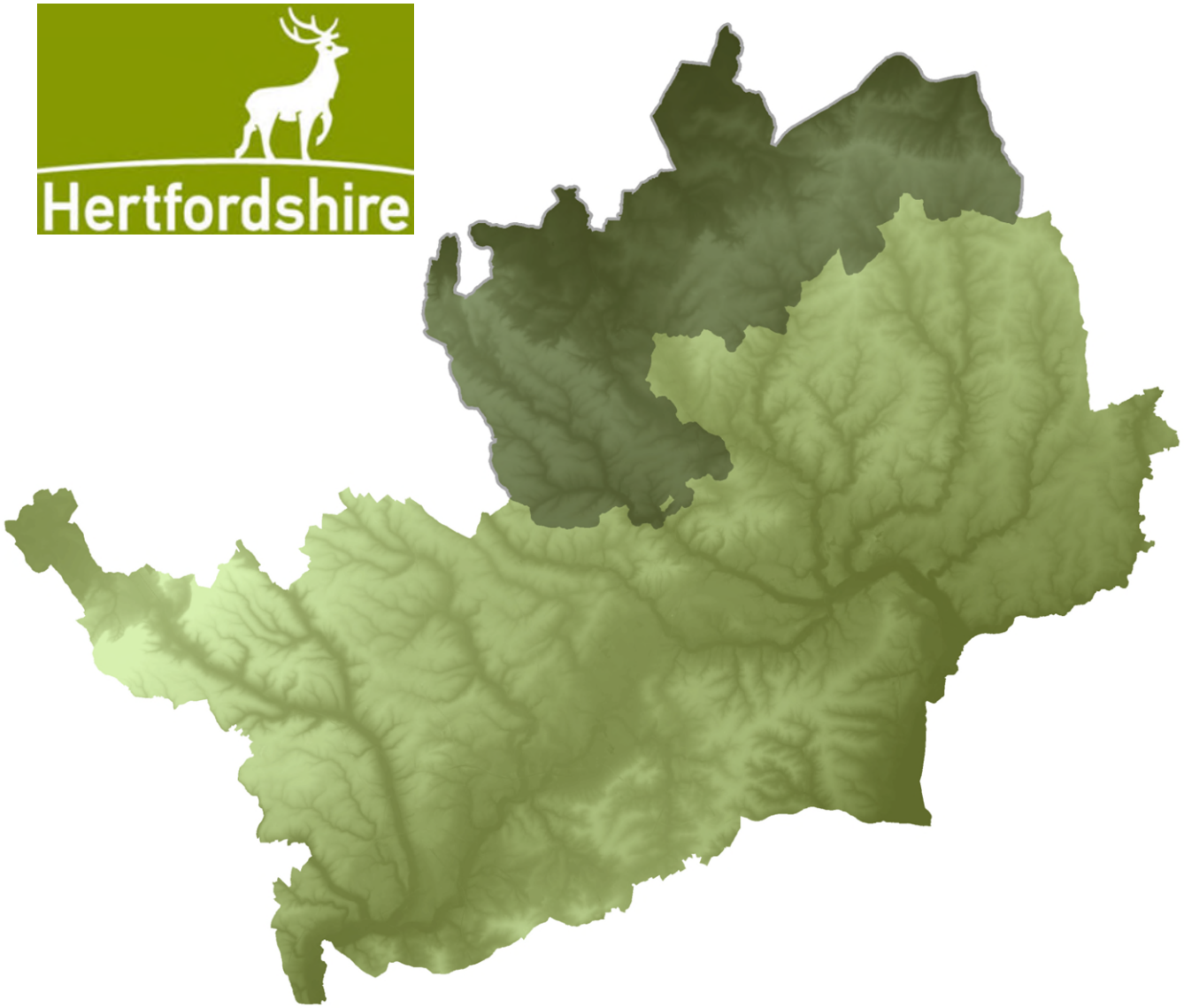

NORTH HERTFORDSHIRE DISTRICT SURFACE WATER MANAGEMENT PLAN

FINAL REPORT

REPORT N^{O} 70006808 - NH_SWMP_01 2017-03-14

WSP | PARSONS BRINCKERHOFF

NORTH HERTFORDSHIRE DISTRICT SURFACE WATER MANAGEMENT PLAN

FINAL REPORT

Hertfordshire County Council

Final

Project no: 70006808
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]**

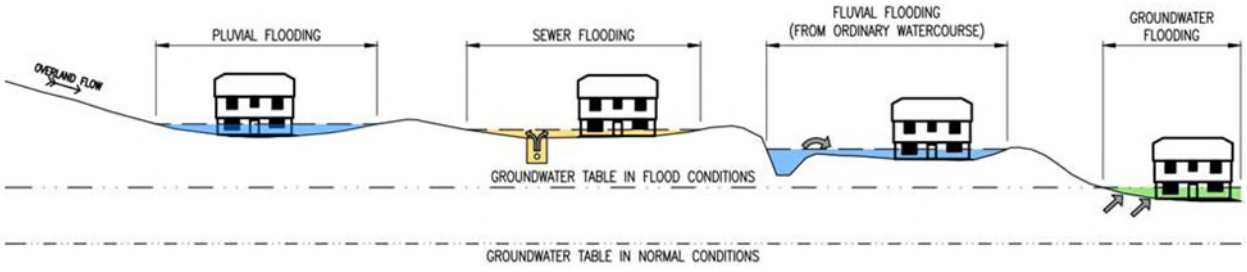


Figure 1: A diagrammatic summary of the key definitions

[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, as stated on Herts Direct (Source: http://www.hertsdirect.org/services/envplan/water/floods/ordwatercourse/)

1 EXECUTIVE SUMMARY

1.1 BACKGROUND

WSP | Parsons Brinckerhoff has completed a Surface Water Management Plan (SWMP) for the District of North Hertfordshire 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 District of North Hertfordshire 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 North Hertfordshire District 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 (sometimes 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. Areas identified include Knebworth and Little Wymondley (which both flooded on 7th February 2014).

A Desk-Based analysis was conducted to assess the flood risk to receptors within the District of North Hertfordshire. From this, 17 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 District of North Hertfordshire. A stakeholder meeting was then held in February 2015, followed by site visits to confirm the findings.

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

- Hotspot 6 Hitchin
- Hotspot 7 Oakfield, Hitchin
- Hotspot 12 Baldock
- Hotspot 13 Clothall Common, Baldock
- Hotspot 17 Knebworth
- Hotspot 30 Cambridge Road, Hitchin

1.3 DETAILED PHASE OF SWMP

The detailed phase of the SWMP focussed on the six 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 flow paths (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 6 - Hitchin	**Upstream:** Flooding is predicted along Wratten Close and across the underpass along Park Way. This equates to danger for most along Wratten Close and danger for all in the underpass below Park Way. **Central:** Flooding is observed along Portmill Lane, Hermitage Road, Hazelwood Close, Grove Road and the A505. Generally this equates to danger for some in the 30 year event, increasing to	• Large storage area to the west of Park Way. • Identify suitable storage or attenuation area upstream of Park Way. • Site visit to determine if Property Level Protection measures are required. • Site visit to confirm the flow paths from Sun Street and Bridge Street to the car parks. • Property Level Protection measures at the junction of Sun Street and Bridge Street. • Speed bump along Queen Street to minimise water draining into Portmill Lane.	• More detailed modelling is required to confirm the flow paths around the risk areas. This will involve an in-depth review of the existing Environment Agency model and potentially upgrade or redevelop the 1D component of the model to improve accuracy. • Secure funding to further investigate the mitigation measures outlined to assess and enable their implementation.

LOCATION	SUMMARY OF FLOOD RISK	PROPOSED MITIGATION MEASURES	RECOMMENDATIONS
	danger for most in the 100 year event. **Downstream:** Flooding is predicted to properties along Walsworth Road from runoff draining from The Avenue and Benslow Lane. Runoff along Walsworth Road will drain towards Radcliffe Road and then to the A505. Hazard rating ranges from danger to some to danger for most.	• Upsize pipes that run from Hazelwood Close to the river to reduce localised flooding. • Install pipes along The Avenue to reduce flooding of Walsworth Road and Radcliffe Road. • More detailed modelling to confirm flow paths at the intersection between Grove Road and the A505.	• Encourage flood awareness and Property Level Measures in areas of risk. • Ensure the highway gully maintenance programme is representative of the flood risks and preferential flow paths. • Topographic survey of the watercourse that drains through The Willows may be required to confirm its flow path towards the River Hiz and its interaction with the A505 upstream.
Hotspot 7 - Oakfield, Hitchin	The flooding is limited to the vicinity of Ippollitts Brook culvert, with depths up to 0.6m. Flooding does not affect any properties. Limited highway flooding is predicted where Stevenage Road (A602) crosses Ash Brook and on Wymondley Road. Hazard rating include areas of danger for some.	• Automated traffic signs on Stevenage Road. • Reprofiling and new headwalls on the Ippollitts Brook culvert.	• These options will be led by HCC and investigation will be needed into whether budget would be available from existing flood risk and highway funds. • A review of suitability of location and number of traffic warning signs is required where Wymondley Road crosses Ippollitts Brook (Culvert 4).
Hotspot 12 - Baldock	Two flowpaths from the south converge in the north of the hotspot. Flooding is predicted on Icknield Way, on and around Hitchin Street, and several roads in the north of the hotspot. Hazard varies across the hotspot with some areas of danger for most.	• Construct a surface water sewer beneath the public footpath in order to increase conveyance under the railway. • SuDS retrofit/detention basin/soakaway in playing fields upstream in order to reduce water flowing downstream. • Detention/soakaway – Natural FRM along flowpath to the east of the hotspot, as permissions/designation allow. • Consider Property Level Measures for properties that have previously experienced flooding and are at high risk.	• Further investigate the construction of a new culvert under the railway • Work with developers/planners to ensure suitable land use as warehousing redeveloped over the longer term. • Consider purchasing one or more of the empty warehouses adjacent to the railway and the associated underpass to provide space for flood storage.
Hotspot 13 - Clothall Common, Baldock	The model predicts an area of flooding up to 0.6m deep flooding to the east of Clothall Common, northwest of the A505, with hazard up to danger for some.	• Ensure that a preferential flow path exists along the highway network.	• If the land in this hotspot comes up for development work with the scheme promoter/developer to ensure that formalised attenuation/detention/soakaways are included in the master plan (if required). • Work with the landowners adjacent to the railway to ensure awareness of wet areas and methods of discharge under the railway and in the downstream ditch network.

