood risk and the priorities for management.

3.3 OTHER PLANNING POLICIES

This section details the different sources of information available to help inform the production of the SWMP and a summary on the content of each planning policy document is detailed further in this section. An overview of the interaction of the documents is provided in Figure 7.

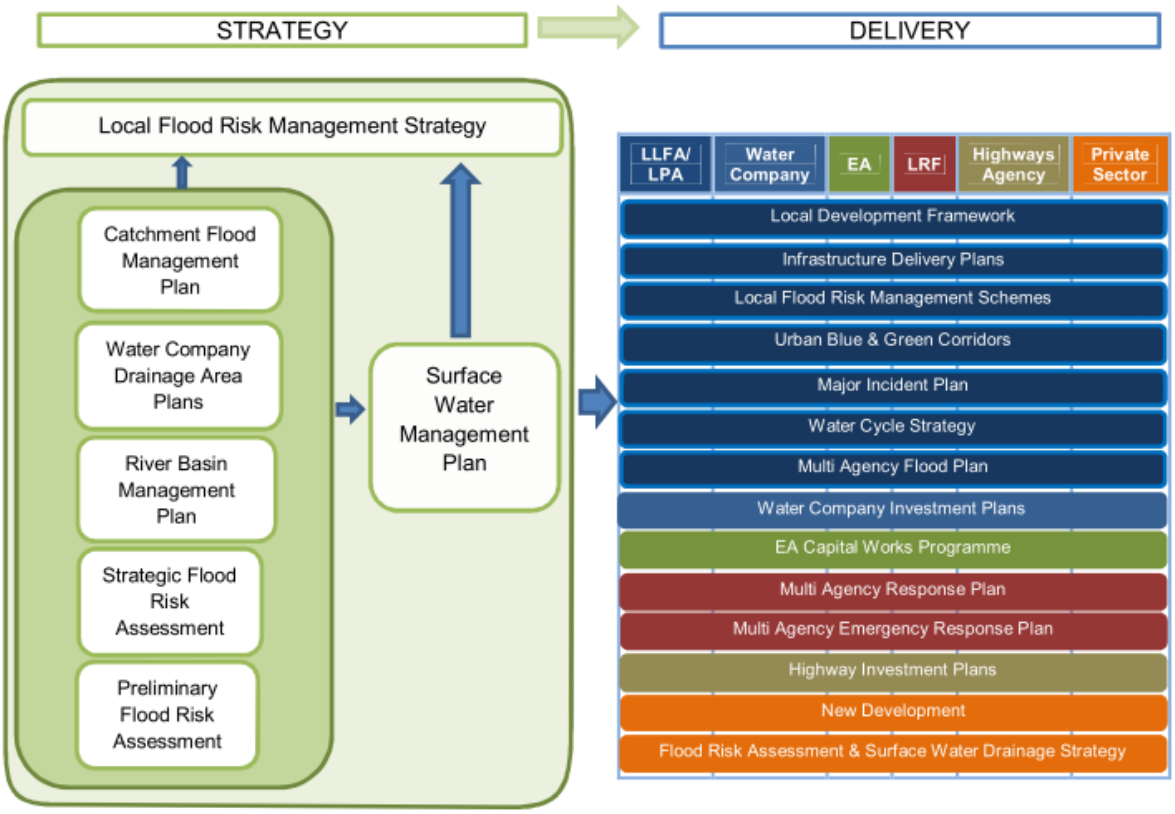


Figure 7: Link between Surface Water Management Plans and other Strategies, Plans and Policies

STRATEGIC FLOOD RISK ASSESSMENTS (SFRA)

The Planning Practice Guidance states the following with regards to Strategic Flood Risk Assessments[5]:

"A Strategic Flood Risk Assessment (SFRA) is a study carried out by one or more local planning authorities to assess the risk to an area from flooding from all sources, now and in the future, taking account of the impacts of climate change, and to assess the impact that land use changes and development in the area will have on flood risk.

The Strategic Flood Risk Assessment will be used to refine information on river and sea flooding risk shown on the Environment Agency's Flood Map for Planning (Rivers and Seas). Local planning authorities should use the Assessment to:

- *Determine the variations in risk from all sources of flooding across their areas, and also the risks to and from surrounding areas in the same flood catchment;*
- *Inform the sustainability appraisal of the Local Plan, so that flood risk is fully taken into account when considering allocation options and in the preparation of plan policies, including policies for flood risk management to ensure that flood risk is not increased;*
- *Apply the Sequential Test and, where necessary, the Exception Test when determining land use allocations;*
- *Identify the requirements for site-specific flood risk assessments in particular locations, including those at risk from sources other than river and sea flooding;*
- *Determine the acceptability of flood risk in relation to emergency planning capability;*
- *Consider opportunities to reduce flood risk to existing communities and developments through better management of surface water, provision for conveyance and of storage for flood water."*

Each Local Planning Authority (LPA) area in Hertfordshire is covered by an SFRA which was produced in 2007-2008. A number have been supplemented with further assessment.

CATCHMENT FLOOD MANAGEMENT PLANS (CFMP)

Catchment Flood Management Plans (CFMPs) are key strategic documents that outline future flood risk management policies on a catchment by catchment basis. The Borough of Broxbourne lies almost entirely within the River Thames CFMP.

CFMPs give an overview of the flood risk across each river catchment. They recommend options for managing those risks at present and over the future 50 – 100 years. CFMPs have been prepared in partnership with regional and local planning authorities, community environmental groups and other stakeholders.

CFMPs consider all types of inland flooding, from rivers, groundwater, surface water and tidal flooding, but not coastal flooding, which is covered in Shoreline Management Plans. They also take into account the likely impacts of climate change, the effects of how we use and manage the land, and how areas could be developed to meet our present day needs without compromising the ability of future generations to meet their own needs.

Figure 8 demonstrates that the Borough of Broxbourne falls entirely within the extents of the River Thames CFMP and Thames RBMP.

[5] http://planningguidance.communities.gov.uk/blog/guidance/flood-risk-and-coastal-change/strategic-flood-risk-assessment/

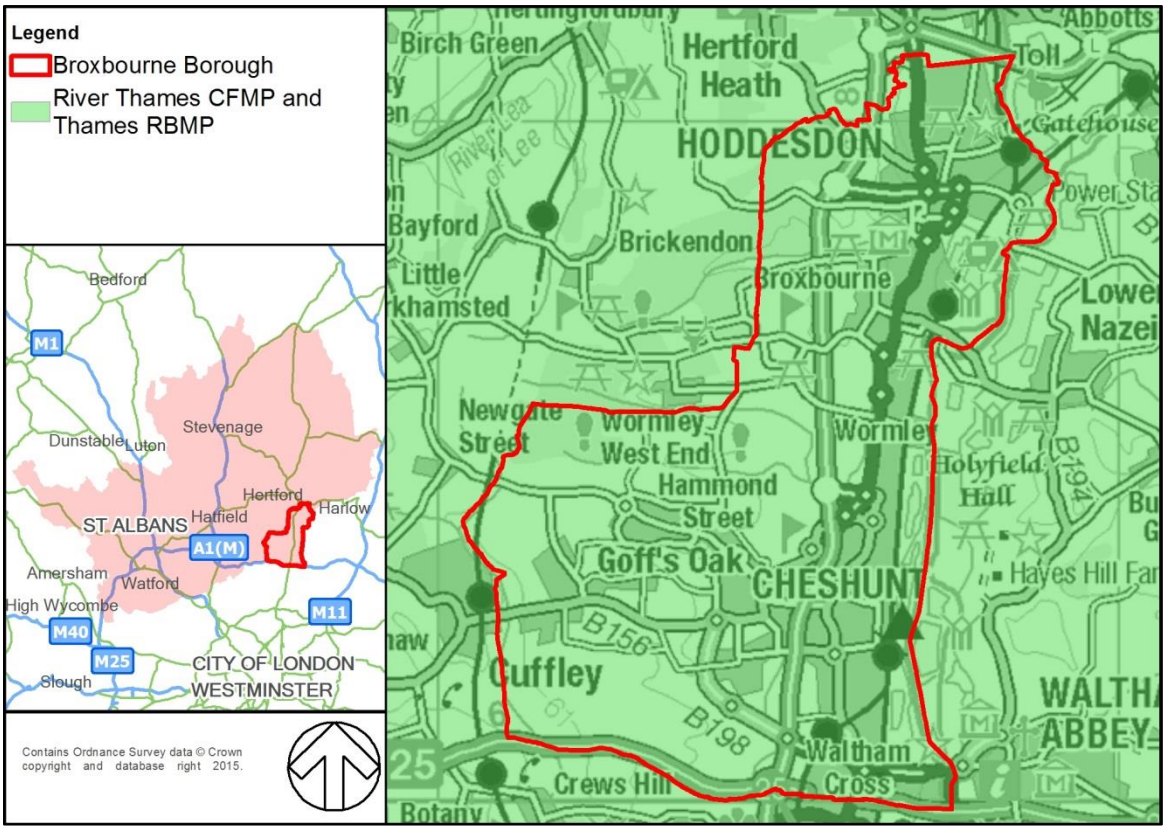


Figure 8: Environment Agency CFMP Areas and RBMP Areas covered within the Borough of Broxbourne

WATER FRAMEWORK DIRECTIVE (WFD)

The Water Framework Directive was introduced in December 2000 and became UK law in December 2003. The directive focuses on improving the ecology of our water ecosystems and aims to protect and enhance the quality of surface water, groundwater, estuaries and coastal waters. The Environment Agency is the lead authority responsible for the delivery of these targets, but must work closely with Lead Local Flood Authorities (LLFAs), in this instance Hertfordshire County Council, to ensure that targets are achieved.

RIVER BASIN MANAGEMENT PLANS (RBMP)

The Borough of Broxbourne lies wholly within the Thames River Basin Management Plan area. Figure 8 shows the RBMP and CFMP areas within the Borough of Broxbourne. The following is quoted from the plan covering 2009-2015[6].

“This plan focuses on the protection, improvement and sustainable use of the water environment. Many organisations and individuals help to protect and improve the water environment for the benefit of people and wildlife. River Basin Management is the approach the Environment Agency is using to ensure our combined efforts achieve the improvement needed in the Thames River Basin District.

This plan has been prepared under the Water Framework Directive, which requires all countries throughout the European Union to manage the water environment to consistent standards. Each country has to:

[6] https://www.gov.uk/government/publications/thames-river-basin-management-plan

- *Prevent deterioration in the status of aquatic ecosystems, protect them and improve the ecological condition of waters;*
- *Aim to achieve at least good status for all water bodies by 2015. Where this is not possible and subject to the criteria set out in the Directive, aim to achieve good status by 2021 or 2027;*
- *Meet the requirements of the WFD protected areas;*
- *Promote sustainable use of water as a natural resource;*
- *Conserve habitats and species that depend directly on water;*
- *Progressively reduce the pollution of groundwater and prevent or limit the entry of pollutants;*
- *Contribute to mitigating the effects of floods and droughts."*

WATER CYCLE STUDY / STRATEGY (WCS)

A Water Cycle Study identifies the potential conflict between growth proposals and environmental requirements and identifies feasible solutions to addressing them. Effective planning and close cooperation between all parties involved is essential to the success of a water cycle study.

The WCS provides the evidence base for setting out allocations, phasing of development, potential developer contributions and further guidance. Since all organisations work in partnership to carry out the WCS, each partner is more likely to be committed to delivering the resulting WCS.

The effect of development on the water environment forms a key part of the Sustainability Appraisal (SA) and Strategic Environmental Assessment (SEA), required under the Local Plan process. As part of the Local Plan a WCS will give planning authorities a robust evidence base to assess this. It identifies and assesses risk, investigates all the options and issues and helps decide which option(s) will best support the Local Plan and related policies.

The WCS helps to plan for water more sustainably by:

- Bringing together all partners and stakeholders existing knowledge, understanding and skills;
- Bringing together all water and planning evidence under a single framework;
- Understanding the environmental and physical constraints to development;
- Working alongside green infrastructure planning to identify opportunities for more sustainable planning, and;
- Identifying water cycle planning policies and a water cycle strategy to help all parties plan for a sustainable future water environment.

The Rye Meads Water Cycle Strategy (WCS) (2009) covers parts of the Borough of Broxbourne including the Hoddesdon area. This WCS is part of the Local Authorities' evidence base for their Local Plans, and sets out the water and wastewater infrastructure, amongst other measures, that will need to be in place to achieve their growth targets. Figure 9 shows the Water Cycle Study area the Borough of Broxbourne was part of.

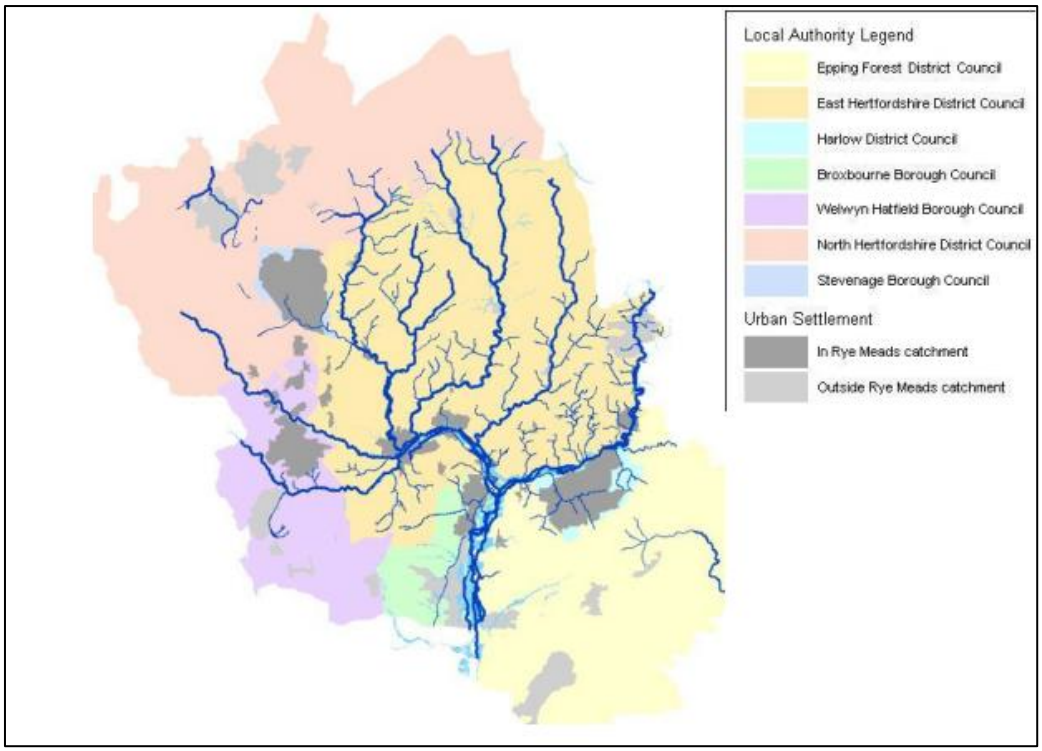


Figure 9: Rye Meads Water Cycle Strategy Study Area

(Source: Rye Meads Water Cycle Strategy - Detailed Study Report, Hyder Consulting (UK), October 2009, page 11)

LOCAL FLOOD RISK MANAGEMENT STRATEGY (LFRMS)

In October 2010 Section 9 of the Flood and Water Management Act (FWMA) 2010 came into force. This element of the FWMA required all Lead Local Flood Authorities (LLFAs) in England to develop, maintain, review, update as well as apply, and monitor the application of a strategy for local flood risk in their area. The overarching aim of the Local Flood Risk Management Strategy is to provide a robust local framework that employs a full range of complementary approaches towards managing and communicating the risks and consequences of flooding arising from surface runoff, groundwater and Ordinary watercourses in Hertfordshire and the surrounding areas.