LOCATION	SUMMARY OF FLOOD RISK	PROPOSED MITIGATION MEASURES	RECOMMENDATIONS
Hotspot 17 - Knebworth	Flooding may affect properties on Gun Lane, Gun Road Gardens and London Road. This equates to danger for most rising to danger for all on Gun Lane.	• Enhance the cut off drain for both of the flow paths that flow from the west in order to attenuate them in the short term, prior to development of the allocated sites. • Implement attenuation/soakaway in the recreation ground adjacent to Lytton Fields. • Ensure preferential flow paths exist along the highways, as required. • Implement an upstream rural attenuation area to the south of Gun Road Gardens. • Ensure that the highway drainage and associated downstream attenuation/ infiltration area that were installed when the B197 was part of the strategic road network are suitably maintained and fully utilised.	• Investigate increasing connectivity to the more permeable geology which underlies the top soils • Work with planners and developers to ensure exceedance pathways and soakaways/detention areas are in place to attenuate the flow paths from the west, as the allocated sites come forward for development. • Liaise with Highways England to ensure that a suitable maintenance regime is in place for the A1(M) highway drainage infrastructure. • Consider the implications of installing conveyance pathways with infiltration elements along Gun Lane and the path behind Gun Road Gardens on the railway. • Consider increasing flow conveyance to Station Road and then utilising Watton Road to convey the flows to the open fields beyond. • Improve drainage and connectivity, as required, preferentially utilising highway drainage.
Hotspot 30 - Cambridge Road, Hitchin	Flooding is predicted along Cambridge Road, properties to the south of the road and at the College. Hazard varies throughout with areas of danger for all.	A combination of the measures below is expected to be required, following further testing in a hydraulic model. Individual/standalone measures are unlikely to be sufficient to manage the complex flow paths that operate in this area. • Construct swales along the north west of Cambridge Road (A505) and east of Stotfold Road. An attenuation area should be incorporated at the Cambridge Road, Stotfold Road junction. • Construct a swale along the east of Queenswood Drive and provide attenuation at the Cambridge Road, Queenswood Drive junction • Provide attenuation and bund in the green triangle area located at the junction between Queenswood Drive and Cambridge Road, along with a speed bump in the northern access to the side road. • Potential attenuation, through a swale or similar on the green strip located in Cambridge Road to the south of the	• Ensure a suitable maintenance plan is in place for the highway drainage along this section of the A505, as this will remain as the preferential flowpath. • Ensure the highway gully maintenance programme is representative of the flood risks and preferential flow paths. • Further assessment/secure financing of mitigation measures outlined above to enable their implementation.

LOCATION	SUMMARY OF FLOOD RISK	PROPOSED MITIGATION MEASURES	RECOMMENDATIONS
		junction with Queenswood Drive. • Further investigation on the potential flow containment to highways and potential installation of Property level measures along Hampden Road. • Site inspection to confirm the permeability of barriers along the flow path in the gardens of properties located between Hampden Road and Cambridge Road. • Options would be to contain water on the A505 and keep it from entering the parallel side road. This could provide the opportunity to relocate accesses onto the side road to reduce flows into the curtilage of properties.	

An economic viability assessment of the potential benefits of each option compared to an indicative cost estimate was then undertaken. This assessment 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. 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
Hotspot 6 - Hitchin	Baseline	66,570,000	-	-	-
	75yr SoP for all benefit areas	60,000,000	6,570,000	4,000,000	1.7
Hotspot 7 – Oakfield	Baseline	190,000	-	-	-
	No options identified	N/A	-	-	-
Hotspot 12 - Baldock	Baseline	48,850,000	-	-	-
	30yr SoP for all benefit areas	27,000,000	21,820,000	2,810,000	7.8
Hotspot 13 - Clothall Common	Baseline	N/A	-	-	-
	No options identified	N/A	-	-	-
Hotspot 17 - Knebworth	Baseline	14,470,000	-	-	-
	30yr SoP for all benefit areas	7,370,000	7,110,000	770,000	9.2
Hotspot 30 - Cambridge Road	Baseline	19,560,000	-	-	-
	30yr SoP for all benefit areas	11,170,000	8,390,000	510,000	16.5

The economic assessment finds that all potential mitigation schemes are 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 Cases). It is advised that HCC work with key stakeholders to secure additional third party funds to improve the overall funding scores for the schemes.

In addition to the six Modelled Hotspots, three of the Non-Modelled hotspots were allocated recommendations and actions, as shown in table below.

HOTSPOT NUMBER	LOCATION	RECOMMENDATIONS AND ACTIONS
■ Hotspot 5	Kimpton	A separately commissioned study was undertaken for Kimpton, apart from this SWMP. The modelling undertaken as part of this study has shown that the significant flood risk is from the emergent groundwater flowing into the village. However, the improved topographical data has revealed the surface water flood risk is not as extensive as first anticipated.
■ Hotspot 11	Letchworth Garden City	North Hertfordshire District Council have recently completed a scheme within the hotspot. It was therefore felt that further funding would be unlikely, hence this hotspot has not been progressed further.
■ Hotspot 14	Royston	Significant investigation into the status and performance of the many soakaways and their associated infrastructure would be required. This would not meet the timescales or budget constraints associated with the SWMP. This is not to be progressed for further assessment at this stage, but to be considered for an individual study at a later date.

1.4 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 District of North Hertfordshire has suffered flooding in February 2014 and more recently in June 2016. 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 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 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

North Hertfordshire District is a local authority in Hertfordshire, England that includes the urban districts of Baldock, Hitchin, Letchworth Garden City and Royston, and the Hitchin Rural District. Figure 2 illustrates the location of the North Hertfordshire district; the area of the district is 375.4km^2.

There are three river catchments within North Hertfordshire District, shown in Figure 3:

- The "Upper and Bedford Ouse" catchment, shown in pink in Figure 3, covers the settlements of Hitchin, Letchworth Garden City and Baldock. This has one Main River, the River Purwell which discharges into the River Ivel north of the district.
- To the south and west of the district, the "Upper Lee" catchment, shown in orange in Figure 3, has a number of Main Rivers including the source of the River Mimram and the River Rib in the west. This catchment drains in a southerly direction into the District of East Hertfordshire.
- The "Cam and Ely Ouse" catchment, shown in green in Figure 3, covers the settlement of Royston. There are no Main Rivers in this catchment within the District of North Hertfordshire.