The objectives in the first LFRMS, by which the county council will achieve this vision are set out below; actions and measures that have been developed to achieve these objectives are set out in Section E7 of the first Hertfordshire LFRMS.

- **Studies, assessments and plans** – Developing a greater understanding of local flood risk in Hertfordshire will be critical to deploying the most effective measures for managing the risk and making the best use of limited resources.
- **Information-sharing protocols** – This function will be developed to understand what data is needed for, what information is available, what information is missing and how information will be shared. The data will help define 'locally significant' flood risk and set criteria for when the LLFA will investigate a flooding incident.
- **Development control** – (The policy context for this area of the LFRMS has recently changed. National Planning Practice Guidance has superseded previous guidance. The Lead Local Flood Authority is identified as a statutory consultee on surface water drainage arrangements for all major development). An improving information base about local sources of flooding will help inform the determination of development proposals and support the Strategic Flood Risk Assessments produced by the local planning authorities.

- **Sustainable Drainage Systems (SuDS) –** The CIRIA SuDS Manual (C753) set out how "Sustainable drainage systems (SuDS) are designed to maximise the opportunities and benefits we obtain from surface water management. SuDS can deliver four main benefits by improving the way we manage water quantity, water quality, amenity and biodiversity"[1] It was anticipated that Hertfordshire County Council would become the SuDS Approving Body (SAB) after enactment of Schedule 3 of the Flood and Water Management Act. Following Defra consultation, Schedule 3 will not be enacted and instead HCC in their role as LLFA will become the statutory consultee on planning applications for major developments with surface water drainage (DMPO 2015)[7].
- **Raising awareness** – Individuals and communities should understand that there will always be a degree of flood risk and the role that they can play in the local management of that risk. Raising awareness will be a critical aspect of the Strategy.
- **Resilience** – The Strategy will explore ways in which flood risk can be reduced through individuals and communities increasing their own resilience.
- **Investment and funding** – The Strategy will look at the development of priorities for investment and at the same time explore opportunities for funding.

Hertfordshire County Council (HCC) has prepared their Local Flood Risk Management Strategy (LFRMS), which is consistent with the national strategy. The Local Flood Risk Management Strategy for Hertfordshire 2013-2016 was published in February 2013), this has identified the following:

- The risk management authorities in the LLFA area and what flood risk management functions they may exercise in relation to the area.
- The objectives for managing local flood risk. These are relevant to the circumstances of the local area.
- The measures proposed to achieve objectives.
- How and when the measures are expected to be implemented. In some instances this could be linked to the Flood Risk Regulations outputs – The Preliminary Flood Risk Assessment.
- The costs and benefits of those measures and how they are to be paid for.
- The assessment of local risk for the purpose of the strategy. HCC as the LLFA have used the information from previous studies to identify the risk and identify gaps in understanding the local flood risk and specify what actions need to be taken to close these gaps (i.e. completion of this SWMP).
- How and when the strategy is to be reviewed.
- How the strategy contributes to the achievement of wider environmental objectives.

[1] The SUDS Manual –C753 (2015) CIRIA
7 http://www.legislation.gov.uk/uksi/2015/595/made

4 PREPARATION

4.1 IDENTIFY THE NEED FOR A SWMP

Action 8.2.4 of the LFRMS 2013 – 2016 is "Develop Surface Water Management Plans based on the boundaries of the 10 district authorities." This SWMP for the Borough of Broxbourne is a realisation of Action 8.2.4.

4.2 ESTABLISH PARTNERSHIP

A SWMP is a framework through which key stakeholders with responsibility for surface water and drainage in their area, work together to understand the causes of surface water flooding and agree the most cost effective way of managing surface water flood risk.

Under the legislative framework, involvement in a SWMP by all stakeholders is voluntary. The Flood and Water Management Act 2010 requires Lead Local Flood Authorities (LLFA) to take the lead role for flood risk management and have a coordination role amongst the other stakeholders, in the development of SWMPs.

The Borough of Broxbourne SWMP was produced in consultation with:

- Hertfordshire County Council;
- Broxbourne Borough Council;
- Thames Water;
- The Environment Agency.

As part of the Strategic Assessment, consultation has been undertaken with a number of stakeholders to obtain historical flooding information. As the SWMP progresses, other stakeholders will be invited to provide additional information.

In addition, parish councils were contacted to inform stakeholders on any flooding issues which they wish to be taken into consideration as part of the hotspot selection.

The project aims to build upon the successful working platform between all bodies responsible for drainage and emergency response and ensure that this will continue after the SWMP is complete. Project meetings (at appropriate times) with the key stakeholders will ensure actions are executed and that any new issues are discussed and reviewed. This is subject to an agreement between all stakeholders and availability of resources.

4.3 SCOPING THE SWMP STUDY

The key objectives of the SWMP are:

- → To continue and enhance the successful working relationship between all stakeholders and to provide a future framework for this forum;
- → Enhance the understanding of local flood risk across the Borough of Broxbourne;
- → Establish the areas at significant risk[8] of flooding and the potential impacts;

[8] In accordance with the NPPF, all areas at risk of flooding are considered. However, weightings are applied to the analysis based on the mechanism of flooding and the annual probability of occurrence. This is done to guide the SWMP to areas most at risk of surface water flooding. Further information can be found within the Hotspot Selection Technical Note.

- Aid in understanding the mechanism of flooding. It may be that while local knowledge suggests one singular cause, there may be multiple factors with interconnectivity between sources;
- Identify various mitigation options (taking into account both the current and future situations, including the impacts of climate change) and prioritise the options;
- Develop an Action Plan to reduce the flood risk within the Borough of Broxbourne.

4.4 POLICY DOCUMENTS REVIEWED

As part of the review of the available information, an assessment was undertaken of the link between the SWMP and other flood related plans and policy.

During the preparation of this Surface Water Management Plan, the following national and local policy documents were referred to:

- The Pitt Review, 2008;
- Water Framework Directive (WFD), 2003;
- Flood Risk Regulations, 2009;
- Flood and Water Management Act (FWMA), 2010;
- National Planning Policy Framework (NPPF), 2012;
- Broxbourne Level 1 Strategic Flood Risk Assessment, December 2007
  - A new Level 1 Strategic Flood Risk Assessment was carried out on behalf of Broxbourne Borough Council, by JBA Consulting and the Final report published in May 2016;
  - The Level 2 Strategic Flood Risk Assessment was completed in 2017;
- Broxbourne Borough Council, St Albans City and District Council, Three Rivers District Council, Watford Borough Council, Welwyn Hatfield Borough Council Water Cycle Study, Scoping study, Final report (WCS), April 2010;
- Thames River Basin Management Plan (RBMP), 2009;
- River Thames Catchment Flood Management Plan (CFMP), December 2009;
- Hertfordshire Preliminary Flood Risk Assessment (PFRA), August 2011;
- Local Flood Risk Management Strategy (LFRMS) for Hertfordshire, February 2013;

The Surface Water Management Plan (SWMP) will be a living document that needs to be reviewed as part of the LFRMS update cycle. This will ensure the implications of the agreed actions and new issues are addressed. However, a review may be required following any future surface water flood events, new data becoming available, new modelling data techniques becoming available or any changes in policy within the catchment.

4.5 COLLATING AVAILABLE INFORMATION

During the preparation stage of the SWMP, consideration was also given to the availability of information and the appropriate sources of this information. This included an assessment of which data could be provided by each stakeholder and the format in which the information can be provided.

A review of all the data received was undertaken as part of the Strategic Assessment.

In addition to an assessment of the historical flooding experienced within the Broxbourne Borough SWMP study area, analysis was also undertaken utilising the following datasets from the Environment Agency (EA):

- Risk of Flooding from Surface Water Maps (the third generation of surface water flood maps);
- Flood Map for Planning;
- Locations of Main Rivers and defences;
- National Receptor Database (information on properties at risk of flooding);
- Areas Susceptible to Groundwater Flooding (AStGWF) Map.

Consideration has also been given to the following data, as well as the reports detailed in earlier sections:

- Broxbourne Strategic Flood Risk Assessment, December 2007;
- Ordnance Survey Data, MasterMap Topography and Integrated Transport Layers;

A Geographic Information System (GIS) was used to collate the available information, including the extents/locations of historical flooding.

4.6 QUALITY, LIMITATIONS AND RESTRICTIONS

Hertfordshire County Council have mechanisms in place to record reported incidents of flooding, this information has been used to inform the study along with the information detailed within other studies, such as the PFRA to provide an assessment of all recorded historical flooding within the study area.

Some of the data collated as part of the SWMP is subject to licensing restrictions. These restrictions include the level of detail that the SWMP is able to make publically available. For instance, the findings of the SWMP are based upon detailed site specific flooding information which cannot always be shown in publically available maps. In some instances assumptions were required and the resulting SWMP should be treated as a ‘living document’ with regular updates in line with improvements in collated data.

The data that has been collated as part of the Strategic Assessment, has come from a number of sources and in some cases is licensed to Hertfordshire County Council for the purposes of preparing this SWMP for the Borough of Broxbourne.

The level of assessment for the Strategic and Intermediate Assessments that was agreed with Hertfordshire County Council was an over-arching assessment, based upon the LFRMS and other recent studies, to cover the flood risk across the whole borough. This identifies the hotspot areas for detailed assessment, which may include hydraulic modelling.

5 STRATEGIC AND INTERMEDIATE RISK ASSESSMENT

5.1 INTRODUCTION

The principle purpose of the Strategic Assessment is to identify broad locations, which are considered vulnerable to surface water flooding. This is undertaken on a coarse spatial scale and therefore provides a simplified assessment using the best information available, starting with a review of the historical events.

The purpose of the Intermediate Assessment is to identify the nature and sources of the flooding, and the frequency and severity of flooding. This improved understanding is then used to identify flood hotspots and begin to identify mitigation measures to reduce surface water flooding.

As there have been several completed assessments that cover Hertfordshire (e.g. the Hertfordshire LFRMS and the Hertfordshire PFRA), it was determined that the Strategic and Intermediate Assessments should be combined.

This phase of the assessment considers flooding from surface water runoff, Ordinary watercourses, sewers, canals and groundwater. This assessment also takes into consideration the interaction of these sources with Main Rivers and their associated tributaries in order to identify areas most at risk of surface water flooding.

In the context of this report, surface water flooding includes the following (as defined in the Key Definitions section):

- Surface water runoff; runoff before it enters the underground drainage network or watercourse, or cannot enter it because the network is full to capacity;
- Flooding from groundwater;
- Sewer flooding; flooding which occurs when the capacity of underground systems is exceeded due to heavy rainfall;
- Flooding from open-channel and culverted watercourses;
- Overland flows from the urban/rural fringe entering the built-up area; and
- Overland flows resulting from groundwater sources.

The following information has been used for this phase of the assessment:

- Historic flooding records;
- Environment Agency's Risk of Flooding from Surface Water maps (sometimes referred to as the updated Flood Map for Surface Water, uFMfSW);
- Environment Agency's Areas Susceptible to Groundwater Flooding (AStGWF);
- Broxbourne Level 1 Strategic Flood Risk Assessment, December 2007 (the new SFRA completed in May 2016 was not consulted in this assessment);
- Local Flood Risk Management Strategy (LFRMS) for Hertfordshire (2013);
- Environment Agency's Flood Maps for Planning.

5.2 FLOODING HISTORY

HISTORIC FLOOD RECORDS

A review of the reported and recorded historical events experienced within the Borough of Broxbourne was undertaken however, it does not constitute a comprehensive assessment of all flood risk. Historical data cannot identify all locations at risk of flooding; it is possible that areas that have experienced flooding are not represented in this assessment as not all occurrences may be reported or recorded.

FLUVIAL FLOODING

The Broxbourne Level 1 SFRA details fluvial flood incidences in the Borough of Broxbourne in Table 1. There have been a large number of recorded incidences within the watercourses within the Borough of Broxbourne.

Table 1: Broxbourne SFRA (Level 1, 2007)

RIVER	YEAR
Lee/Lea	1947; 1987; 1993; 2000;
Rags Brook	1974; 1978; 1979; 1982; 1988; 1990; 1993;
Spital Brook	1978; 1979; 1983; 1987; 1990;
Theobalds Brook	1979; 1987;
Theobalds Lane/Trinity Marsh Ditch	1947; 1968; 1974; 1979; 1982; 1983; 2000;
Trinity Marsh Ditch	1974; 1979; 1982;
Turkey Brook	1974; 1978; 1987; 1990; 1993; 2000; 2001;
Turnford Brook	1947; 1974; 1979; 1993;
Woollens Brook	1993

The SFRA discusses a number of reasons to cause fluvial flooding. A number of rivers within the borough are culverted beneath urban areas and many have limited capacity to deal with the quick flash flooding typical of a highly urbanised catchment such as the Borough of Broxbourne.

Also through development in the borough, there has been a tendency to realign channels to a straighter course thereby increasing the velocity of flows. There has also been little consideration as to the rate of runoff from new developments into the watercourses.

Flooding was recorded on the 20th June 2015 on College Road, Cheshunt. The exact cause of this flooding is unknown however College Brook is culverted in this area, running in an easterly direction. Hence it is unknown whether flooding was caused by surface water runoff, capacity issues in the culvert, or a combination of both.

FLOOD RISK FROM CANALS

RIVER LEE NAVIGATION

The River Lee Navigation is located to the east of the borough in the River Lea Country Park and is a canalised watercourse alongside the River Lea. The canal is managed by the Canal and River Trust who is responsible for ensuring the water level within the channel is high enough to allow navigation. However, navigable sections of rivers can still be designated as Main Rivers which is the case with the River Lee Navigation. It is more responsive to changes in water level than a standard canal and as it is classed as Main River, it remains the responsibility of the Environment Agency for Flood Risk Management activities.

The River Lee Navigation begins at Hertford Castle Weir in Hertford and runs through East Hertfordshire. The canal forms the eastern boundary of the borough for its full length between the A414 to the north-east of Hoddesdon and the M25 to the east of Waltham Cross.

NEW RIVER

The New River is a water supply aqueduct managed and maintained by Thames Water. It is a key asset supplying around 180Ml/d (around 8%) of London's drinking water from the Lea River and natural springs around the Ware. The canal is regularly assessed and maintained due to its significance. Stretches of the canal are raised above ground level. Structural failure of any of the raised sections of the canal could lead to large localised flooding. Due to the monitoring and flow control along the canal it is assumed that surface water flood risk from rain events is low.

The New River starts at Ware, just north of Hertford and runs south to Stoke Newington. The canal enters the borough at Hoddesdon in the north western corner and leaves through Bullsmoor in the south.

SURFACE WATER FLOODING

Table 4-2 within the SFRA provides 23 surface water flood events within the Borough of Broxbourne however the dates of these events are not given. The majority of the events have a recorded consequence of "Flooding of the Road"; the causes of each event are documented, with a significant number caused by capacity issues in either culverts or sewers.

GROUNDWATER FLOODING

Five groundwater flooding events are recorded within the SFRA, however, as with surface water flooding events; the date of these events is unknown. Table 2 shows Table 4-3 of the SFRA.