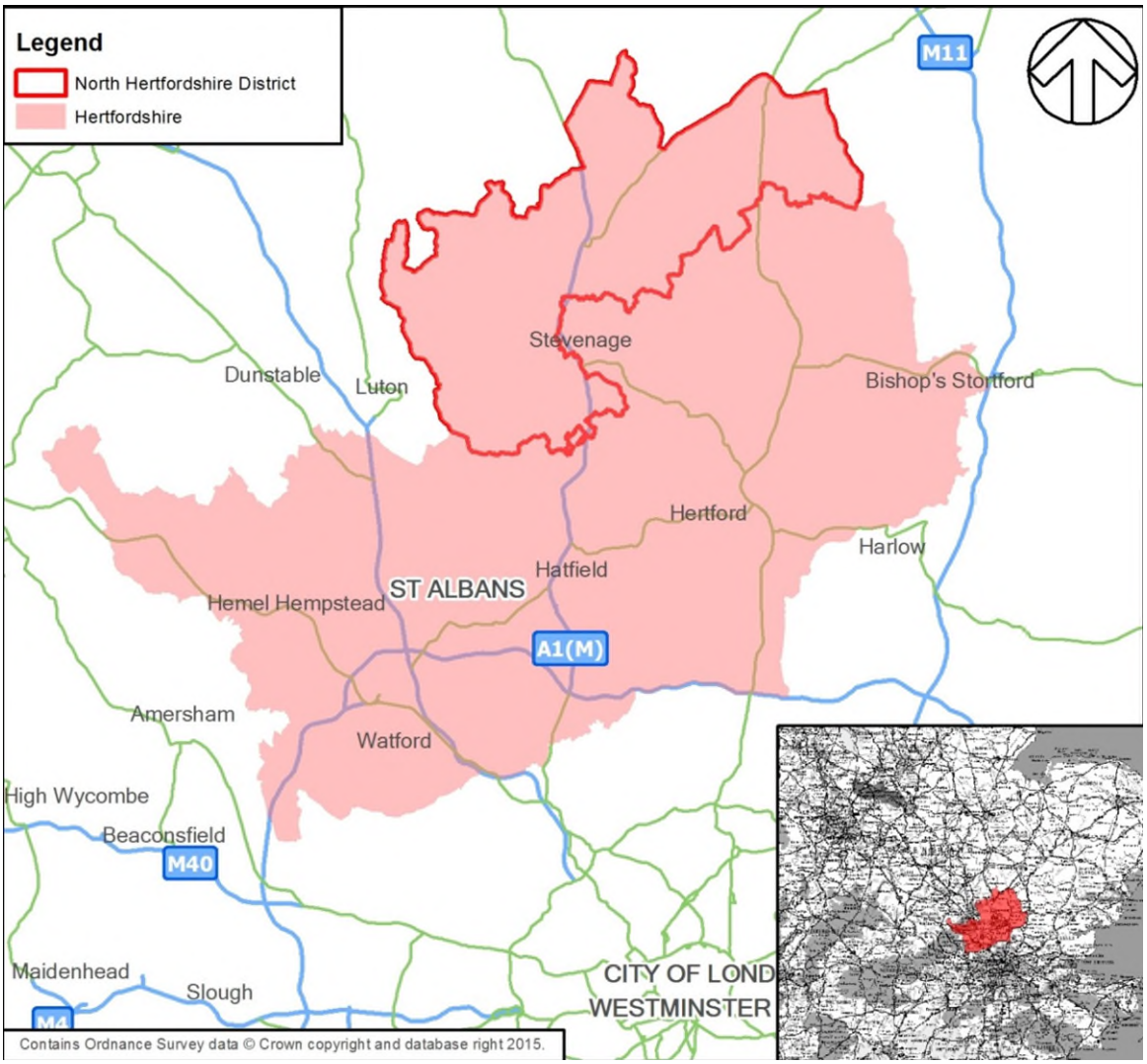


Figure 2: District of North Hertfordshire Location Plan

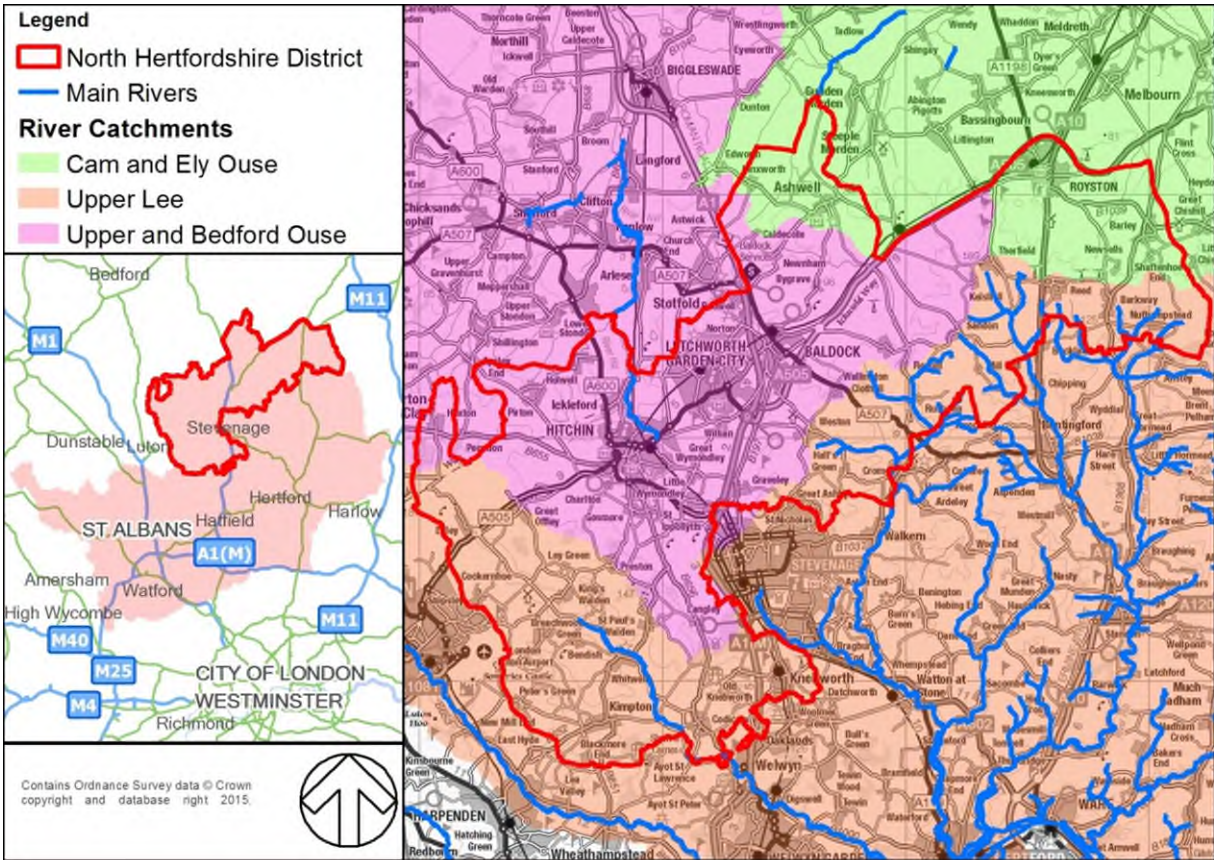


Figure 3: River Catchments within the District of North Hertfordshire

The British Geological Survey (BGS) mapping indicates that North Hertfordshire is underlain by various chalk formations as shown by Figure 4.

In general, chalk catchments are considered to be permeable with large proportions of the rain falling on the ground able to infiltrate, providing baseflow to the surface water features, often delaying the flood peak. Certain types of storms, particularly heavy summer storms, can however lead to flooding.

The majority of the bedrock underlying the district 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.

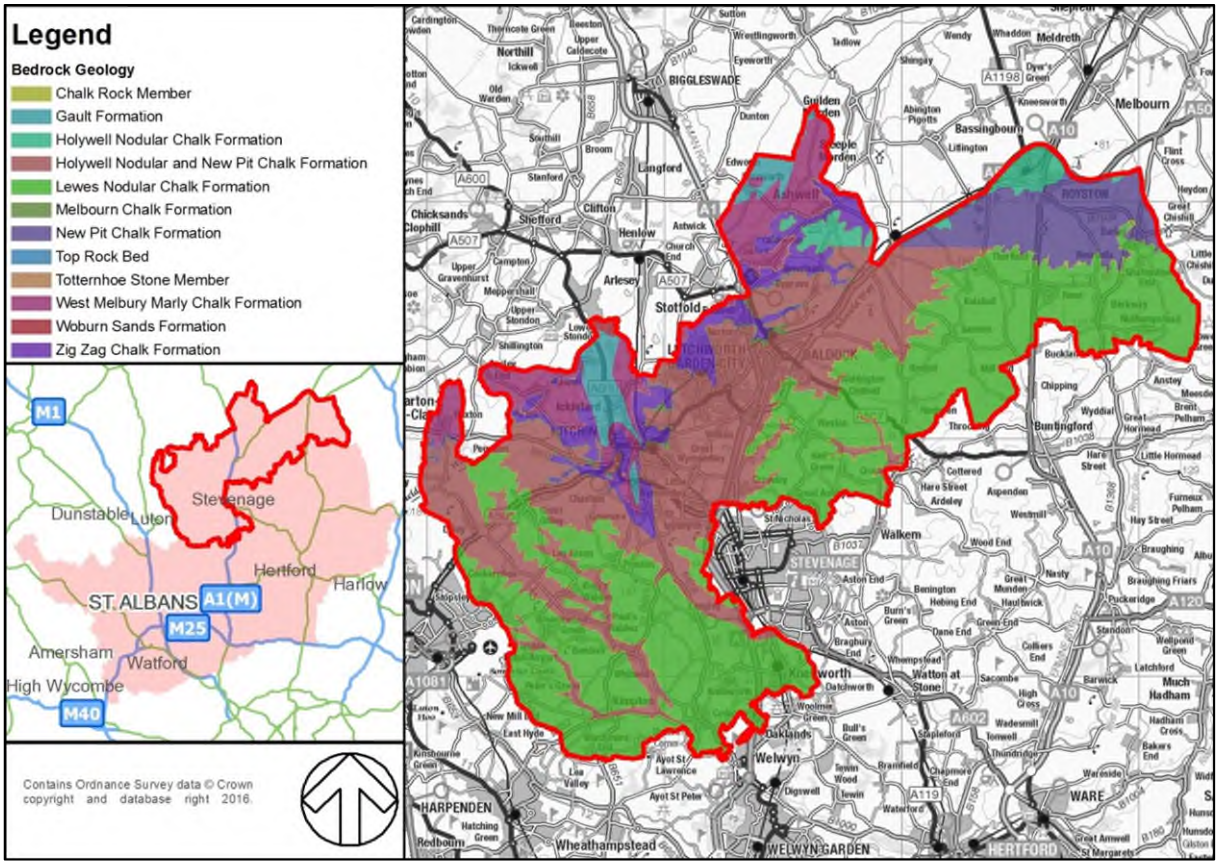


Figure 4: British Geological Survey Map of North Hertfordshire District – Bedrock Deposits

Figure 5 shows the superficial deposits overlaying the chalk bedrock. The superficial deposits include a number of different formations but most are as a result of glacial deposits during the Pleistocene Epoch. Infiltration rates will be localised depending on deposit type and depth.

The majority of the superficial deposits are classified 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.