Table 2: SFRA (2007) Table 4-3 Environment Agency records of groundwater flooding

LOCATION	CAUSE	CONSEQUENCE
Admirals Walk, Spital Brook	Groundwater table near surface	Ditch at end of garden filling up
Paddick Close, Rye Park	Gravel overlaying London Clay	Basement flooding
Hilltop Close, Hammond Street	Ponding in garden running from neighbours property	Garden flooding
Nazeing Road, Broxbourne	Garden has had shallow groundwater since 2001 and is continuously waterlogged	Garden flooding
Dig Dag Hill, Flamstead End	Edge of gravel formation on top of London clay – possible seepage	Verge/hill flooding

It should be noted from the data provided and following consultation with the key stakeholders, it is sometimes difficult to ascertain if a source of flooding is from groundwater only. This is because flood risk may be as a result of a combination of sources, or a culverted watercourse may have been mistaken for a spring or underground stream.

WATER COMPANIES FLOOD RISK REGISTER

The water company for the borough (Thames Water) has also been consulted to obtain the sewer flooding records from their flood risk register. This register lists the areas and properties which have previously experienced an internal or external sewer flooding incident caused by overloaded sewers or other causes (temporary problems) (whether foul, combined or surface water sewers).

Temporary problems such as blockages, siltation, sewer collapses and equipment or operational failures have been excluded from the register. An entry upon this register will not be removed until the problem has been solved. It should be recognised that reporting is not necessarily complete as some property owners do not report sewer flooding events. In addition, instances of surface water flooding in remote areas are unlikely to be reported.

The water companies supplied partial postcodes of places that have been subject to sewer flooding. The listing gives the number of properties which suffered internal flooding and the number of places subject to external flooding. External flooding includes highways, public open space, open land, parkland, as well as private gardens. As this information is in the form of partial postcodes it can be used to inform the assessments of historical flooding in hotspots, but is not appropriate to be shown on a map within this report.

5.3 AVAILABLE DATA

DATASETS

In recent years, the risk of flooding from non-fluvial sources has become better understood and information about the risk has become more informed. This information is now publicly available with further data held by stakeholders or commercially available; these datasets are:

- Areas Susceptible to Groundwater Flooding (greater than 75%);
- Risk of Surface Water Flooding Maps – 1 in 30, 1 in 100 and 1 in 1,000 year (this is sometimes known as the updated Flood Map for Surface Water, uFMfSW);
- Flood Map for Planning Flood Zones 2 and 3;
- Areas Benefitting from Defences.

AREAS SUSCEPTIBLE TO GROUNDWATER FLOODING (ASTGWF)

This is a strategic scale map showing groundwater flood areas on a 1km square grid. It was developed specifically by the Environment Agency for use by Lead Local Flood Authorities (LLFAs) to inform their Preliminary Flood Risk Assessments (PFRA). Greater than 75% refers to the percentage of the 1km square that has the potential for groundwater flooding.

RISK OF FLOODING FROM SURFACE WATER MAPS (SOMETIMES REFERRED TO AS THE UPDATED FLOOD MAP FOR SURFACE WATER, UFMFSW)

These maps are the third generation of surface water flooding maps produced by the Environment Agency. The earlier generations were “Areas Susceptible to Surface Water Flooding” and “Flood Map for Surface Water Flooding.” The Risk of Flooding from Surface Water maps are the most recently produced dataset developed by the Environment Agency. They represent the mechanisms that cause surface water flooding in the following ways[9]:

- Better ground and surface elevation data in many areas – using ‘local’ data;

[9] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/297432/LIT_8988_0bf634.pdf

- Drainage capacity – using a single ‘national’ figure of 12mm/hour;
- Infiltration now represented – using ‘national’ figures;
- Storm duration more representative – using a single ‘national’ figure;
- Buildings now included – using ‘local’ data;
- Different roughness figures for urban and rural now included – using ‘national’ figures.

It is considered that the latest map is the best available Hertfordshire-wide representation of potential surface water flood risk, using the Historic Flooding incidents as supporting evidence.

The Environment Agency has put in place an update cycle in conjunction with the LLFAs to ensure that these maps are based upon the latest available information.

FLOOD MAP FOR PLANNING

The Environment Agency Flood Map for Planning was previously the only available flood map for fluvial and coastal flooding. There are Flood Risk Maps available online; these are largely based upon the National Flood Risk Assessment undertaken by the Environment Agency. However, it was determined that for the purposes of this stage of the study, the Flood Map for Planning would be more suitable given, that it is largely based upon more detailed modelling and focuses on the Main River network. Assessment of flooding from Main Rivers is not within the scope of SWMP studies, yet any detailed modelling previously undertaken could be suitable for using as boundary conditions for any future modelling work undertaken as part of the Broxbourne Borough SWMP.

These maps show areas that could be affected by flooding from rivers or the sea. It does not show the effects of climate change, ignores the presence of flood defences and is divided into 3 main flood zones. Flood Zone 3 is land assessed as having a 1% (1 in 100 year) or greater annual probability of fluvial flooding. Flood Zone 2 shows land assessed as having between a 1% (1 in 100 year) and 0.1% (1 in 1,000 year) annual probability of fluvial flooding.

AREAS BENEFITTING FROM FLOOD DEFENCES (ABD)

The ABD maps highlights areas of land that may benefit from the presence of major defences during the 1% (1 in 100 year) annual probability of fluvial flood events. These are areas that would flood if the defence were not present, but may not flood because the defence is present.

PUBLISHED STUDIES

STRATEGIC FLOOD RISK ASSESSMENT (SFRA)

Flooding can result not only in costly damage to property, but can also pose a risk to life and livelihood. It is essential that future development is planned carefully, steering it away from areas that are most at risk from flooding, and ensuring that it does not exacerbate existing known flooding problems. The Strategic Flood Risk Assessment is the first step in this process, and it provides the building blocks upon which the council’s planning and development control decisions will be made.

PRELIMINARY FLOOD RISK ASSESSMENT (PFRA)

The Preliminary Flood Risk Assessment was published by Hertfordshire County Council (HCC), in June 2011 to meet their duties as Lead Local Flood Authority (LLFA) and the requirements of the Flood Risk Regulations 2009 (FRR 2009). The Flood Risk Regulations came into force in England and Wales in December 2009. The Regulations transposed the EC Floods Directive (2007/60/EC) on the assessment and management of flood risks across EU Member States into domestic law and now implements its provision.

The Preliminary Flood Risk Assessment represents the first stage of the requirements of the Regulations. The PFRA process is aimed at providing a high level overview of historical and future flood risk from local sources, including surface water, groundwater, Ordinary watercourses and canals. Flooding from the sewerage systems will also be included. Flooding associated with the sea, Main Rivers and reservoirs is the responsibility of the Environment Agency and does not need to be considered by the LLFA as part of the PFRA, unless it is considered that it may affect flooding from one of the sources listed above.

The PFRA is a high-level screening exercise and must therefore consider floods which have significant harmful consequences for human health, economic activity, the environment and cultural heritage. The PFRA identifies such areas and if they are considered to be nationally significant, as defined by Defra, they are highlighted as 'Flood Risk Areas'. Flood Risk Areas warrant further examination and management through the production of flood risk and flood hazard maps and flood risk management plans.

The methodology for identifying a Flood Risk Area involves the assessment of the national flood risk information, which was used to identify 1km grid squares where local flood risk is considered to be an issue. Thresholds for these squares are:

- Number of people at risk greater or equal to 200;
- Critical Services (i.e. schools, hospitals, fire and police stations, sewage treatment works) at risk greater or equal to 1;
- Non-residential properties at risk greater or equal to 20.

A Flood Risk Area is identified using the above set of criteria to form a cluster. Where more than 5 highlighted grid squares are touching a cluster is formed. If these clusters contain more than 30,000 people at risk, the cluster is identified as an indicative Flood Risk Area.

No Flood Risk Areas with a total population of greater than 30,000 people were identified within Hertfordshire. The three largest clusters identified were around Watford (11,946 people), Hemel Hempstead (5,655) and Stevenage (5,110), all outside of the Borough of Broxbourne.

HYDRAULIC MODELS

The SWMP will build upon previous flood investigations and other capacity assessments (e.g. hydraulic models to assess the surface water runoff, surface water sewer capacities and fluvial flooding). This will ensure consistency between all previous work and on-going assessments, while minimising any duplication and data collection requirements. It will also maximise the local knowledge, the number of sites that can be assessed and the potential to secure funds for future mitigation schemes.

5.4 AREAS IDENTIFIED AT SIGNIFICANT RISK OF FLOODING

The methodology used to select the hotspots is contained within the Hotspot Selection Technical Note, included in Appendix B of this report. The Summary section of the Hotspot Selection Technical Note is also presented here.

A Desk-Based analysis was conducted to assess the flood risk to receptors within the Borough of Broxbourne. From this, 19 hotspots were analysed using a GIS Multi-Criteria Analysis (MCA) to prioritise the hotspots most at risk of flooding within the Borough of Broxbourne.

A stakeholder meeting was held in spring 2015 to discuss the results of the analysis with relevant stakeholders and to allow stakeholders to share information and recommend further sites that should be analysed.

Site visits were conducted with Hertfordshire County Council in attendance following the Stakeholder meeting. The aim of the site visits was to assess hotspots on the ground and determine if the proposed solutions would be appropriate and cost-beneficial.

The initial top five Desk-Based Identified Hotspots, produced as a result of the Multi-Criteria Analysis (MCA) were:

- Hotspot 9 Rye House / North Hoddesdon
- Hotspot 55 Cozens Lane East, Wormley
- Hotspot 56 Broxbourne town
- Hotspot 50 Waltham Cross (south);
- Hotspot 52 Cheshunt

Following stakeholder engagement and site visits, three of the Desk-Based Identified Hotspots have been chosen to be progressed as SWMP Modelled Hotspots. It was decided that Hotspot 56 – Broxbourne town and Hotspot 50 –Waltham Cross (south) would not be taken forward for detailed modelling. These have been included here as SWMP Non-Modelled Hotspots. Two other hotspots as a result of site visits, further analysis and stakeholder input, have been chosen to be included as SWMP Modelled Hotspots. The final five SWMP Modelled Hotspots to be taken forward for further assessment and detailed hydraulic modelling are:

- Hotspot 9 Rye House / North Hoddesdon
- Hotspot 52 Cheshunt
- Hotspot 55 Cozens Lane East, Wormley
- Hotspot 62 Rosedale North – Flamstead End
- Hotspot 63 Rosedale South – Flamstead End

The hotspots detailed in Table 3 are not being considered further; however, recommendations and actions, detailed in Table 3, are included in the Action Plan as appropriate.

Table 3: Initial Recommendations and Actions for the Borough of Broxbourne – SWMP Non-Modelled Hotspots

HOTSPOT NUMBER	LOCATION	RECOMMENDATIONS AND ACTIONS
Hotspot 49	Crossbrook Street, Cheshunt	Investigation of any culverts under the railway. Increased maintenance of these culverts could reduce the flood risk in the area around Limes Road where existing flooding incidents have been reported.
Hotspot 50	Waltham Cross (south)	Ensure suitable highway drainage infrastructure is in place. Work with property owners to recommend PLP where appropriate.
Hotspot 56	Broxbourne town	Review exceedance routes for overland flows near to the New River, with the aim of avoiding areas of substantial ponding. Review maintenance regimes in the critical areas.
Hotspot 65	Longfield Lane, Cheshunt	Increased maintenance of the ditch running alongside Longfield Lane may alleviate some flood risk in the area.
Hotspot 69	Little Grove Avenue, Cheshunt	Possible inclusion of a cut-off drain to the west of Cony Close may reduce the flood risk to the residential area.
Hotspot 71	Greta Groves, Goff's Oak, Waltham Cross	HCC LLFA staff to undertake a site investigation to ensure that flowpaths exist through the residential area or recommend changes to divert water to a preferential flowpath. A review of the highway drainage should also be undertaken.
Additional Stakeholder Selection	Hell Wood	If any development in the Hell Wood area was to take place, it is recommended that this include some flood storage, with the aim to reduce the flood risk to the area around Thomas Rochford Way.

6 DETAILED RISK ASSESSMENT - APPROACH

6.1 INTRODUCTION

The intermediate assessment (Section 5) identified five hotspots for a detailed assessment of surface water flood risk through hydraulic modelling, although Rosedale North and South have been considered together. The Defra SWMP technical guidance suggests that hydraulic modelling must be outcome-focussed and improve the understanding of the surface water flood risk. The key components of the detailed assessment are shown in Table 4.[10]

Table 4: Key components of detailed assessment *(based on Table 6-1 in the Defra SWMP technical guidance)*

COMPONENT	DESCRIPTION
Purpose	To understand the causes, probability and consequences of surface water flooding in a greater level of detail, and to consider mitigation measures to reduce surface water flooding.
Scale	Hotspot level.
Inputs	Information from the intermediate assessment. Additional evidence collated from site visits, surveys or modelling. Local knowledge (Hertfordshire County Council/Broxbourne Borough Council/Environment Agency/Thames Water).
Process	Use of modelling approaches to assess surface water flood risk (where the conceptual equation is used: risk = probability x consequence).
Outputs	Understanding of 'annualised' surface water flood risk, both now and in the future. Understanding the benefits and costs of mitigation measures to reduce surface water flooding. Detailed mapping of baseline flood risk and flood hazard.
Benefits	Improved understanding of the probability and consequences of flooding. Detailed understanding of the flood risk will enable informed judgements to be made of the benefits and costs of potential mitigation measures. Assess benefits of mitigation measures (where a benefit is a reduction in damages due to surface water flooding). Justification for mitigation measures based on benefits and costs.

Each of the hotspots identified for further assessment within the intermediate phase are covered in turn below, with their specific considerations and modelling approach summarised. More specific and detailed information on the considerations, constraints and adopted approach can be found in the modelling methodology (Appendix C).

6.2 DATA COLLECTION

The hydraulic models were generally constructed utilising the data outlined below, the exact data/combinations are detailed in the hotspot specific modelling report (Appendix C):

TOPOGRAPHY

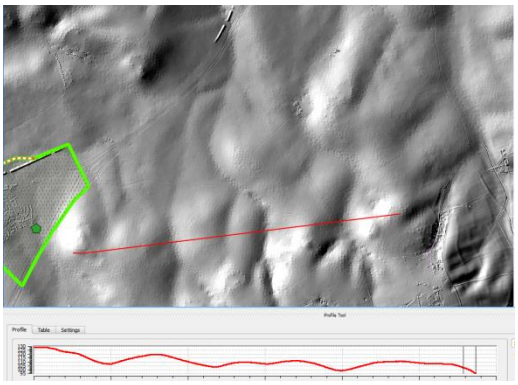
DTM

The Environment Agency provided a Digital Terrain Model (DTM) for all the hotspots, in some instances this was based upon LiDAR (which has a vertical accuracy of 5-15cm +/- RMSE and a horizontal accuracy of 40cm +/- RMSE), in others NEXTMap Height Data (which has a vertical accuracy of around 1m +/- RMSE and a horizontal accuracy of 2.5m +/- RMSE). In some

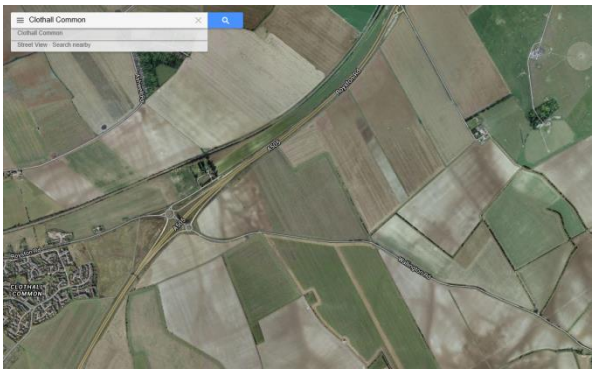
[10] Based on Table 6-1 in the Defra guidance, page 44 - https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69342/pb13546-swmp-guidance-100319.pdf

instances a combination of sources were used to construct the DTM, with preference given to the highest level of accuracy.

Prior to the commencement of the modelling, investigations were undertaken into ground truthing the DTM to ensure that any processing undertaken by others (e.g. the Environment Agency to construct their Risk of Flooding from Surface Water Maps) did not adversely impact the accuracy or level of resolution. These investigations established that the LiDAR part of the DTM was suitable for use across all hotspots where the data was available. However, questions were raised over the presence of small pit like features in some of the areas covered by the NEXTMap part of the DTM. One example of this is to the west of Clothall Common, Baldock, which is within North Hertfordshire District but the assessment was undertaken concurrently. At this location the features are observed to the east of the main hotspot, as shown in Figure 10, but are not visible in the aerial imagery or during site inspections. A representative area of the maximum flood depth of these pit like features was extracted in GIS and the volume within the raster extract calculated. The total area of the model domain with these features present was then estimated in comparison to the whole area. The volume of the extract was scaled up to cover the affected area and this was compared to the whole model domain volume. These calculations suggested less than 2% of the volume was present in the pit like features, and therefore these features can be considered insignificant with respect to the overall model accuracy, given that no other appropriate DTM was readily available.



a) DTM extract



b) Google Aerial Image

Figure 10: Example of uncertainties in the DTM

SURVEY

A topographical survey was specified for each hotspot to enable the DTM to be refined and key elements within the flowpath to be better represented within the model (these key elements can include walls, underpasses or road bridges etc. Topographical survey generally included road levels and kerb heights in specific locations, footpath levels and some property thresholds.

BELOW GROUND INFRASTRUCTURE

The hydraulic models required a representation of the culverted watercourses and public surface water drainage network, as these networks can be complicated to model and limited data is available for some aspects (particularly the connectivity aspects of the highway drainage). The following aspects were included to provide a suitable level of representation within the strategic scale models:

- Pipes equal to or greater than 225mm;
- Flow between the pipe network and the floodplain was represented by connectors at every pipe junction;

- Pipe information was sourced from the sewage undertaker (i.e. Thames Water);
- Where information was missing or considered to be incorrect, engineering judgement was used to estimate the pipe direction, location or gradient.

LAND USE

The locations of land use features across the study area were identified through the incorporation of Ordnance Survey MasterMap data and the National Receptor Database to combine location with the type of building. This enabled temporary/outbuildings etc. to be removed from the modelling (i.e. buildings which are unlikely to be barriers to flow) in accordance with best practise. The mapping also enable varying roughness coefficients to be applied, along with ensuring that preferential flowpaths (i.e. highways) were suitably represented, lowered by 125mm (the height of a standard kerb) and buildings raised by 300mm (a typical freeboard level). This is also in accordance with the updated Flood Map for Surface Water Modelling Guidance.

CONSIDERATIONS

Prior to and during the modelling process some elements were identified that required further consideration to ensure that they were suitably represented in the model. For instance at some hotspots there was a degree of uncertainty that could not be addressed through engineering judgement and modelling assumptions, these required further site specific investigations to establish linkages. These are detailed in each hotspot as applicable; these included a range of features, an example of which is Hotspot 30, Cambridge Road, Hitchin (North Hertfordshire District SWMP). In this hotspot, the sewer records were considered ambiguous when compared to the current land uses and the inferred discharge routes and mechanisms could no longer operate. To provide a suitable level of certainty for the modelling a separate investigation into the sewer connectivity was commissioned and undertaken by the surveyor.

6.3 MODEL APPROACH

All the modelled hotspots use a direct rainfall approach. An ESTRY-TUFLOW (hydraulic modelling software) approach was preferentially undertaken as this combines an accurate 1D channel and pipe solver (with the allowance for complicated structures) with a 2D floodplain model based on a finite grid approach. The two solvers are dynamically linked, such that water can flow from the channel/pipe to the floodplain, and vice-versa. In some instances it was necessary to use other software packages such as InfoWorks ICM or Flood Modeller Pro; this was largely dependent on previous studies.

Hydrological analysis was undertaken with reference to the Flood Estimation Handbook (FEH) and the Flood Estimation Guidelines[1] to produce flow estimates following best practice techniques.

More information is provided in the modelling methodology reports (Appendix C) and individual model reports.

The hydraulic modelling provides estimates of flood risk in terms of extent, depth, velocity and hazard. Flood hazard is defined by the Environment Agency's Flood Risks to People Guidance Document[11] as being a function of depth and velocity with a debris factor and breaks the resulting hazards into four categories:

- Very low hazard – Less than 0.75 – Caution;
- Danger for some – 0.75 to 1.25 – Includes children, the elderly and the infirm;
- Danger for most – 1.25 to 2.0 – Includes the general public;

[1] Published by the Environment Agency as Operational Instruction 197_08, Version 3 on 06/11/2009
[11] Defra/Environment Agency R&D Outputs: Flood Risks to People, Phase 2 FD2321/TR2

- Danger for all – More then 2.0 – Includes the emergency services.

6.4 MITIGATION OPTIONEERING

For each hotspot, a review of the flood extents and mechanisms was undertaken following completion of hydraulic modelling. From this review it was possible to determine the types of measures which could be implemented in each hotspot to mitigate the impacts and damage associated with flooding. At each hotspot several measures were identified and assessed as a first step in evaluating the various options to manage surface water flood risk in line with the SWMP objectives. The mitigation measures have not been modelled within the hydraulic models, given the strategic nature of this study. If the economic benefits are such that schemes are considered suitable for a funding application, detailed studies which will include further hydraulic modelling will be required,

The following categories of measures have been considered:

- Technical;
- Maintenance;
- Development, building control and policy;
- Awareness;
- Resilience;
- Other.

A measure is defined as a proposed individual action or procedure intended to minimise current and future surface water flood risk. An option (or options) is made up of a single, or a combination of defined measures.

The measures and options were discussed during meetings and site visits. Throughout this process the criteria in Table 5 were considered to ensure the options were feasible, viable and beneficial.

Table 5: Option Criteria

CRITERIA	DESCRIPTION
Technical	Is it technically possible and buildable? Will it be robust and reliable?
Economic	Is it affordable and will benefits exceed costs?
Social	Is the option socially acceptable and in keeping with the local area.
Environmental	Is the option environmentally acceptable and in keeping with the local area and designations.
Objectives	Will it help to achieve the objectives set at the beginning of the SWMP?

In addition to the criteria in Table 5, certain land uses (e.g. cemeteries) have been excluded as being unsuitable for flood storage. For any land or property considered for flood mitigation options, the ownership and operation of these will be assessed and documented as part of the feasibility for any future projects taken forward as a result of this SWMP.

6.5 ECONOMIC ASSESSMENT

INTRODUCTION

Economic analysis has been undertaken to assess the predicted economic damages that may occur from flooding in each hotspot. This economic analysis is based on the current arrangements for management of surface water, and the benefits that may accrue from the proposed mitigation options. This has been undertaken to a level of detail which is suitable to inform inclusion of potential schemes within the Environment Agency's Medium Term Plan (MTP). It will also enable the LLFA to establish the order of priority for further assessment and implementation of the mitigation options across all SWMPs in Hertfordshire. The inclusion of schemes within the Environment Agency's MTP is the first step towards securing funding, once a scheme is included, further studies are undertaken to refine the assumptions and demonstrate its financial viability.

METHODOLOGY

The financial viability of a flood defence scheme is assessed by looking at the *Benefit Cost Ratio* (BCR) between the present value benefits and the present value costs. The *present value benefits*, is the *present value damages* (the damages that are forecast to be incurred over the assessment period, in this instance 100 years) minus the reduced damages that would be realised with the scheme in place through the alleviation of flooding at events below the design threshold (standard of protection of the scheme). The *present value costs* are the costs associated with design and build along with maintenance of the scheme.

In all instances the present value is utilised as this provides a standardised approach for comparing the differing levels of investment that will be required to deliver and maintain the scheme, it also assumes that all the funding required for this is allocated at the approval stage of the scheme.

PRESENT VALUE DAMAGES

The calculation of economic damages from flooding has used the standard approaches and data of Flood and Costal Risk Management - A Manual for Economic Assessment (Flood Hazard Research Centre 2013)[12] and the 'Green Book' (HM Treasury, 2003)[13].

The properties shown by the hydraulic modelling to be within the main surface water flowpaths have been identified using OS MasterMap and the National Receptor Database. The economic analysis assessment area for each hotspot is shown in the study area plans included in Appendix F.

This assessment has taken into account and monetised the direct damages to properties, the costs of evacuation, the costs to the emergency services, damages to parked vehicles at residential properties and the impact of flooding on human health. Other damages that have not been monetised include disruption of road traffic, disruption to rail traffic, risk to life, damage to utilities/highway etc.

Damages have only been calculated for the flood risk associated with the main surface water flowpaths in each hotspot, for the mitigation specific standard of protection, which the SWMP will seek to address. Isolated flooding of properties within the hotspots outside of these areas have not been included as it is unlikely that any options proposed by the SWMP will be able to have any impact on reducing this type of flooding.

[12] https://www.mdx.ac.uk/our-research/centres/flood-hazard/projects/multi-coloured-manual
[13] https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent

Climate change has been incorporated into the assessment of damages to obtain present value damages that are expected to occur over the next 100 years. This has utilised the allowances for increases in peak rainfall intensity given by Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities (Environment Agency, 2016). This guidance gives a central and upper estimate of the expected change in peak rainfall intensity over the next 100 years. A conservative approach has been taken using the central estimate so that the economic damages from flooding are not overestimated.

PRESENT VALUE COSTS

Mitigation options were identified at a strategic scale for each hotspot and these are illustrated in the plans in Appendix E and discussed in the relevant parts of Section 6.4 above. The likely requirements and impacts of the options were identified utilising engineering judgement. This has mainly been to identify the return period for which a standard of protection can be achieved, the associated properties that are likely to be removed from the flood risk area and the possible engineering intervention. The costs for the selected mitigation options have been developed through the use of the Environment Agency's Long Term Costing Tool.

6.6 ECOLOGICAL VIABILITY

There are important designated sites (SSSI and SAC) along the River Lee corridor within and in close proximity to the Borough of Broxbourne. To ensure that the implementation phases of the SWMP will not lead to adverse impacts within these sites a Habitats Regulation Assessment (HRA) has been undertaken in conjunction with this study. This is provided in Appendix H and demonstrates that the SWMP will not lead to adverse impacts on the designated sites.

7 DETAILED RISK ASSESSMENT - INVESTIGATION

7.1 DEFINITIONS

The Environment Agency use a variety of terms when describing the flood risk in their Risk of Flooding from Surface Water Maps, for consistency these have been adopted here when describing the risk in the baseline information section for each of the hotspots, these are:

- Very Low – means that each year, this area has a chance of flooding of less than 1 in 1000 (0.1%);
- Low – means that each year, this area has a chance of flooding of between 1 in 1000 (0.1%) and 1 in 100 (1%);
- Medium – means that each year, this area has a chance of flooding of between 1 in 100 (1%) and 1 in 30 (3.3%);
- High - means that each year, this area has a chance of flooding of greater than 1 in 30 (3.3%).

7.2 MITIGATION CONSIDERATION

When determining whether the use of PLP is the most appropriate scheme for an individual hotspot, HCC will need to consider the following aspects:

- PLP have been used as a benchmark to determine the likely economic viability of interventions. This is based on the speed of implementation and that they will not require further investigations/ studies;
- Non PLP may perform better, and protect a wider area, but may be more complex due to the required engineering works as opposed to protecting individual or rows of properties;
- Benefits of non PLP are generally noticeable across wider areas and can protect areas outside immediate risk area e.g. through adjusting the flow conveyance/direction;
- Flood mitigation measures such as flood storage and attenuation keep the water away from the properties. Whereas PLP is a form of resilience; a form of flood defence that resists the ingress of water at the site of the actual property.

7.3 HOTSPOT 9 - RYE HOUSE/NORTH HODDESDON

KEY CONSIDERATIONS

It was decided that Rye House/North Hoddesdon should be taken forward for hydraulic modelling. The main elements taken into consideration when determining the need for hydraulic modelling to refine the understanding of the flood extents and mechanisms were the following (as shown in **Error! Reference source not found.**):

- The Environment Agency's Risk of Flooding from Surface Water map which shows:
  - Isolated areas of surface water flooding within the eastern area of the relatively flat hotspot;
  - Surface water flows through the residential area can cause several properties to be inundated (although flooding is constrained to the highway network for lower order events).
- It was determined that the focus of this model was the flowpath east of Ware Road (A1170).

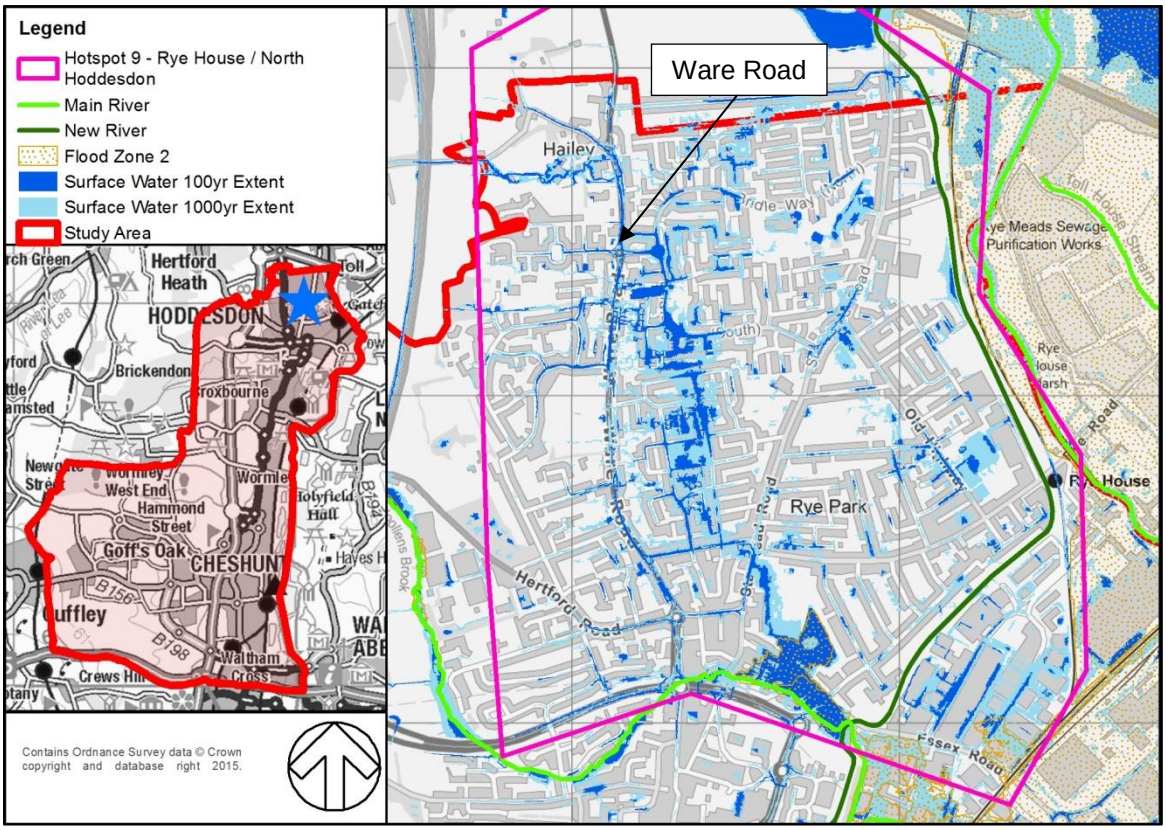


Figure 11: Hotspot 9 - Rye House / North Hoddesdon - extent and baseline information

HYDRAULIC MODEL SUMMARY

The model has been developed in ESTRY-TUFLOW with a direct rainfall approach. The uFMfSW DTM was used as the basis of the topographical data. This was supplemented by topographical surveys undertaken to ensure that the flowpaths along highway junctions were accurately represented.