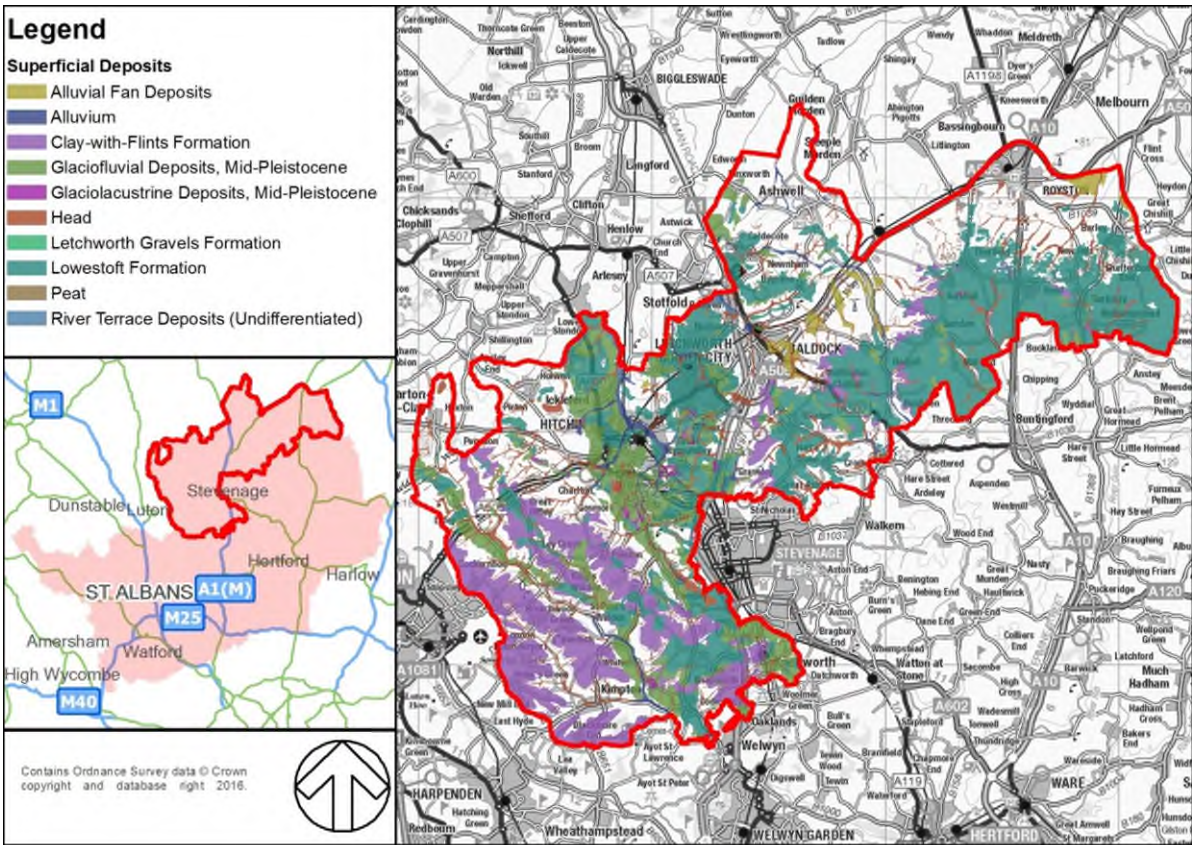


Figure 5: British Geological Survey Map of North Hertfordshire District – Superficial Deposits

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[3]:

[3] Page xvi, Paragraphs i29 to i32.

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

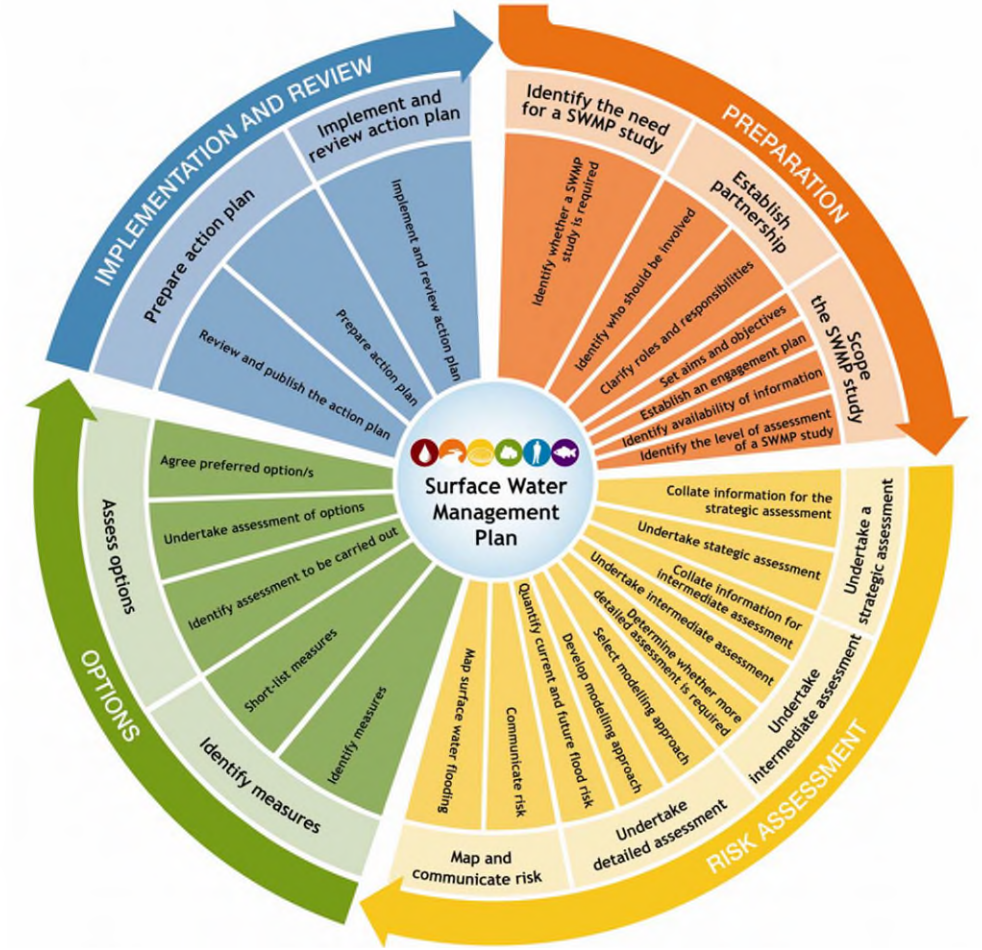


Figure 6: Different Stages of a SWMP study

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 below.

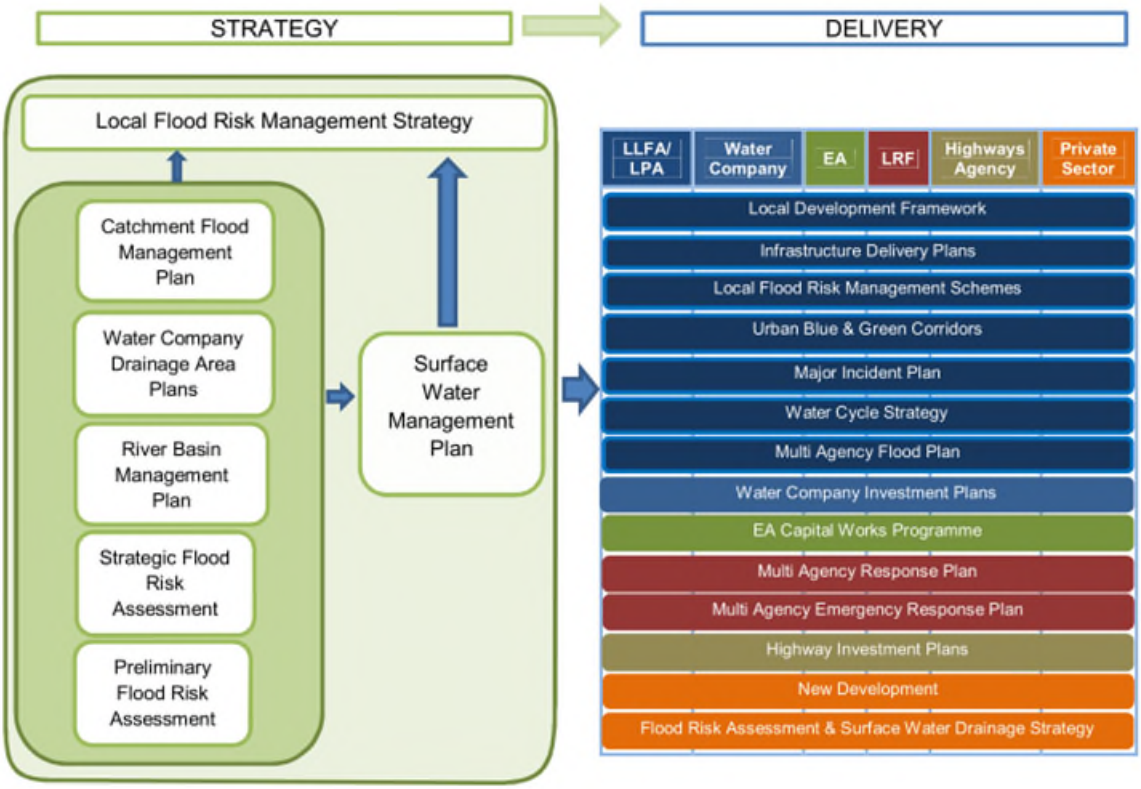


Figure 7: Link between Surface Water Management Plans and other Strategies, Plans and Policies

STRATEGIC FLOOD RISK ASSESSMENTS (SFRAS)

The Planning Practice Guidance states the following with regards to Strategic Flood Risk Assessments[4]:

"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 are key strategic documents that outline future flood risk management policies on a catchment by catchment basis. A large proportion of the North Hertfordshire District area lies within the Great Ouse CFMP, the remainder lies within the 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.

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

Figure 8 illustrates the area extents of the River Thames CFMP and River Great Ouse CFMP within the District of North Hertfordshire.