Outputs from the ISIS-TUFLOW models of Woollens Brook and the Upper River Lea from the Environment Agency were used as downstream boundaries in the model.

KEY CONSTRAINTS

LiDAR was missing in the north western part of the hotspot, so the updated Flood Map for Surface Water (uFMfSW) DTM was used. The uFMfSW DTM is a merged dataset; for this catchment it comprises of LiDAR for the majority of the catchment and NEXTMap data for only the north western part of the hotspot (west of Ware Road). It was checked that no more recent LiDAR was flown after the production of the uFMfSW DTM.

Based on the topography and that the area of interest is to the east of Ware Road, the lack of LiDAR to the west of Ware Road is not considered critical, as this area has been included to understand flow conveyance rather than a refinement of risk.

KEY ASSUMPTONS AND LIMITATIONS

The fluvial floodplain of the Woollens Brook extends into Rye Park. If options other than Property Level Protection are to be progressed, then further investigation into the overlap and interactions between the fluvial and surface water flooding (in terms of both extents and mechanisms) will be

required. In addition, further investigation on the preferential flowpaths between the properties to the east of Ware road (A1170), particularly in the area around Beyers Gardens, will be required.

The results show flooding in the area to the north of The Coppings (to the south of Beyers Gardens), just to the west of the underpass in Bridle Way South. Further investigation would be required to understand the flood mechanisms in this area and the potential impact of the wall to the west of the underpass, along with its ability to withstand flood waters, and if it is providing any exisiting flood protection.

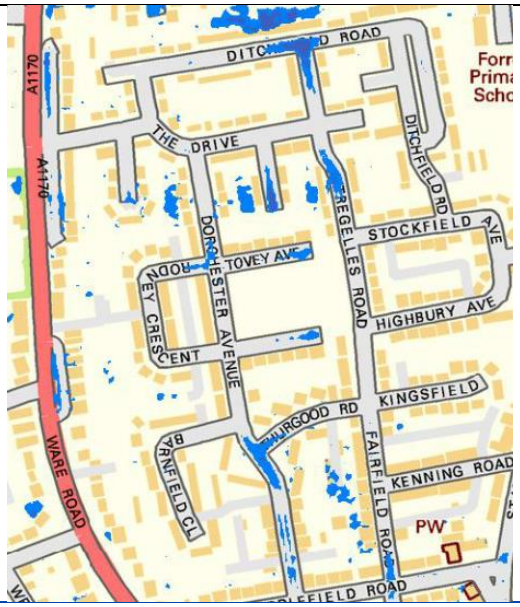
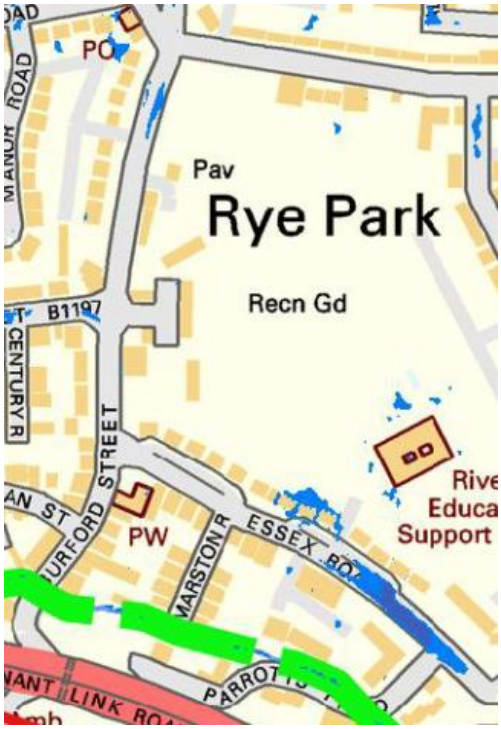
KEY FINDINGS

The key findings of the hydraulic modelling are detailed in Table 6 for the 1 in 30 and 1 in 100 year events. This includes snapshots of the key flood extents.

Mapping of the whole hotspot is provided in Appendix D, including better resolution mapping and a legend.

Table 6: Key Findings – Hotspot 9 - Rye House / North Hoddesdon

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
Flood Depth	Ponding is predicted along Beyers Prospect, Ware Road and Bridle Way. It is mainly contained to the highways with a maximum depth of 0.5m. Flooding depths up to1.3m are predicted in the area to the west of the underpass in Bridle Way South. These depths are believed to be caused because the existing wall was not included into the model.	For the 1 in 100 year event, the flood extents are similar to the 1 in 30 outlines, with deeper flooding along the roads, up to 0.6m in Beyers Prospect. Flooding depths to the west of the underpass are predicted to be up to 1.6m.
		

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
Flood Depth	Ponding is predicted around some properties to the south of The Drive but mainly constrained to Ditchfield Road, Tregelles Road and Thurfood Road, with flood depths up to 0.4m.	Greater flood extents affecting not only roads but also properties in the 1 in 100 year. Flood depths up to 0.5m.
		
	Ponding affecting properties to the south of Rye Park, with depths below 0.3m.	Ponding affecting properties to the south of Rye Park, with depths up to 0.4m.
		

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
Flood Hazard	For flood hazard, the areas of high flood depths are classed as danger for some, with small areas of danger for most around the north of Ware Road and Bridle Way roundabout.	For flood hazard in the 1 in 100 year event, the areas of high flood depths are classed as danger for most, coinciding with the flowpaths along Ware Road, Bridle Way and Tregelles Road.

SENSITIVITY TESTING

In line with the modelling methodology, no sensitivity testing was undertaken on this hotspot.

POTENTIAL MITIGATION

The absence of established preferential flowpaths along the highway or through public open space within this hotspot causes water to flow between properties. Property Level Protection is recommended as mitigation for properties affected by flooding in this area, as this is relatively quick and easy to implement. These areas are listed below and shown in the option maps in Appendix E.

- Ware Road (properties on the east side);
- Area to the south of Bridle Way South;

- Area between The Drive and Tovey Avenue;
- Area between Thurgood Road, Middlefield Road and Fairfield Road;
- Post office and properties located in the junction between Middlefield Road and Stanstead Road;
- Properties located in Essex Road, to the south of Rye Park.

RECOMMENDATIONS

Property Level Protection is one method that can be used to make properties more resilient to flooding. However, by its nature it will only protect properties upon which it is installed and implemented/actively managed. A constraint of the funding process is that if PLP measures are funded through Local Levy or FCERM GiA then these properties cannot be used to justify further alleviation measures, which could benefit a wider area.

It is therefore recommended that consideration is given to alternative measures, which are expected to reduce flood risk and may remove the need for Property Level Protection in some of the areas. These measures focus mainly on providing attenuation upstream and utilising the roads as preferential flowpaths in order to reduce uncontrolled flowpaths between properties.

- Attenuation of water spilling from Hailey Lane into Hailey Hall School fields could reduce flooding to the properties downstream of Ware Road;
- Further investigation on the flowpaths between properties from Ware Road to the east would be required. Measures to keep preferential flowpaths along the road or alleyways should be further investigated. Property Level Protection should be investigated further if there are no viable alternative measures;
- Install a speedbump or high capacity drain at the entrance of Beyers Prospect linked to a swale in the green island between Beyers Prospect and Bridle Way North. This recommendation is expected to keep the preferential flowpath along the swale, thus reducing water flowing through the properties to the east of Beyers Prospect;
- Maximize attenuation area in the park to the east of Bridle Way South and ensure that the swale upstream is connected to this attenuation area (e.g. pipe under Dymokes Way). Flows along Bridle Way should also be diverted and spill into this attenuation area;
- Enhance the extents and status of the wall at the underpass in Bridle Way South, as a flood defence barrier;
- Investigate the installation of high capacity drains at the three junctions of Glenester Close and Bridle Way South. This is expected to reduce flows affecting the properties downstream;
- Potential attenuation in the park between Dorchester Avenue and Tregelles Road, ensuring the preferential flowpath is kept along Tregelles Road and spills into the attenuation area;
- Investigate blocking the flowpath between the properties located in the area between Thurgood Road, Middlefield Road and Fairfield Road;
- Ensure that the preferential flowpath is kept along Middle Field Road and Stansted Road and directed into Rye Park, where attenuation should be provided;
- A bund within the northern section of Rye Park would reduce the interaction between the fluvial and surface water flooding and limit the combined depths. This bund is expected to protect properties to the south of the park from surface water flooding, while allowing attenuation space for fluvial flooding in the southern part of the park. If this mitigation is progressed, further investigation into the overlap and interactions between the fluvial flooding and the surface water flooding will be required.

Detailed modelling of these measures should be undertaken to test their feasibility before implementation. The impact of combinations of the above measures should also be considered, alongside Property Level Protection.

7.4 HOTSPOT 52 - CHESHUNT

KEY CONSIDERATIONS

It was decided that Cheshunt should be taken forward for hydraulic modelling. The main elements taken into consideration when determining the need for hydraulic modelling to refine the understanding of the flood extents and mechanisms were the following (as shown in **Error! eference source not found.**):

- The Environment Agency's Risk of Flooding from Surface Water map which shows:
  - In lower order magnitude events the surface water flowpath runs east along Great Cambridge Road (A10) and High Street (B1176). It then flows across residential areas towards the Small River Lea and marshes.
  - In higher order magnitude events (e.g. the 1 in 1,000 year event) the surface water flood risk is compounded by fluvial flood waters.
- There has been a history of flooding in this area, for example flooding was recorded on 20th June 2015 on College Road (B198).

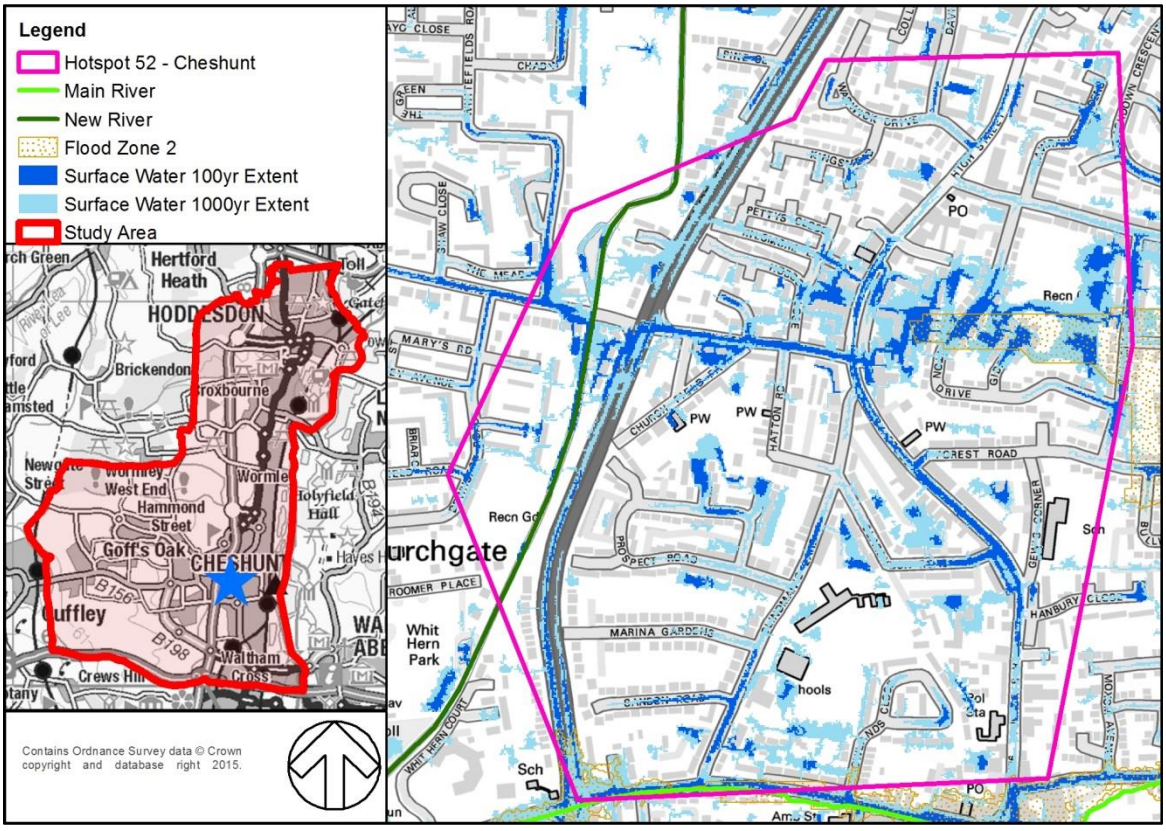


Figure 12: Hotspot 52 - Cheshunt - extent and baseline information

HYDRAULIC MODEL SUMMARY

The model of this hotspot was extended to combine with the model for Hotspots 62 and 63 due to the linkages of the surface water drainage network.

The model has been developed in ESTRY-TUFLOW with a direct rainfall approach.

LiDAR data is available for 100% of the catchment and Thames Water asset data also covers the whole hotspot.

The College Brook was excluded from the model because it was determined that the focus of the modelling was to be further to the north and the brook is mostly culverted. This meant that the downstream boundary of the model was represented by water level in the culvert (a Head Time boundary).

Site specific topographical data was obtained to ensure flowpaths are accurately represented. This included levels to be taken at various points along the section of Great Cambridge Road (A10) and the High Street (B176).

KEY CONSTRAINTS

Following site inspections with HCC it was determined that the most appropriate way of modelling the New River (an artificial waterway) was to represent it as a barrier to overland, surface water flow, as in most instances it is raised above the adjacent ground level. If any surface water were to enter the aqueduct it would be conveyed away from the hotspot; surface water flow routes are not able to cross the New River.

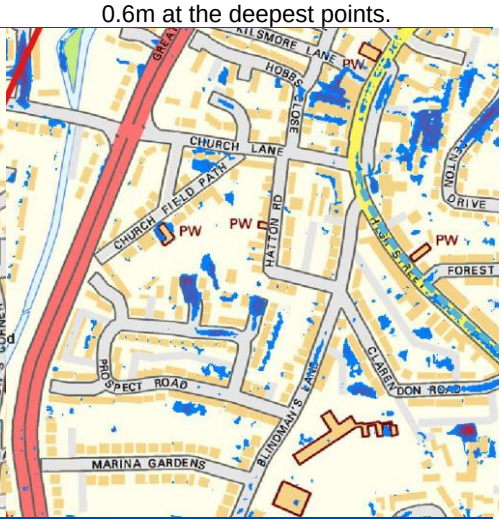
KEY LIMITATIONS

The key limitation of this hydraulic model is the interaction with the fluvial floodplain in the eastern area of the hotspot. This will require further investigation if a detailed mitigation model is to be developed. The focus of this assessment has been the surface water flows only.

KEY FINDINGS

The key findings of the hydraulic modelling are detailed in Table 7 for the critical 1 in 30 and 1 in 100 year events, including snapshots of the key flood extents. Mapping of the whole hotspot is in Appendix D, which provides a better resolution and colour key.

Table 7: Key Findings – Hotspot 52 - Cheshunt

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
Flood Depth	Localised but deep flooding (0.75m) is predicted between The Mead and Church Lane. The main flowpath extends from west to east through properties between the High Street and the recreation ground. Flood depths predicted up to 0.5m.	In the 1 in 100 year event, flood depth increases (maximum depth of 0.8m) on the highway between The Mead and Church Lane. The area flooded does not substantially increase because flooding is contained to the highway. For the flowpath on the High Street to the recreation ground, flooding through the properties increases, with depths rising to 0.6m at the deepest points.
		
Flood Hazard	An area of danger for most is predicted on the highway between The Mead and Church Lane. There are also areas of danger for some along the flowpath that flows from east to west.	The hazard areas follow the same pattern as for the 1 in 30 year outline. The area posing danger for some near Church Lane has increased. The hazard risk for the properties along the east-west flowpath has increased to danger for most.
		

SENSITIVITY TESTING

Sensitivity was undertaken to assess the impact of a blockage (75% and 50%) on all the pipes, culverts and underpasses in the model. Results (flood model summary report in Appendix C) show that the mean difference in flood levels between baseline and sensitivity scenarios are less than 1mm for both 50% and 75% blockage.

POTENTIAL MITIGATION

Mitigation measures which could be considered for Hotspot 52 - Cheshunt are outlined below and shown in Appendix E:

- Property Level Protection on the properties located to the east of High Street. Further investigation should be undertaken on the feasibility to implement alternative measures to remove the flowpath through these properties (see recommendations section below), which would reduce flooding downstream and thus the need for Property Level Protection in this area;
- The installation of a swale along the side of Church Lane to convey flows from Church Lane and a depression to connect to either the drainage system or the New River given that the swale will provide water quality treatment. This is expected to reduce ponding in Whitefields Road;
- Infill the existing wall at the back entrance to the courtyards located to the south of Kilsmore Lane. This wall is expected to cut the flowpath into the service yards of the shops and remove the ponding.

RECOMMENDATIONS

The following recommendations are made for further consideration of this hotspot as alternatives for Property Level Protection and for inclusion within the Action Plan:

- To reduce the reliance on Property Level Protection, an investigation should be undertaken into measures to keep the preferential flowpath on the High Street as this is expected to reduce flooding of the properties downstream. Such measures for consideration could be reprofiling or speedbumps on the High Street and/or the side roads and measures which ensure redirection of the flowpaths between the properties located to the east of High Street;
- Likewise, reprofiling or installation of a speedbump in the junction of High Street with Gew's Corner and Hanbury Close should be investigated;

  These two measures will require further modelling to ensure that there are no adverse cumulative impacts downstream. For example, they could have the potential to lead to an increase in flows conveyed along the High Street into Woollens Brook or further ponding on the road downstream; should this further modelling demonstrate that additional storage is required, then the potential for attenuation on the recreation grounds located in Penton Drive could be investigated;
- A further site visit, potentially combined with further investigation, should be undertaken to determine the preferential flowpath and need for Property Level Protection in Prospect Road.

7.5 HOTSPOT 55 - COZENS LANE EAST, WORMLEY

KEY CONSIDERATIONS

It was decided that Cozens Lane East, Wormley should be taken forward for hydraulic modelling. The main elements taken into consideration when determining the need for hydraulic modelling to refine the understanding of the flood extents and mechanisms were **Error! Reference source ot found.**):

- The Environment Agency's Risk of Flooding from Surface Water map which shows:
  - Water flows from north of the New River (in the Broxbourne area) and into the Cozens Lane East area. This map could be over predicting the flow into the hotspot because it doesn't take into account the slightly elevated New River, bounding overland flow.
  - Surface water is shown to pond in the housing estate bounded by the railway. However, the inclusion of the Thames Water sewers and drainage infrastructure under the railway provides an increased understanding of flowpaths and reduces the risk in this area.
- A detailed DTM (LiDAR) is not available for the whole hotspot. This means that higher accuracy predictions of likely flooding will not be possible for the southern section.

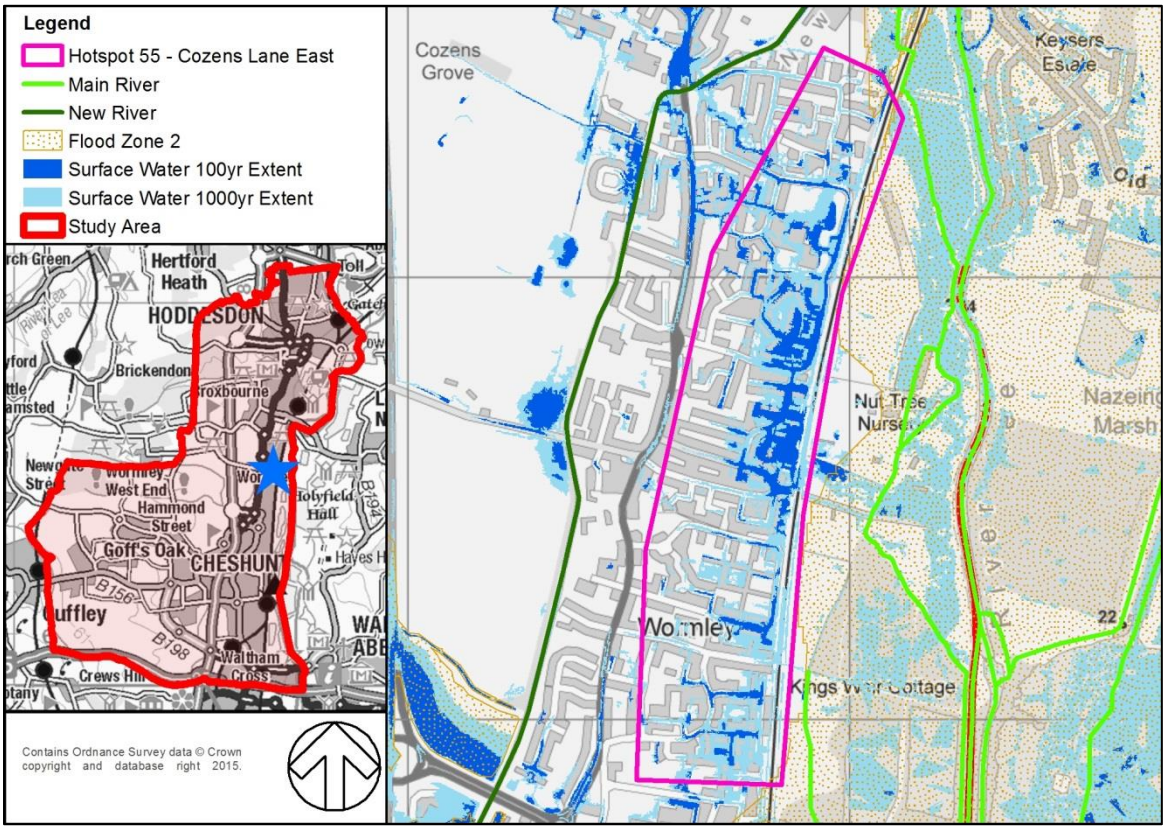


Figure 13: Hotspot 55 - Cozens Lane East, Wormley - extent and baseline information

HYDRAULIC MODEL SUMMARY

The model has been developed in ESTRY-TUFLOW with a direct rainfall approach, the sewer network was developed based on the Thames Water records.

The downstream boundary of the model was based on the floodplain downstream of the culverts under the railway. A Normal Depth (HQ) boundary was used based on the slope of the ground, as inferred from the DTM.

The field drains to the east of the railway were represented by lowering the DTM along the channels (it was considered that these watercourses would have a significant influence on the volumes and rates of water that can be conveyed under the railway).

KEY CONSTRAINTS

There was limited data available from Network Rail on the culverts crossing the railway in the east of the hotspot. The data provided mostly included pipe diameter but excluded soffit, invert and other information. This was considered the best information that could be obtained without employing rail closures, which was beyond the realms of this strategic level study. Therefore, assumptions had to be made based upon cross-sections upstream and downstream of the culverts.

KEY LIMITATIONS

The key limitations of this hydraulic model are the interactions with the fluvial floodplain downstream of the railway, and the assumptions that were required with the representation of the culverts and downstream channels associated with the railway. These limitations will require further investigation if a detailed mitigation model is to be developed.

KEY FINDINGS

The key findings of the hydraulic modelling are detailed in Table 8 for the critical 1 in 30 and 1 in 100 year events, including snapshots of the key flood extents. Mapping of the whole hotspot is provided in Appendix D, which provides a better resolution and colour key.

Table 8: Key Findings – Hotspot 55 - Cozens Lane East, Wormley

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
Flood Depth	Flooding is predicted along estate roads associated with Cozens Lane East and Lammasmead. The flooding is contained to the road for the 1 in 30 year outline and has a maximum depth of 0.7m. 	For the 1 in 100 year event, flooding is predicted to follow the same pattern as the 1 in 30 year outline, but is predicted to spill beyond the road and into properties. The maximum depth increases to 0.9m. 

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
Hazard	For flood hazard, it is predicted that there will be areas of danger for some along Cozens Lane East. There are also areas of danger for most at the end of the side roads of Lammasmead.	The flood hazard lies in an extended area over Lammasmead and Cozens Lane East. The flood hazard is predicted to increase to danger for most in most areas that are predicted to flood.
		

SENSITIVITY TESTING

Sensitivity was undertaken to assess the impact of a blockage (75% and 50%) on the culverts crossing the railway. Results (flood model summary report in Appendix C) show that the mean difference in flood levels between baseline and sensitivity scenarios are 3mm and 6mm, for 50% and 75% blockage scenarios respectively. This confirms that the ponding against the railway is not overly sensitive to culvert blockage. This is because these pipes are already running full in the baseline scenario.

POTENTIAL MITIGATION

Results of the modelling, including the existing Thames Water sewers and drainage infrastructure under the railway, show surface water ponding in the housing estate bounded by the railway. This is because the existing network does not have sufficient capacity, particularly for the large magnitude events, which are beyond the design standards of the culverts. Therefore, mitigation options are focused on increasing the capacity of the existing culverts running under the railway and installing additional culverts. These measures are outlined below and shown in Appendix E:

→ Improve capacity of existing culverts crossing the railway at the following locations:

- Lammasmead
- Fairfield Drive
- Sorbus Road

→ New culverts crossing the railway at the following locations:

- Cozens Lane East

- Wharf Road
- Slipe Lane

The installation of additional culverts under the railway, together with the increase in the capacity of existing culverts could reduce the flooding associated with ponding against the railway. Extensive consultation with Network Rail would need to be undertaken in order to determine the viability of this option. Key limitations with this mitigation option include the fact that is would be very expensive; including the large expenditure and infrastructure disruption associated with the railway, other limitations include the consultation needed with Network Rail. A potential opportunity could be the proposed Crossrail 2 works.

Detailed modelling should be undertaken before implementation of these measures in order to determine culvert sizes. Should the detailed modelling results show that these measures are not sufficient to remove ponding against the railway, Property Level Protection measures are recommended to protect any properties shown to be affected by flooding associated with the predicted ponding.

RECOMMENDATIONS

The following recommendations are made for further consideration and for inclusion within the Action Plan. These are expected to further reduce flood risk, where the potential mitigation measures above are not sufficient or easily implementable to remove ponding against the railway.

These measures focus mainly on keeping a preferential flowpath on the roads, which then spills into a swale that will convey flows into the culverts running under the railway.

→ Investigation into building a swale running between Cozens Lane East and the railway. This swale would provide additional attenuation and convey flows into the existing (and potential new) culverts under the railway.

→ Investigation into measures to keep a preferential flowpath on the following roads, e.g. via raising kerbs, rills or reprofiling levels, and then connecting these into the swale downstream:

- Cozens Lane East (speedbump / reprofiling at Silverfield and Lammasmead junction)
- Fairfield Drive
- Slipe Lane

→ The following areas have been identified where potential attenuation could be provided, thus reducing water flowing downstream:

- Potential attenuation in Wormley Primary School fields for water flowing from Cozens Lane East and Winford Drive.
- Potential attenuation in Broxbourne Junior Mixed and Infant School fields. A bund to the south of the school fields would retain water that flows down to Winford Drive and result in ponding against the railway.

→ Further investigation on the flowpaths between properties from High Road Wormley would be required. Measures to keep preferential flowpaths along the road or alleyways should be further investigated (e.g. by raising kerbs, installing rills or reprofiling levels).

→ In the 1 in 100 year event and those of larger magnitude, ponding is shown around properties to the east of High Road Broxbourne and to the east of High Road Turnford. Further investigation on the flowpaths between properties from this road to the east would be required. Measures to keep preferential flowpaths along the road or alleyways should be further investigated (e.g. by raising kerbs, installing rills or reprofiling levels).

Investigation should be undertaken on the feasibility and cumulative effects of these recommendations before their implementation.

7.6 HOTSPOT 62 & 63 - ROSEDALE NORTH & ROSEDALE SOUTH – FLAMSTEAD END

KEY CONSIDERATIONS

It was decided that this area of Flamstead End should be taken forward for hydraulic modelling. The main elements taken into consideration when determining the need for hydraulic modelling to refine the understanding of the flood extents and mechanisms were the following (as shown in **Error! Reference source not found.**):

- The Environment Agency's Risk of Flooding from Surface Water map which shows:
  - Flooding extends across a relatively flat area;
  - There is an interaction between surface water with Rags Brook and College Brook;
  - The event magnitude, severity and flood depth determine whether the water flows towards the north or south catchments. However, further inspections during the stakeholder site visits indicated that the map over estimates the complexity and risk, probably because Rags Brook is largely within a deep incised channel that may not be incorporated within the LiDAR.