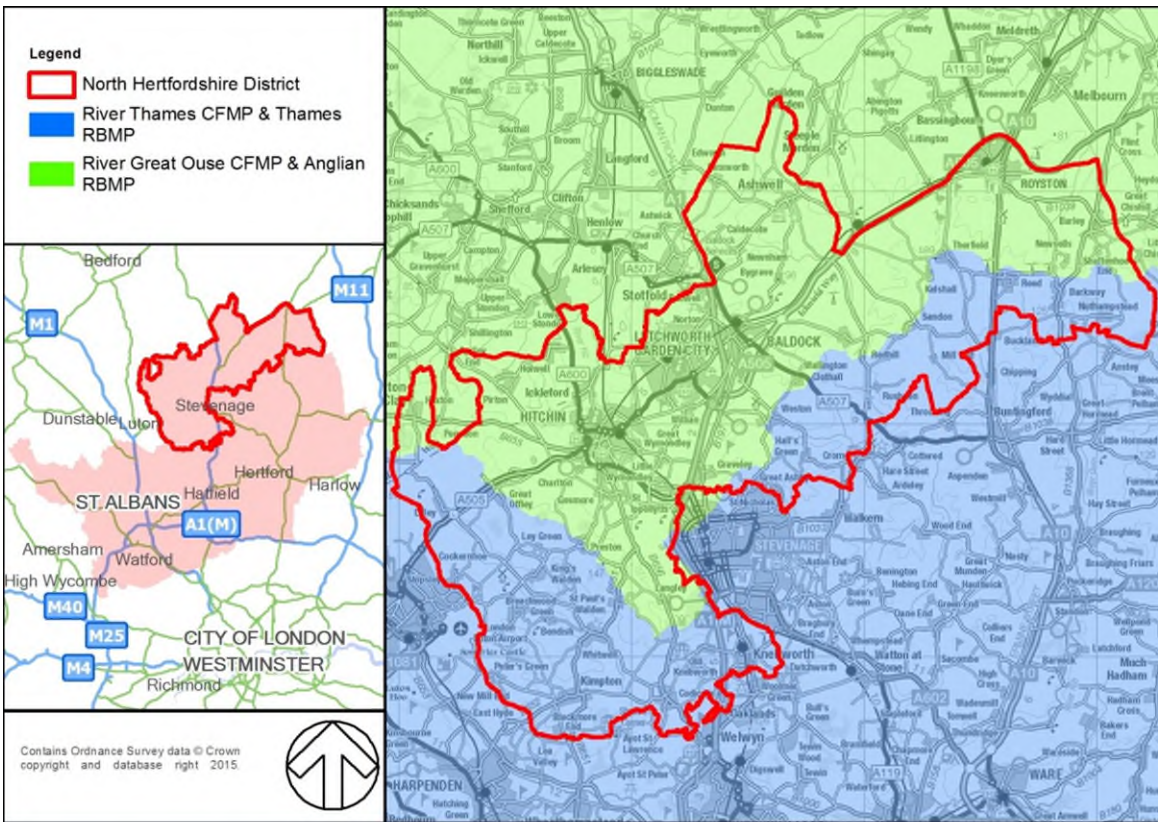


Figure 8: Environment Agency CFMP Areas and RBMP Areas covered within the District of North Hertfordshire

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)

North Hertfordshire mainly lies within the Anglian RBMP however, some areas to the south of the district fall within the Thames RBMP Figure 8 shows which areas of North Hertfordshire are covered by the Anglian and Thames River Basin Management Plans. The Following is quoted from the 2009-2015 Anglian RBMP but is similarly applicable to the Thames RBMP Area[5]:

“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

[5] https://www.gov.uk/government/publications/anglian-district-river-basin-management-plan

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:

- *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[6] covers small parts of North Hertfordshire District and was produced by Hyder Consulting (UK) Limited in October 2009. Please refer to Figure 9 for a map showing the Districts covered by this Water Cycle Strategy. This WCS is intended to form part of the Local Authorities' evidence base for their LDFs, and sets out the water and wastewater

[6] Stevenage Borough Council. Rye Meads Water Cycle Strategy. Detailed Study Report. October 2009

infrastructure, amongst other measures, that will need to be in place to achieve their growth targets.

A separate WCS covers the Royston Sewage Treatment Works (STW), produced in 2012 and assesses the growth targets around Royston in respect to the Royston STW. The sewage treatment works covering the settlements of Hitchin, Baldock and Letchworth Garden City were deemed to not need a Water Cycle Assessment.

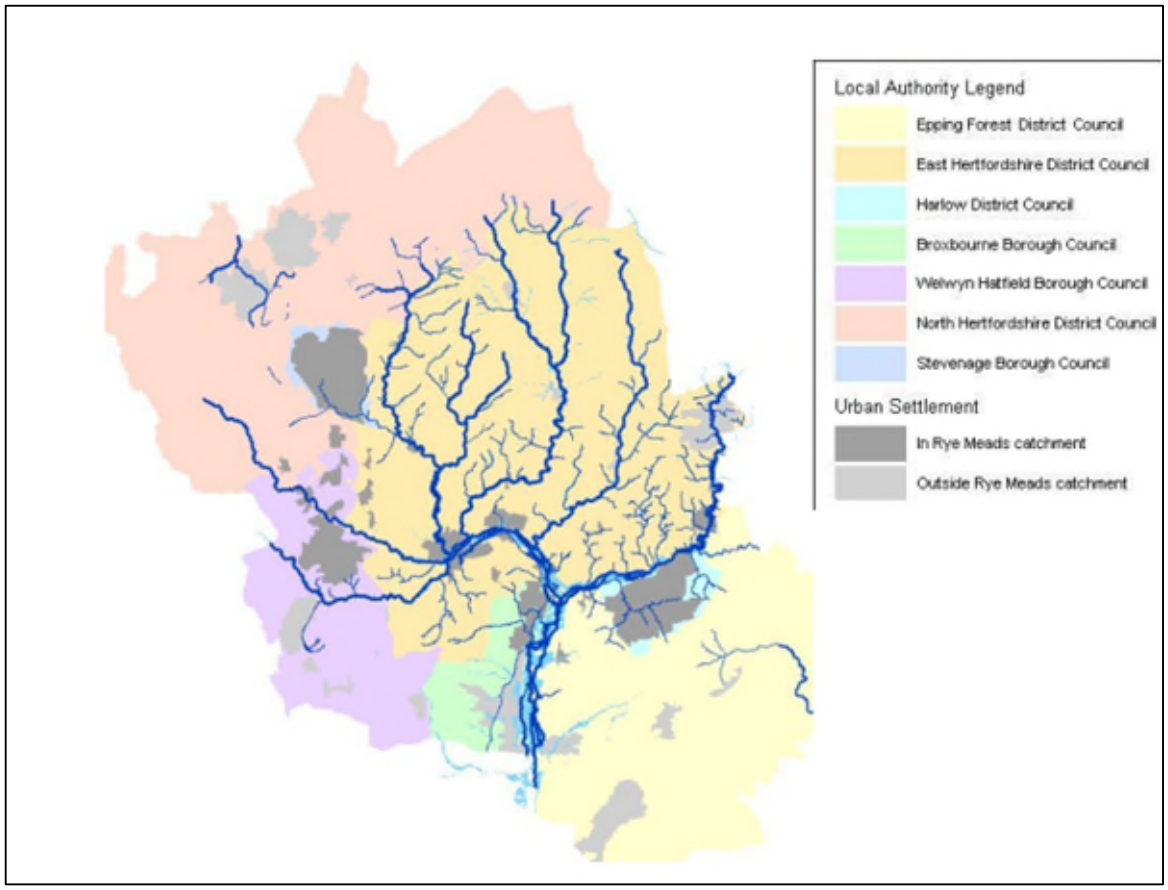


Figure 9: Rye Meads Water Cycle Strategy Study Area. (Rye Meads Water Cycle Strategy, Detailed Study Report, October 2009, page 11).

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 by which the county council will achieve this vision are set out below and actions and measures that have been developed to achieve these objectives are set out in Section E7 of the 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) sets 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"7 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)8.
- **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 objectives:

- 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

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

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.

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 North Hertfordshire District 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 North Hertfordshire District SWMP was produced in consultation with:

- Hertfordshire County Council;
- North Hertfordshire District Council;
- Anglian Water;
- 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 agreed 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 North Hertfordshire District;

- Establish the areas at significant risk9 of flooding and the potential impacts;
- 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; and
- Develop an Action Plan to reduce the flood risk within the North Hertfordshire District.

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;
- North Hertfordshire Strategic Flood Risk Assessment10 (SFRA), July 2008;
- Rye Meads Water Cycle Study, Outline Study Phase 1 (WCS), 2009;
- Royston Sewage Treatment Works Water Cycle Study, August 2012;
- Anglian River Basin Management Plan (RBMP), 2009;
- Thames River Basin Management Plan (RBMP), 2009;
- River Great Ouse Catchment Flood Management Plan (CFMP), January 2011;
- 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.

[9] 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.

[10] WSP (2008) North Hertfordshire District Council Strategic Flood Risk Assessment, July 2008

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 North Hertfordshire District 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:

- North Hertfordshire, Strategic Flood Risk Assessment, July 2008;
- 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 North Hertfordshire District.

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 district. 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);
- North Hertfordshire Level 1 Strategic Flood Risk Assessment, Feb 2009;
- 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 North Hertfordshire District 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 North Hertfordshire Level 1 SFRA (July 2008) establishes that fluvial flooding is the dominant source of flooding within North Hertfordshire. North Hertfordshire District is split between the catchments of the River Ivel and the River Lea which drain in a northerly and southerly direction respectively.

The River Ivel is served by its tributaries the Pix Brook, the River Purwell, the River Hiz and the River Oughton and is part of the River Great Ouse CFMP. In North Hertfordshire, the River Lea catchment is served by the Rivers Mimram and Kym and is part of the Thames CFMP.