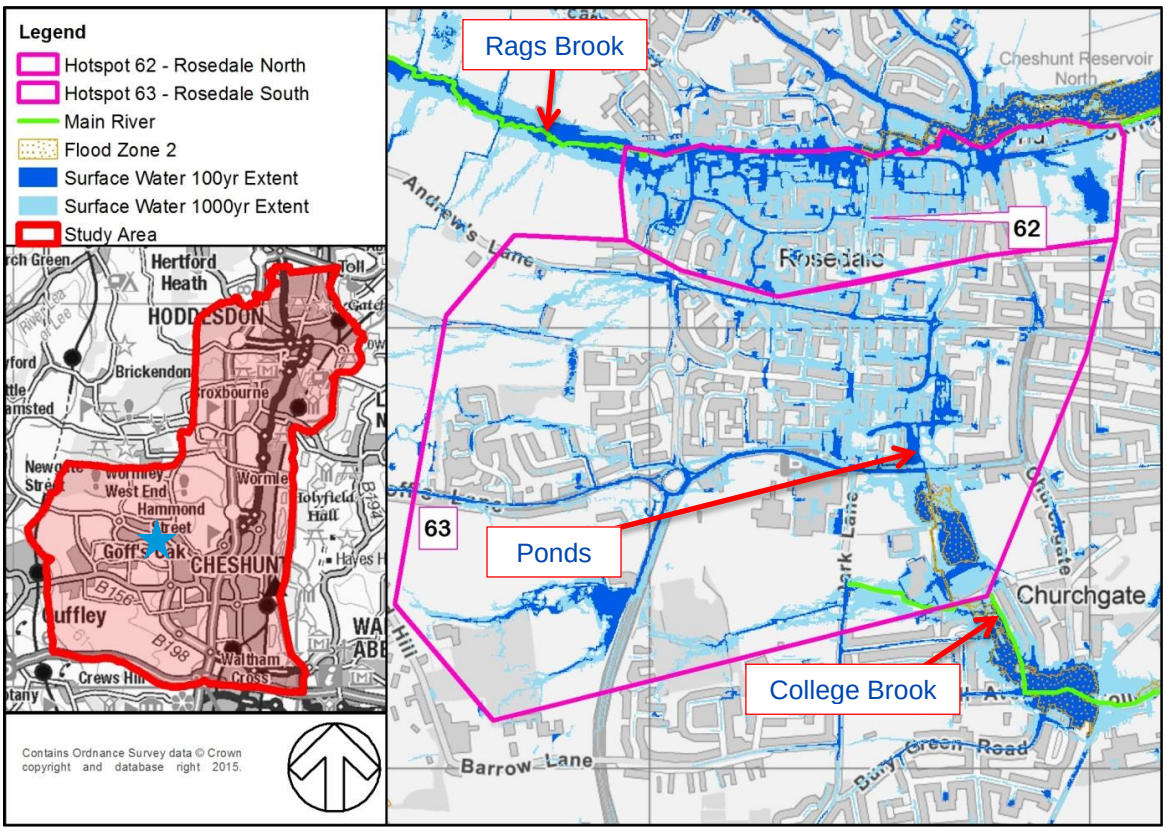


Figure 14: Hotspot 62 & 63 - Rosedale North &South / Flamstead End - extent and baseline information

HYDRAULIC MODEL SUMMARY

This hotspot model was extended to include Hotspot 52 due to a linkage of the surface water drainage network.

The model has been developed in ESTRY-TUFLOW with a direct rainfall approach, using the surface water sewer network as detailed on the Thames Water records.

Rags Brook was included at the downstream of the hotspot and a Head-Time boundary condition was adopted. The 2D model also included a representation of the connected ponds.

LiDAR and Thames Water asset data was available for 100% of the catchment. The updated Flood Map for Surface Water (uFMfSW) DTM (based on the LiDAR) was used as there was no more recent LiDAR flown after the production of the uFMfSW DTM. This meant that the refinements as part of the uFMfSW process were already included in the DTM. Additional topographical data was required to give more information on cross sections of watercourses, road levels on the College Road and Goff's Lane (B156), surveyed levels on drains and ponds.

KEY CONSTRAINTS

Site investigation or topographical survey was not obtained for the area in which water is shown to pond east of Lieutenant Ellis Way (B198). This was considered to operate as shown on the DTM.

KEY LIMITATIONS

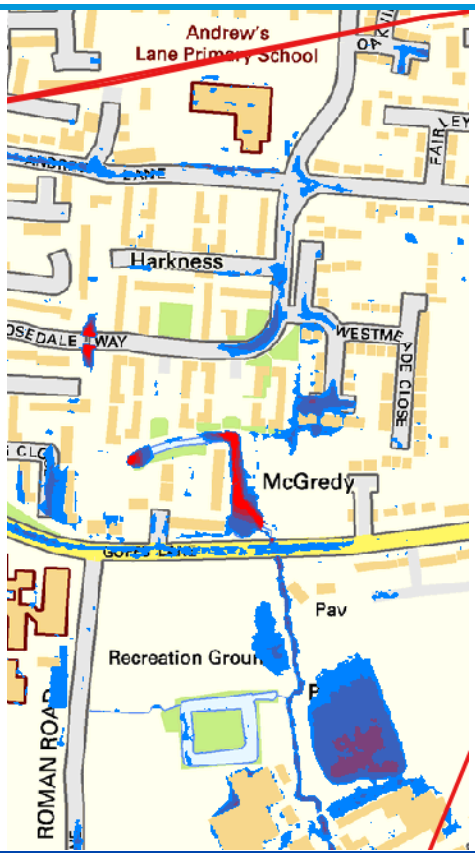
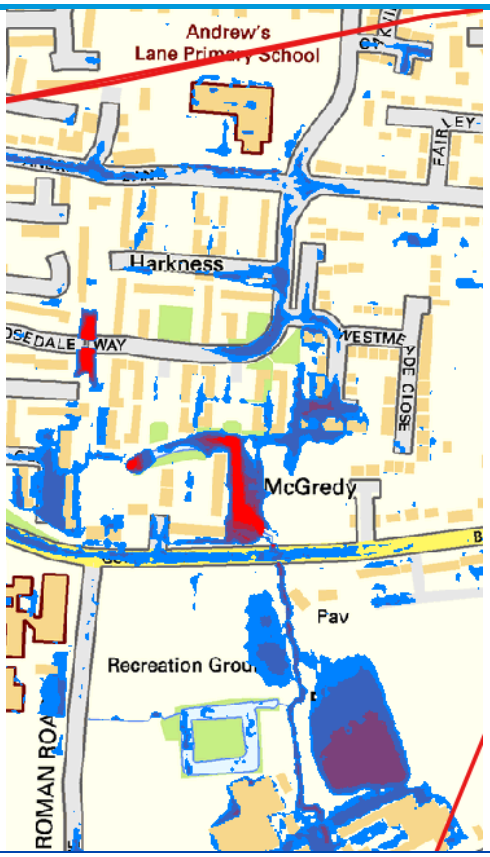
If further modelling is required to refine the mitigation options then the interactions with the associated watercourses will need to be considered further.

KEY FINDINGS

The key findings of the hydraulic modelling are detailed in Table 9, for the critical 1 in 30 and 1 in 100 year events, including snapshots of the key flood extents. Mapping of the whole hotspot is in Appendix D, which provides a better resolution and colour key.

Table 9: Key Findings – Hotspot 62 & 63 - Rosedale North & South / Flamstead End

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
Flood Depth	Flooding is predicted along Andrew's Lane and across to the underpasses on Rosedale Way (maximum depth of 2.5m in the underpass upstream of Andrew's Lane and 0.4m along Andrew's Lane itself). Ponding to the south of Rosedale Way and Westmeade Close. Predicted flood depths of up to 0.6m. There is also predicted flooding associated with the pond north of Goff's Lane across the road into the recreation ground. Flooding in the park reaches a depth of 0.6m and covers an area of 7000m^2. Flooding is predicted by Lieutenant Ellis Way (B198), though this poses no risk to properties.	Flooding along Andrew's Lane follows the same path as the 1 in 30 year outline but is deeper and more extensive (maximum depth increases to 3.5m in the underpass and 0.45m along Andrew's Lane itself). Ponding to the south of Rosedale Way and Westmeade Close. Flood depths up to 0.8m predicted. The predicted flooding in the recreation ground also deepens in the 1 in 100 year event, to 0.8m and extends further along Goff's Lane. In the 1 in 100 year event, the flooding along Lieutenant Ellis Way (B198) extends onto the road in this event.
		

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
		

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
Flood Hazard	For flood hazard, it is predicted that there is an area of danger for most, extending beyond Andrew's Lane from east to west. Flood hazard is predicted to be danger for some along Rosedale Way and in the side roads north of Goff's Lane (B156). The ponding shown in the recreation ground in the south are predicted to be danger for most. The underpasses are shown as danger for all as this is where the greatest flood depths are predicted.	For the 1 in 100 year event, greatest flood hazard is predicted to be in the same locations as the 1 in 30 year outline but flood hazard is predicted to increase to danger for most. The flood hazard along the B198 poses danger for most. Alike to the 1 in 30 year event, for the 1 in 100 year event, the underpasses are shown are showing a flood hazard rating of danger for all.

SENSITIVITY TESTING

Sensitivity was undertaken to assess the impact of a blockage (50% and 75%) on all the pipes, culverts and underpasses in the model. Results (flood model summary report in Appendix C) show that the mean difference in flood levels between baseline and sensitivity scenarios are less than 1mm for both the 50% and 75% blockage scenarios.

POTENTIAL MITIGATION

Mitigation measures which could be considered for Rosedale North & South, Flamstead End are outlined below and shown in Appendix E:

→ At the north eastern corner of Rosedale Way undertake road reprofiling or install a speedbump in order to divert flows and keep the preferential flowpath along Rosedale Way. This should be combined with installation of a high capacity drain and culvert to collect this

flow and discharge it into Rags Brook. This measure is anticipated to relieve flooding of the junction between Brookfield Lane West and Flamstead End Road;

- Construction of a ditch parallel to Rosedale Way to convey surface water to Rags Brook. Ensure that flows from Granby Park Road are diverted into this swale instead of flowing down Rosedale Way (e.g. high capacity drain/reprofiling road). This measure is expected to reduce flooding in the junction between Graney Park Road and Rosedale Way. It is also expected to reduce the water flowing from Valence Drive and Cranleigh Close that joins the main flowpath along Andrew's Lane downstream;
- Property Level Protection on the properties to the south of Rosedale Way and Westmeade Close;
- Property Level Protection on the properties to the south of the recreation grounds (south of Goff's Lane).

RECOMMENDATIONS

Property Level Protection is one method that can be used to improve a property's resilience to flooding. However, by its nature it will only protect properties upon which it is installed, implemented and actively managed. A constraint of the national funding process, is associated with the fact that if PLP measures are funded through national FCERM GiA or regional Local Levy, then these properties cannot be used to justify further funding for flood alleviation measures, which could benefit a wider area.

It is therefore recommended that consideration is given to all measures, before deciding which is the best flood mitigation option to implement. Some flood mitigation measures have benefits to a wider area and may remove the need for PLP. The following recommendations are made for further consideration of this site and for inclusion within the Action Plan for both Rosedale North and Rosedale South, Flamstead End; and these are shown in Appendix E:

- Obtain topographical survey to confirm whether the flowpath splits at the pedestrian crossing. There is potentially a need for a wall to impede the flowpath from Goff's Lane to Cussons Close;
- Investigate measures to keep preferential flow along Rosedale Way, such as:
  - Road reprofiling / speedbump on the junction between Westmeade Close and Rosedale Way (by Westmeade Close); and
  - Reprofiling of footpath in order to provide a consistent high level barrier utilising existing grass landscaping.

  These measures may remove the need for Property Level Protection in the properties to the south of Rosedale Way and Westmeade Close.
- Ensure that the preferential flowpath along Rosedale Way spills into the drain downstream. Reprofile the drain to ensure the preferential flowpath can flow freely into the drain, ensuring this does not affect any properties;
- Investigate potential attenuation (e.g. pond) on the playing fields, which would reduce the need for Property Level Protection in the properties downstream of the recreation grounds;
- Ensure the attenuation area to the west of Lieutenant Ellis Way (B198) operates and is controlled as modelled. Investigate the potential to increase the attenuation capacity upstream, with upstream storage in appropriate areas, in order to reduce water flowing downstream.

8 VIABILITY SUMMARY

The results of the baseline economic analysis for each hotspot are summarised in Table 10. This illustrates the number of properties currently at risk of internal flooding, in line with the Environment Agency's bands for economic assessment.

Table 10: Number of Commercial and Residential Properties at Risk of Flooding

HOTSPOT	PROPERTIES AT RISK OF FLOODING		
	VERY SIGNIFICANT (>5% AEP) 1 IN 20	SIGNIFICANT (5% – 1.33% AEP) 1 IN 75	MODERATE (1.33% – 0.5% AEP) 1 IN 200
9 - Rye House, Hoddesdon	42	68	64
52- Cheshunt	8	26	77
55 - Cozens Lane East, Wormley	23	97	333
62 - Rosedale North / Flamstead End	6	7	16
63 - Rosedale South / Flamstead End	11	46	150

The results of the mitigation options economic damages for each hotspot are summarised in Table 11. This illustrates the expected present value economic damages from flooding over a 100 year period. It also provides the present value benefits and costs associated with the mitigation options that have been considered at each hotspot. For each mitigation option the Benefit Cost Ratio is provided to demonstrate its viability. When considering the findings of the economic assessment, it needs to be considered that this has been undertaken at a strategic scale. The associated benefit cost ratio for a proposed scheme, will need to be refined as the scheme is progressed through later stages of the funding process; where greater information is available on the local flood mechanisms and associated depths, along with the forecast mitigation requirements and cost.

Each mitigation option as identified in Section 7 was assigned a standard of protection, below which it is considered, through engineering judgement, that property flooding would be alleviated, for the purposes of the high level assessment within this SWMP. The area which would benefit from the mitigation scheme, the 'benefit area' is identified in the Economic Analysis Maps (Appendix F).

Table 11: Baseline and Mitigation Options* Economic Damages

HOTSPOT	MITIGATION OPTION	PRESENT VALUE DAMAGES [£]	PRESENT VALUE BENEFITS [£]	PRESENT VALUE COSTS [£]	BC RATIO
9 - Rye House, Hoddesdon	Baseline	60,651,000	/	/	/
	100yr SOP	50,277,000	10,424,000	3,101,000	3.4
52 - Cheshunt	Baseline	38,578,000	/	/	/
	30yr SOP	36,550,000	2,028,000	800,000	2.5
55 - Cozens Lane East, Wormley	Baseline	47,059,000	/	/	/
	100yr SOP	22,109,000	24,951,000	4,592,000	5.4
62 - Rosedale North / Flamstead End	Baseline	12,521,000	/	/	/
	30yr SOP	11,932,000	588,748	115,000	5.1
63 - Rosedale South / Flamstead End	Baseline	31,905,000	/	/	/
	30yr SOP	29,952,000	1,953,000	752,000	2.6

**each mitigation option can be seen in Appendix E (Options) and Appendix F (Economic Analysis)*

The viability assessment demonstrates that all the proposed mitigation options are economically viable, as the benefit cost ratio is greater than 1.

Further work will be required to consider the costs for the Cheshunt and Rosedale South benefit areas prior to any further assessment works being undertaken. This is because, should the land not be freely available, or other currently unforeseen elements be encountered, then the benefit cost ratio could drop below 1, at which point schemes are not considered economically viable.

To secure FCERM GiA funding, a benefit cost ratio of greater than 1 is needed in order for a scheme to be viable. The current funding process, which aims to get third party funding (e.g. from Local Levy, private or public contributions) means that the majority of the schemes proposed here, would not be viable without attracting additional (partner) funds. The types and availability of these additional funding streams are discussed in the following section (Section 9).

9 FUNDING

The hydraulic modelling and optioneering phases have identified a range of potential mitigation measures that could be implemented to help reduce flood risk. Where these measures are the promotion of capital local flood risk management schemes, the delivery depends on sufficient funding being available, either from ongoing revenue funding or project based support for capital schemes.

The funding available for any measure will be linked to the outcomes it will provide. Measures that deliver benefits beyond flood risk management, such as enhanced ecosystems, public amenity, economic growth or cultural heritage, may attract funding from alternative sources beyond those typically used to support flood risk management. Funding is therefore based on the economic viability of schemes; not all potential flood alleviation schemes will be viable and not all will achieve funding.

This chapter describes the available sources of funding that could be used to support the measures previously identified. Hertfordshire County Council have already achieved funding for flood risk projects from various sources, including Local Levy and Grant in Aid. HCC as the LLFA also receives separate funding from government to fund delivery of their statutory duties under the Flood and Water Management Act (2010). This is separate from the funding described in the following sections that are focused on delivery of specific flood risk management schemes.