FLOOD RISK FROM CANALS

There are no canals as managed by the Canals and Rivers Trust within the district of North Hertfordshire. There is therefore no risk of flooding from canals

SURFACE WATER FLOODING

Local knowledge was used to pinpoint instances of surface water flooding. However, only broad areas were identified (by the Local Planning Authorities and 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. Areas identified are as follows:

- ***Knebworth –*** *Flooding on the 7th February 2014, flooded 18 properties internally with a further two properties suffering external flooding. It was concluded that the flooding was a result of successive storms combined with heavy rainfall over an extended period of time saturating the surrounding catchment prior to the event. As a result, rainfall on the morning of 7th February 2014 was unable to infiltrate and instead ran-off to the edge of farmland and subsequently flooded the properties. Other factors identified include possible overspill of the A1(M) attenuation storage pond and the existing highway drainage being unable to cope with the volume of flood water.*
- ***Little Wymondley –*** *Flooding on 7th February 2014 (the same event as Knebworth) caused internal damage to at least four residential properties and one commercial property. Flooding also made the main road impassable, those vehicles that did make it through created bow waves which increased the impact of flooding. It was concluded that the flooding occurred as a result of prolonged rainfall which saturated the catchment of Ash Brook prior to the event. Whilst prolonged rainfall was the main cause, other factors were identified such as blocked trash screens, culverts with insufficient capacity and a lack of maintenance to the watercourse. There has been a history of flooding in the same locations with varying severity.*
- ***Kimpton –*** *The village is built along the course of the former River Kym. The river appeared in 1975 and briefly in 1947 following snowmelt. The river emerged again in 2001 due to a large amount of winter rainfall. The river followed its natural course through Kimpton to join the River Mimram at Kimpton Mill. However, during prolonged wet weather in the winter of*

2013/14 flooding within Kimpton did not occur despite groundwater flooding elsewhere in the Thames Valley.

GROUNDWATER FLOODING

Groundwater flooding occurs when the water held underground rises to a level where it breaks the surface in areas away from usual channels and drainage pathways. 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. Once groundwater flooding has occurred, the water can be in situ for a lengthy period of time.

The presence of the chalk aquifer in Hertfordshire and other underground water bearing areas such as the river gravel deposits, mean that there is potential for groundwater flooding. There are confirmed cases, both widespread and in settlements known to be at particular risk.

As detailed in Section 3.3 North Hertfordshire District is predominantly underlain by chalk formations and much of it is water bearing aquifers. This is overlain by superficial deposits, mainly composed of clays and silts which will provide some capping to the aquifers underneath.

As a result, there is a risk of artesian conditions within the chalk aquifers below clay deposits and where superficial deposits become sandier in nature, there is a risk that high groundwater levels could lead to 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 companies for the District (Anglian Water and Thames Water) have 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 have subsequently supplied 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.

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[11]:

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

11 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/297432/LIT_8988_0bf634.pdf

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 North Hertfordshire District 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).

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 across North Hertfordshire District. From this, 17 hotspots were analysed using a GIS Multi-Criteria Analysis (MCA) to prioritise the hotspots most at risk of flooding within the district.

A stakeholder meeting was held on 3rd February 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 in February 2015. 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 11 Letchworth Garden City
- Hotspot 12 Baldock Centre
- Hotspot 6 Hitchin
- Hotspot 14 Royston
- Hotspot 17 Knebworth

Following stakeholder engagement and site visits, three of the Desk-Based Identified Hotspots and three Stakeholder Identified Hotspots were chosen to be considered for hydraulic modelling, and further analysis in the Modelling Methodology Technical Note. The six hotspots to be taken forward for further assessment are below, these are SWMP Modelled Hotspots:

- Hotspot 6 Hitchin
- Hotspot 7 Oakfield, Hitchin
- Hotspot 12 Baldock
- Hotspot 13 Clothall Common, Baldock
- Hotspot 17 Knebworth
- Hotspot 30 Cambridge Road, Hitchin

These six SWMP Modelled Hotspots have been assessed as to the suitability of modelling and those to be taken forward as SWMP Modelled Hotspots have been determined from the list of hotspots analysed for both the District of North Hertfordshire and the Borough of Dacorum (as these were assessed in tandem). SWMP Modelled Hotspots have been modelled prior to undertaking a mitigation and economic assessment. Further information on the hotspots taken forward as SWMP Modelled Hotspots can be found in the Modelling Methodology Technical Note in Appendix B.

The hotspots detailed in Table 1 are not being progressed further as SWMP Modelled Hotspots; however these are included in the SWMP as SWMP Non-Modelled Hotspots. Possible actions and mitigations are provided where appropriate.

Table 1: Recommendations and Actions for the District of North Hertfordshire – SWMP Non-Modelled Hotspots

HOTSPOT NUMBER	LOCATION	RECOMMENDATIONS AND ACTIONS
■ Hotspot 5	Kimpton	A separately commissioned study was undertaken for Kimpton, apart from this SWMP. The modelling undertaken as part of this study has shown that the significant flood risk is from the emergent groundwater flowing into the village. However, the improved topographical data has revealed the surface water flood risk is not as extensive as first anticipated.
■ Hotspot 11	Letchworth Garden City	North Hertfordshire District Council have recently completed a scheme within the hotspot. It was therefore felt that further funding would be unlikely, hence this hotspot has not been progressed further.
■ Hotspot 14	Royston	Significant investigation into the status and performance of the many soakaways and their associated infrastructure would be required. This would not meet the timescales or budget constraints associated with the SWMP. This is not to be progressed for further assessment at this stage, but is to be considered for an individual study at a later date.

6 DETAILED RISK ASSESSMENT - APPROACH

6.1 INTRODUCTION

The intermediate assessment (Section 5.4) identified six hotspots for a detailed assessment of surface water flood risk through hydraulic modelling. The Defra 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 2.[12]

Table 2: Key components of detailed assessment *(based on Table 6-1 in the Defra 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 (Local knowledge (Hertfordshire County Council/North Hertfordshire District Council/Environment Agency/Thames Water /Anglian 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 six hotspots identified for further assessment within the intermediate phase are covered in turn below, with their specific considerations, modelling approach and summarised. Further more specific 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

[12] 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

accuracy of around 1m +/- RMSE and a horizontal accuracy of 2.5m +/- RMSE). In some 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, within North Hertfordshire District. 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 ratioed 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 flow path to be better represented within the model. 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 225m;

- Flow between the pipe network and the flood plain was represented by connectors at every pipe junction;
- Pipe information was sourced from the sewage undertaker (i.e.Thames Water/Anglian 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 flow paths (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 the Cambridge Road Hotspot, where 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

[1] Published by the Environment Agency as Operational Instruction 197_08, Version 3 on 06/11/2009

Document[13] 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;
- 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 3 were considered to ensure the options were viable and beneficial.

Table 3: 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?

[13] Defra/Environment Agency R&D Outputs: Flood Risks to People, Phase 2 FD2321/TR2

In addition to the criteria in Table 3, it was considered that certain land uses (e.g. cemeteries) are unsuitable for flood storage.

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 prevention 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)[14] and the 'Green Book' (HM Treasury, 2003)[15].

The properties shown by the hydraulic modelling to be within the main surface water flow paths 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 flow paths in each hotspot, for the mitigation specific standard of protection , which the SWMP will

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

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.

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 6.4above. 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.

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%).

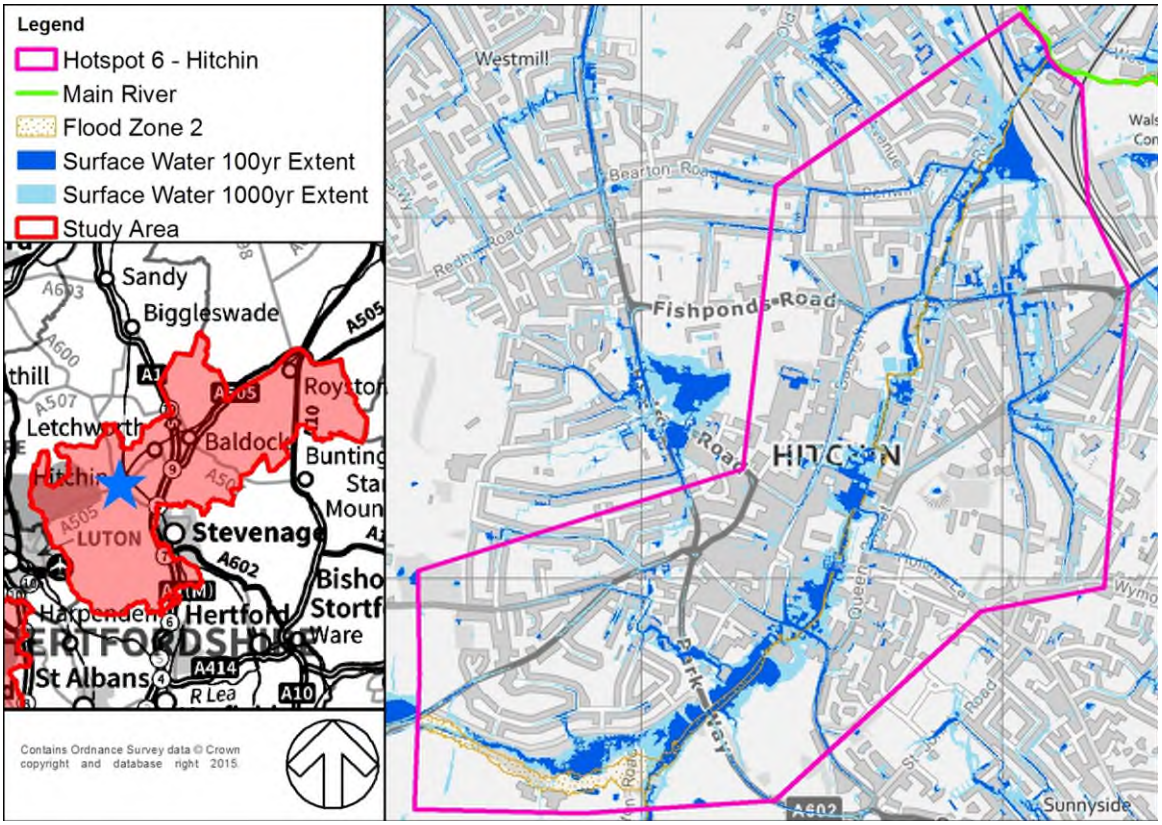
7.2 HOTSPOT 6 - HITCHIN

KEY CONSIDERATIONS

It was decided that this area of Hitchin 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 elements (as shown in Figure 11):

- The Environment Agency's Risk of Flooding from Surface Water map which shows:
  - A medium to high risk of flooding from surface water around the upstream face of the culvert underneath the railway line associated with the River Hiz.

Figure 11: Hotspot 6 - Hitchin– extents and baseline information



HYDRAULIC MODEL SUMMARY

The model has been developed in ESTRY-TUFLOW with a direct rainfall approach utilising the uFMfSW DTM for the whole study area. An existing Environment Agency model is available for the River Hiz that flows through the centre of Hitchin. The existing model was assumed to be suitable for use in this study, given that it was developed for the Environment Agency, and it was incorporated into the modelling of this hotspot. The model domain for Hotspot 6 was extended to include the entire length of the River Hiz from its origin near Wellhead Farm to its confluence with the River Purwell.

Key Constraints

No significant constraints with the surface water model construction were observed. The fluvial model will require improvements to bring it up to current best practise, if it is to be used in future stages to refine the option assessment and support an application for funding.

Key Assumptions and Limitations

The accuracy of the eastern tributary of River Hiz and other watercourses that were not included in the existing Environment Agency model would be lower, as additional topographical survey was not extensively sought with channel characteristics obtained from the uFMfSW DTM.

If the options are to be assessed further, alternative probability scenarios should be investigated to assess the potential interactions between the surface and fluvial flooding mechanisms and pathways.

A conservative approach has been adopted on the eastern tributary of the River Hiz prior to it flowing past The Willows. This has involved positioning the inflow to the watercourse downstream

of the A505, thus not including any flow constriction/ attenuation offered by the highway culvert. More extensive topographical survey should be sought to inform further optioneering models.

Key Findings

The key findings of the hydraulic modelling for the 1 in 30 and 1 in 100 year events are shown in Table 4, Table 5 and Table 6 for the key parts of the upstream, central and downstream areas respectively; mapping of the whole hotspot is in Appendix D, which provides better resolution maps and a legend.

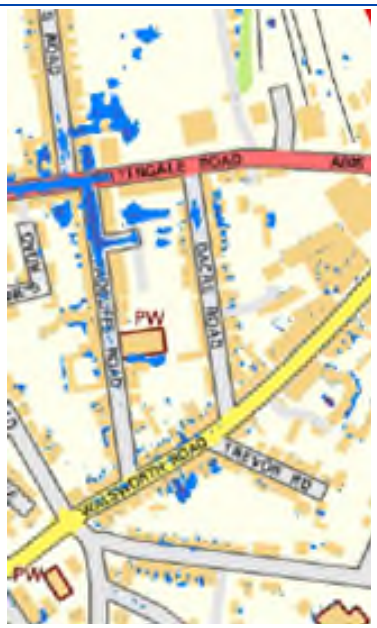
Table 4: Key Findings – Hotspot 6 - Hitchin - Upstream

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
Flood Depth	Flooding is predicted along Wratten Close and across the underpass along Park Way (maximum depth of 2.3 m in the underpass and 0.4 m along the road).	Flooding along Wratten Close follows the same path as the 1 in 30 year event but is deeper and more extensive (maximum depth increases to 2.5 m in the underpass and 0.5 m along the road).
		
Hazard	It is predicted that there is an area of danger for most along Wratten Close and an area of danger for all in the underpass below Park Way.	Flood hazard shows the same pattern as in the 1 in 30 year outline but the extent of the area of danger for most has increased in this event.
		

Table 5: Key Findings – Hotspot 6 - Hitchin - Central

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
	Flooding is observed along Portmill Lane, Hermitage Road, Hazelwood Close, Grove Road and the A505. It is mainly contained to the roads with a maximum depth of 0.5 m but houses at the western end of Hazelwood Close are shown to experience flooding with a depth of up to 0.9 m.	Significant flooding is observed along Portmill Lane, Hermitage Road and Hazelwood Close during the 1 in 100 year event. Water along Portmill Lane will spill downstream to impact properties north of the road. A maximum flood depth of 1.8 m is predicted in this area. Flood depth around the area west of Hazelwood Close is similar to that in the 1 in 30 year event but the extent of flooding has increased.
		
	The regions of high flooding equate to danger for some, with a small area of danger for most predicted at the western end of Hazelwood Close.	The extent of the hazard areas increases significantly with danger for most predicted for the area around Portmill Lane, along Hermitage Road, west of Hazelwood Close, along Grove Road and the A505.
		

Table 6: Key Findings – Hotspot 6 - Hitchin - Downstream

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
	Flooding is predicted to properties along Walsworth Road from runoff draining from The Avenue and Benslow Lane. Flooding in this area reaches a maximum depth of 0.4 m. Runoff along Walsworth Road will drain towards Radcliffe Road and then to the A505 road. Maximum flood depth along Radcliffe Road reaches approximately 0.4 m.	Flooding across properties along Walsworth Road increases, with depths rising to 0.6 m at the deepest points. Flooding along Radcliffe Road also increases, with the maximum flood depth approaching 0.6 m. In addition, the area between Radcliffe Road and Dacre Road shows greater flooding due to increased runoff contribution from the roads.
		
	It is predicted that there is danger for some around the properties along Walsworth Road but the deep areas of flooding along Radcliffe Road pose danger for most.	The hazard rating for some of the properties along Walsworth Road has increased to danger for most in this event. The area that poses danger for most along Radcliffe Road has extended to include the A505.
		

Sensitivity Testing

Sensitivity testing was undertaken on inflows by the A505 road and at Charlton. The flood extents were not deemed to be overly sensitive to the changes in inflows, with water levels varying by no more than ± 3 mm.

POTENTIAL MITIGATION

Mitigation measures which could be considered for Hotspot 6 - Hitchin are outlined below and shown in Appendix E:

- Large storage area to the west of Park Way to reduce river levels throughout the town.
- Identify suitable storage or attenuation area upstream of Park Way to reduce river flows downstream and therefore the potential risk of fluvial flooding.
- Site visit to determine if Property Level Measures are required in Radcliffe House.
- Site visit to confirm the flowpaths from Sun Street and Bridge Street t the car parks. Some landscaping may be required within the car park to encourage flows towards the river. Property Level Measures at the junction of Sun Street and Bridge Street.
- Speed bump along Queen Street to minimise water draining into Portmill Lane. Minor landscaping of Queen Street is also recommended to encourage water to flow towards the car park and then into the river south of Portmill Lane.
- Upsize pipes that run from Hazelwood Close to the river to reduce localised flooding.
- Install pipes along The Avenue to reduce flooding of Walsworth Road and Radcliffe Road. It is recommended that the pipes along Verulam Road are upgraded.
- More detailed modelling is required to confirm flow paths at the intersection between Grove Road and the A505.

RECOMMENDATIONS

The following recommendations are made for further consideration of this site and for inclusion within the action plan:

- It is necessary to carry out more detailed modelling to confirm the flow paths around the risk areas. This will involve an in-depth review of the existing Environment Agency model and potentially upgrade or redevelop the 1D component of the model to improve accuracy.
- Secure funding to further investigate the mitigation measures outlined above to assess and enable their implementation.
- Encourage flood awareness and Property Level Measures in areas of risk.
- Ensure the highway gully maintenance programme is representative of the flood risks and preferential flow paths.
- Topographic survey of the watercourse that drains through The Willows may be required to confirm its flow path towards the River Hiz and its interaction with the A505 road upstream.

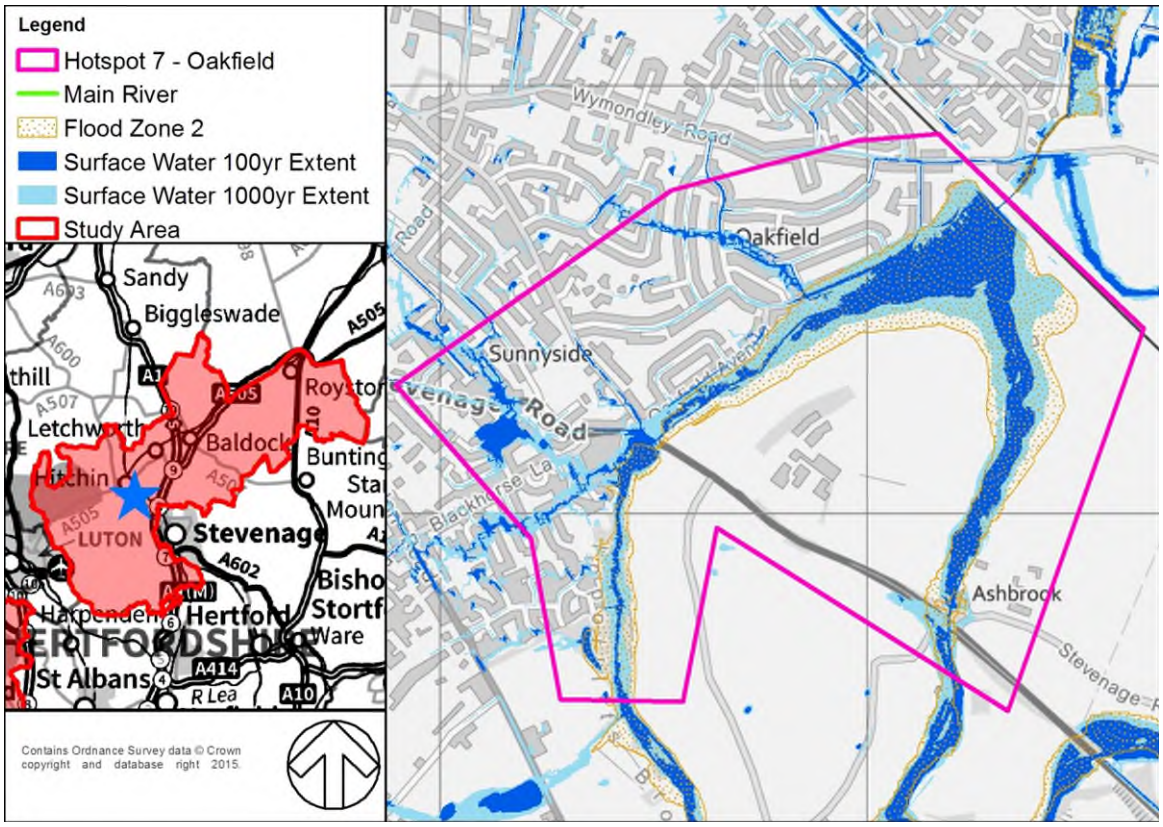
7.4 HOTSPOT 7 – OAKFIELD

KEY CONSIDERATIONS

It was decided that Oakfield 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 elements (as shown in Figure 12):

- The Environment Agency's Risk of Flooding from Surface Water map which shows:
  - Medium to high risk of flooding around Ippollitts Brook and Ash Brook.
- The Environment Agency's Flood Map for Planning which shows:
  - Flood Zone 2 along this section of the watercourses.
- There is a risk in relation to the blocking of the culverts underneath the A602 and the railway.