9.1 NATIONAL FUNDING

FLOOD AND COASTAL EROSION RISK MANAGEMENT GRANT IN AID FUNDING

Defra has the national policy responsibility for Flood and Coastal Erosion Risk Management (FCERM) and provides funding through Grant in Aid (GiA) to the Environment Agency, who then administer grants for capital projects. Risk Management Authorities (RMAs), such as Hertfordshire County Council as LLFA, are also able to request FCERM GiA.

A contribution to flood risk management schemes from the Flood and Coastal Erosion Risk Management Grant in Aid (FCERM GiA) funding will be provided whenever there is a positive ratio of benefit to cost. However, a positive ratio does not necessitate full funding and the formula determines the amount of Central Government funds based on the calculated ratio.

Funding levels for each scheme are linked to the number of households protected, the damages prevented, environmental benefits, amenity improvements, agricultural productivity and economic benefits. The payment rates for household protection vary depending on the index of multiple deprivation; with more deprived households receiving higher payment rates. This ensures that schemes identified within poorer areas are more likely to receive full funding from Central Government.

The calculation of funds to be provided by FCERM GiA is as follows[14]:

$$\text{Share of costs funded by Defra} = \frac{\text{Household benefits} + \text{other whole-life benefits} + \text{environmental outcomes}}{\text{Amount of funding required}} \times \text{Fixed payment rates}$$

[14] Taken from the Framework to assist the development of the Local Strategy for Flood Risk Management, 2nd Edition (Local Government Association, 2011)

The benefit of this approach is that more schemes will be eligible for some national funding including minor schemes and those not solely related to fluvial and/or surface flooding. However, it will be more difficult to obtain 100% funding from national sources and therefore cost saving measures and other sources of funding are likely to be required to ensure that the scheme is fully funded.

9.2 REGIONAL FUNDING

LOCAL LEVY

Local Levy funding is an additional locally-raised source of income, gathered by way of a levy on Local Authorities and collected via the council tax. The levy is used to support (with the approval of the Regional Flood and Coastal Committee) flood risk management projects that are not considered to be national priorities and hence do not attract national funding through FCERM GiA. Alternatively, local levy funding can be applied to FCERM GiA projects, at the discretion of the Regional Flood and Coastal Committee (RFCC), to meet the partnership funding requirements. Each RFCC annually sets the level of local authority funding that local authorities will contribute in the following year.

Hertfordshire is covered by the Thames and Anglian Central RFCC. Each RFCC collects Local Levy funds from the county, which are used to contribute towards locally important flood risk management schemes across their areas of responsibility.

To obtain these funds it is important to engage with the RFCC early in the allocation process once possible schemes have been identified. To facilitate this officers and elected members from the council attend and are part of the RFCC.

9.3 LOCAL FUNDING

Depending on the shortfall from FCERM GiA and the number of schemes competing for the RFCC's allocation, it is possible that the Local Levy will not solely provide all the required funding for a scheme. Other funding measures will also need too be explored.

Potential sources of local funding could include:

- **Section 106 Agreements**, in accordance with the Local Planning Authority – this is a contribution, linked to specific developments and the related infrastructure required to make them acceptable in planning terms.
- **Community Infrastructure Levy (CIL)** – this is a sum levied upon development in line with a locally set charging schedule to be used by local authorities to provide the necessary infrastructure to support development generally.
  - Currently only four of the ten districts in Hertfordshire (Dacorum, Hertsmere, Three Rivers, and Watford) have adopted CIL charging schedules.
  - Where there is a neighbourhood plan in place the parish or town council are eligible for 25% of the CIL charge relating to a development in the plan area.
- **Local Authority Funding** – for capital schemes funded through Council Tax and Revenue Support Grant. Where there is benefit to business, Business Rates levies and Business Improvement Districts could provide source funding.
- **Private Funding Sources** – Landowners, Natural England and other relevant agencies in some circumstances may be willing to contribute funds to flood risk management where they can see a direct benefit to reducing their flood risk or improving their land drainage.

For both Section 106 Agreements and Community Infrastructure Levy (CIL) it should be noted that it is a competitive process to receive money from these sources; competing with lots of other aspects of new developments, including affordable housing, schools, doctors, parks, roads etc.

9.4 COMBINATION OF FUNDING SOURCES

The preferred approach for funding schemes is to use a variety of funding sources. No flood risk mitigation schemes proposed in this SWMP are likely to have sufficient benefits to be 100% funded through the FCERM GiA system. The use of multiple and combined sources of funding is shown in Figure 15[15] as "Payment for Outcomes (anticipated)".

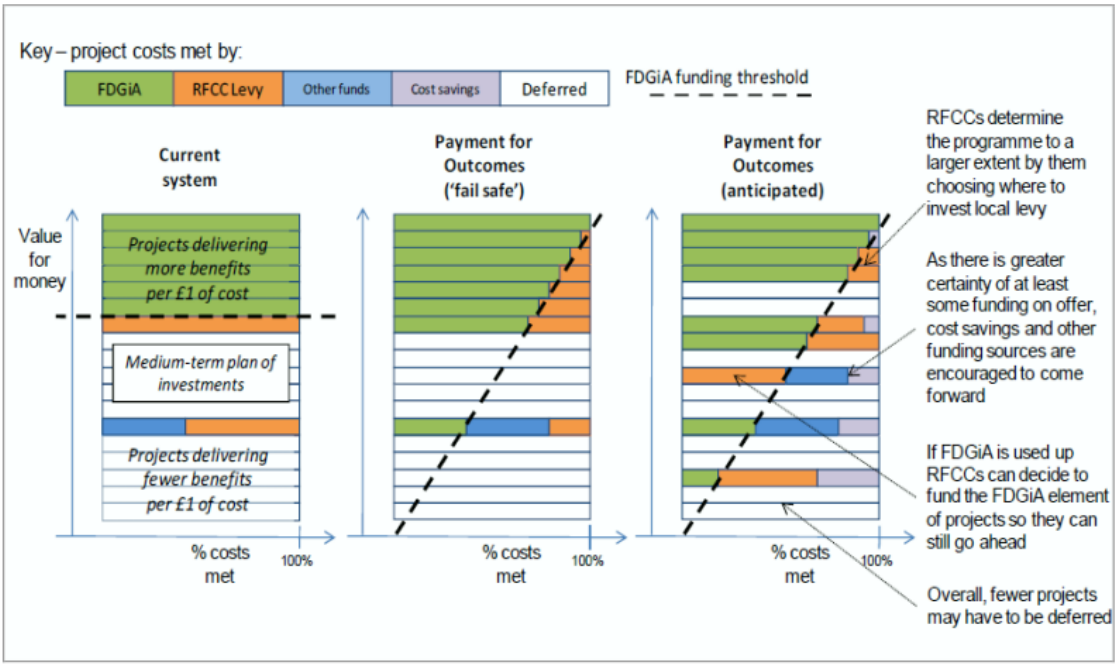


Figure 15: Combination of possible different funding sources to cover costs of flood risk management schemes

9.5 FUNDING CONCLUSIONS

The economic assessment found that a number of the recommended schemes across the Broxbourne Borough hotspots were considered sufficiently viable to be submitted to the Environment Agency for inclusion on their MTP and further assessments undertaken to refine the schemes to a level suitable for a formal funding application (Outline Business Case). For these schemes HCC will need to work with key stakeholders in Hertfordshire to secure additional third party funds to ensure the schemes to have sufficient funding for delivery. Alternatively, smaller more localised schemes could be considered as part of current operational and capital work streams.

[15] Taken from the Framework to assist the development of the Local Strategy for Flood Risk Management, 2nd Edition (Local Government Association, 2011)

10 IMPLEMENTATION AND REVIEW

The Surface Water Management Plan (SWMP) is a living document that should be reviewed approximately every five years, to ensure the correct implementation of the agreed actions and that any new issues are addressed. A review may be required following any new flood event, when new flood data becomes available, new modelling techniques are developed or when there is a change of policy.

The SWMP will be used as an evidence base for the Local Flood Risk Management Strategy (LFRMS) for Hertfordshire. It will inform the Local Plan and lead the direction of flood risk projects within each district and borough.

10.1 ACTION PLAN

The Action Plan for each hotspot details recommendations for options to be explored, in addition to what actions will be needed if this hotspot is taken forward for further assessment after the completion of this SWMP. The Action Plan is targeted towards each of the assessed hotspots and provides a summary of all the mitigation measures that are likely to lead to a reduction in flood risk if they are implemented. As many of these actions are likely to require capital costs to be implemented, funding will need to be secured to fully investigate their feasibility.

Any options involving construction works will require the development of a detailed study, refining the assumptions and undertaking hydraulic modelling of the option in order to verify the approaches adopted within this strategic study. This detailed study will also enable a better understanding of the baseline risk prior to testing a range of mitigation measures to determine the best option in both economic and environmental terms.

The stages that would be involved in this process are outlined in Figure 6, during this process community involvement should be considered at each stage to ensure that they have a greater stake in project design and delivery. Involving the community at an early stage of flood risk management schemes ensures ownership of the final solution. Other elements which will run throughout a scheme include consideration of how the scheme will be funded, how to maximise the environmental benefits and reduce the impacts of flooding.

Table 12: Further Assessment Phases

TIME	ACTION	REASON/WHAT IS NEEDED FOR THIS?
	County Wide Priority Site Review	HCC LLFA team to review priority sites from this SWMP in conjunction with other SWMPs to determine the list of overall priority sites.
	Determine Workstream	HCC LLFA team to determine the approach for incorporating SWMP findings in overall deliverables.
	Agree funding approach	Assess third party funding options, FCERM GiA, HCC or contributions from stakeholders.
	Set up project Steering Group	Co-ordinated approach between the EA, HCC, BBC, TW and other stakeholders.
	Appoint Project Team	Consult with stakeholders involved. This should include, if necessary, consultants.
	Undertake further studies	Undertake modelling and further studies to fully understand surface water flooding issues at the site. Any surveys required to facilitate and future mitigation solutions or modelling are to also be undertaken (i.e. soakaway tests / topographical surveys etc.).
	Mitigation Review	Based on the results of the further studies, review mitigation options and confirm adopting authority (LLFA, Hertfordshire Highways, BBC and TW).
	Economic Viability	Undertake a review of the economic assessment for the updated mitigation studies.
	Funding	Identify and maximise all other funding sources including CIL, local authorities, environmental funding, and other external organisations.
	Supplementary Studies	Undertake any additional studies (ecology / site investigations / additional topographical surveys).
	Apply for Funding	Apply for funding.
	Detailed Design	Undertake detailed design of the proposed mitigation option and gain approvals from the LPA, regulators and adopting authorities
	Tender	Issue proposed design for tender.
	Appoint Contractor	A rigorous selection programme.
	Construction	Construction and final approval (including amending the flood map).

10.2 EMERGENCY PLANNING

The findings from the SWMP should be used to inform the Major Incident Plan and improve the Multi Agency Flood Plan.

The findings and outputs of the SWMP such as the flood hazard maps should be used to inform the emergency plan for Hertfordshire in terms of drainage and flooding issues. This should include the identification of properties within the floodplain inhabited by vulnerable people, to ensure they are prioritised should evacuation be required.

The Multi Agency Flood Plan which will assess flood risk in terms of Health, Social, Economic and Environmental issues.

10.3 NEXT STEPS

Hertfordshire County Council, as LLFA, will prioritise the actions of this SWMP. Outcomes of this SWMP will need to be undertaken in conjunction with the LFRMS and HCCs role as LLFA. This will lead to a prioritisation of actions into their workstream, which includes the findings of other SWMPs and Section 19 Flood Investigations amongst other aspects of the LLFA role.

To ensure a successful implementation and review of the Surface Water Management Plan, all stakeholders must contribute to the process. Clear lines of communication and defined responsibilities are critical.

The SWMP should be used to inform and advise the Plans and Policies for the area and emergency planning as well as inform local planning decisions.

A program of further works to include implementation of the elements within the Action Plan should be prepared and a provisional timetable for completing follow up actions should be agreed by stakeholders. As a SWMP study is considered to be a long-term plan, all stakeholders should continue to work together after the SWMP study has been completed.

The SWMP will inform the LLFA work stream as well as a range of further studies/measures which will include:

- LFRMS evidence base;
- Focus for future projects;
- Strategy for local flood risk management in each district/borough.

11 CONCLUSIONS

WSP | Parsons Brinckerhoff has completed a Surface Water Management Plan (SWMP) for the Borough of Broxbourne on behalf of Hertfordshire County Council, as Lead Local Flood Authority. The study has been undertaken in consultation with key stakeholders who are responsible for surface water management and drainage in the area. This SWMP has worked with key stakeholders to understand the causes and effects of surface water flooding and agree the most cost effective processes of managing surface water flood risk for the long term. This SWMP has been designed to encourage the development of innovative solutions and practices as well as identifying funding streams to assist in the delivery of the outcomes of the SWMP.

The Defra SWMP Technical Guidance (2010) suggests that a SWMP study will not be required in all locations but rather where areas are "considered to be at greatest risk of surface water flooding or where partnership working is considered essential to both understand and address surface water flooding concerns".

The first stage of the Broxbourne Borough SWMP was the Preparation Phase; this identified the need for the SWMP. The need for the SWMP was identified within the Local Flood Risk Management Strategy (LFRMS) for Hertfordshire 2013-2016[16]. The SWMP study was then scoped and the aims and objectives set. The level of assessment needed was identified, as well as the identification of the available information.

The second stage of the SWMP was the Risk Assessment Phase, this was undertaken in two parts; the first, a Strategic and Intermediate Assessment, and the second, a Detailed Assessment. The principle purpose of the Strategic and Intermediate assessment was to identify broad locations which were considered to be vulnerable to surface water flooding. This was undertaken using the best information available, including some GIS analytical techniques. Potential hotspots (areas perceived and identified locally as being at greatest risk of surface water flooding) were identified from this information, and information made available from stakeholders. This list of hotspots was presented to the key stakeholders for discussion and finalisation. It was determined that five were to be taken forward to Detailed Assessment.

The Detailed Assessment part of the SWMP involved detailed hydraulic modelling. Individual hotspot models were constructed to assess the baseline flood mechanisms, pathways and extents. Following the hydraulic modelling, a review of the revised flood extents was undertaken and the numbers of properties in the floodplain determined. From this review it was possible to determine the type of mitigation measures which could be possible to implement for each hotspot to reduce the impacts and damage associated with flooding.

During the Preparation Phase of the SWMP when the objectives were set, one of the aims of this SWMP for Broxbourne Borough was to determine the economic viability of mitigation schemes. This was undertaken to ensure, that HCC could prioritise their future work to focus on measures which not only would reduce flood risk but also be the most attractive in securing funding to facilitate their construction.

All suggested options are considered to be economically viable; however, those with higher cost benefit ratios, third party contributions or demonstrable history of flooding should be progressed first, as these are most likely to attract funding.

The final phase of the SWMP is the Implementation and Review Phase. During this phase an Action Plan is prepared. Action Plans have been developed to cover the measures identified in the Strategic and Intermediate Assessment, and the Detailed Assessment. The Detailed Action

[16] Local Flood Risk Management Strategy for Hertfordshire, available at: http://www.hertfordshire.gov.uk/services/envplan/water/floods/floodrisk/lfrmsherts/

Plan is accompanied by a workstream which identifies the process that would need to be undertaken for each element in order to acquire the capital funds to facilitate its implementation.

This Surface Water Management Plan for the Borough of Broxbourne is to be a living document that should be reviewed approximately every five years, to ensure the implementation of the agreed actions is correct and that any new issues are addressed. A review may be required following any new flood event, when new flood data becomes available, or new modelling techniques are developed, and when there is a change of policy, which affects the borough.