Figure 12: Hotspot 7 - Oakfield– extents and baseline information



HYDRAULIC MODEL SUMMARY

The existing 2008 1D InfoWorks model (provided by the Environment Agency), was adapted to form a 1D-2D InfoWorks Integrated Catchment Model (ICM) with a direct rainfall approach and extended to include Ash Brook.

Key Constraints

No significant constraints with the surface water model construction were observed.

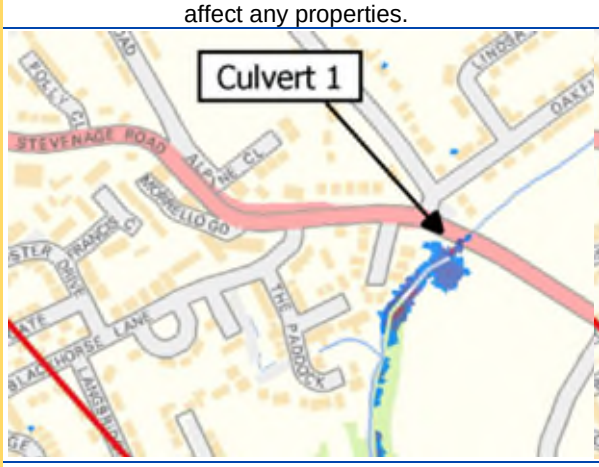
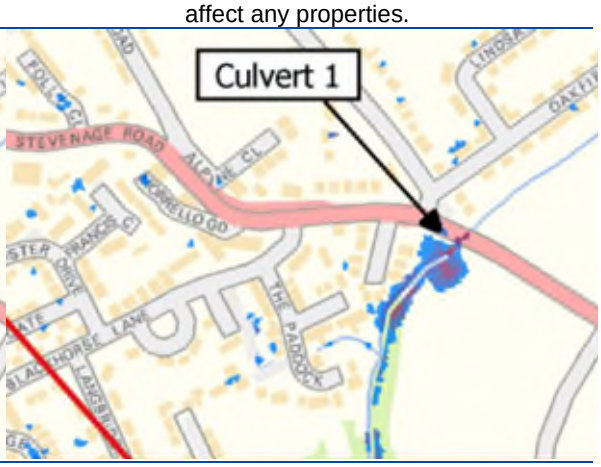
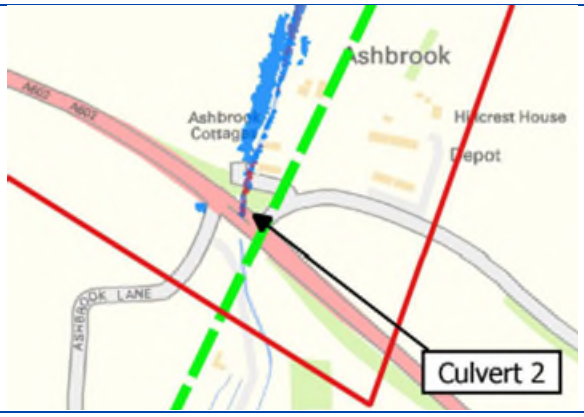
Key Limitations

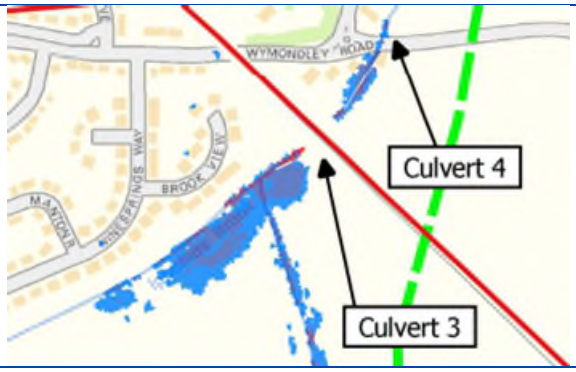
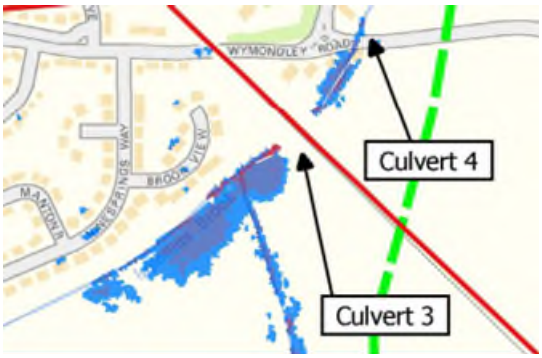
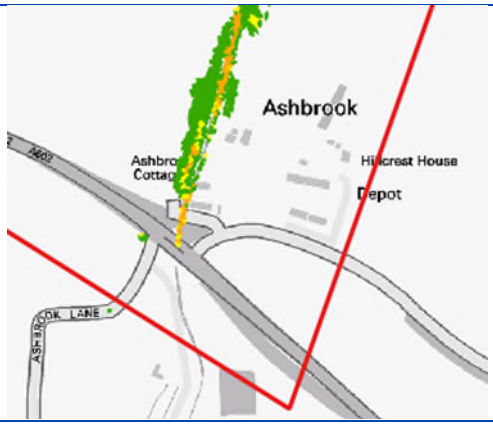
The accuracy of the watercourses is based upon the existing Environment Agency model, given the date of construction the survey would not have been based upon current best practise of GPS datum's. If this model is to be utilised to inform any design works then consideration should be given to enhancing the survey.

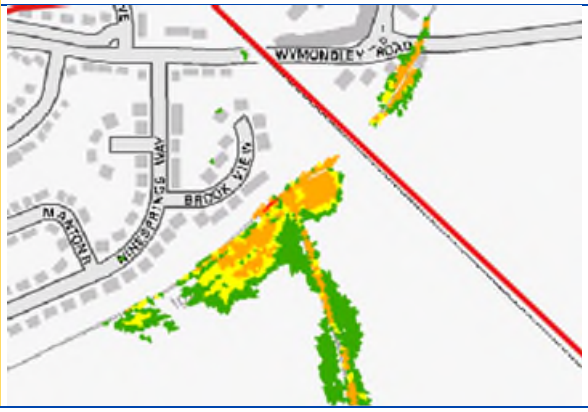
Key Findings

The key findings of the hydraulic modelling are detailed in Table 7 below for the critical 1 in 30 and 1 in 100 year events, snap shots of the key flooding extents are provided; mapping of the whole hotspot is in Appendix D, which provides a better resolution and colour key.

Table 7: Key Findings – Hotspot 7 - Oakfield

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
Flood Depth	Interrogation of the model confirms that limited flooding is predicted on Stevenage Road (A602). The flooding is limited to being around Ippollitts Brook culvert, with depths up to 0.6m. Flooding does not affect any properties.	Interrogation of the model confirms that limited flooding is predicted on Stevenage Road (A602). The flooding is limited to being around Ippollitts Brook culvert, with depths up to 0.6m. Flooding does not affect any properties.
		
	Limited highway flooding is predicted where Stevenage Road (A602) crosses Ash Brook, with depths up to 0.2m.	Little change between the 1 in 30 year and 1 in 100 year event. Limited highway flooding is predicted where Stevenage Road (A602) crosses Ash Brook, with depths up to 0.2m.
		

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
	Some flooding on Wymondley Road where Ippollitts Brook crosses (Culvert 4), with depths up to 0.3m. Flooding is constrained to the existing floodplain of the watercourse with no property flooded predicted.	Little change between the 1 in 30 year and 1 in 100 year event. Depths in Wymondley Road increase to 0.6m. Flooding is constrained to the existing floodplain of the watercourse with no property flooded predicted.
		
Hazard	All the hazard ratings are around the Ippollitts Brook culvert. There is no hazard for Stevenage Road itself.	Little change between the 1 in 30 year and 1 in 100 year event.
		
	No hazard on Stevenage Road in around Ash Brook culvert.	Little change between the 1 in 30 year and 1 in 100 year event. No hazard on Stevenage Road in around Ash Brook culvert.
		

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
	There are areas showing danger for most in the existing floodplain.	Little change between the 1 in 30 year and 1 in 100 year event.
		

Sensitivity Testing

Sensitivity was not required to be undertaken for this hotspot.

POTENTIAL MITIGATION

Potential mitigation measures which could be considered to reduce the flooding on Stevenage Road at the culverted Ippollitts Brook (Culvert 1) are:

- Automated traffic signs;
- Reprofiling and new headwalls.

These options will be led by HCC and investigation will be needed into whether budget would be available from existing flood risk and highway funds.

RECOMMENDATIONS

The following recommendations are made for further consideration of this site and for inclusion within the action plan:

- Review of suitability of location and number of traffic warning signs where Wymondley Road crosses Ippollitts Brook (Culvert 4).

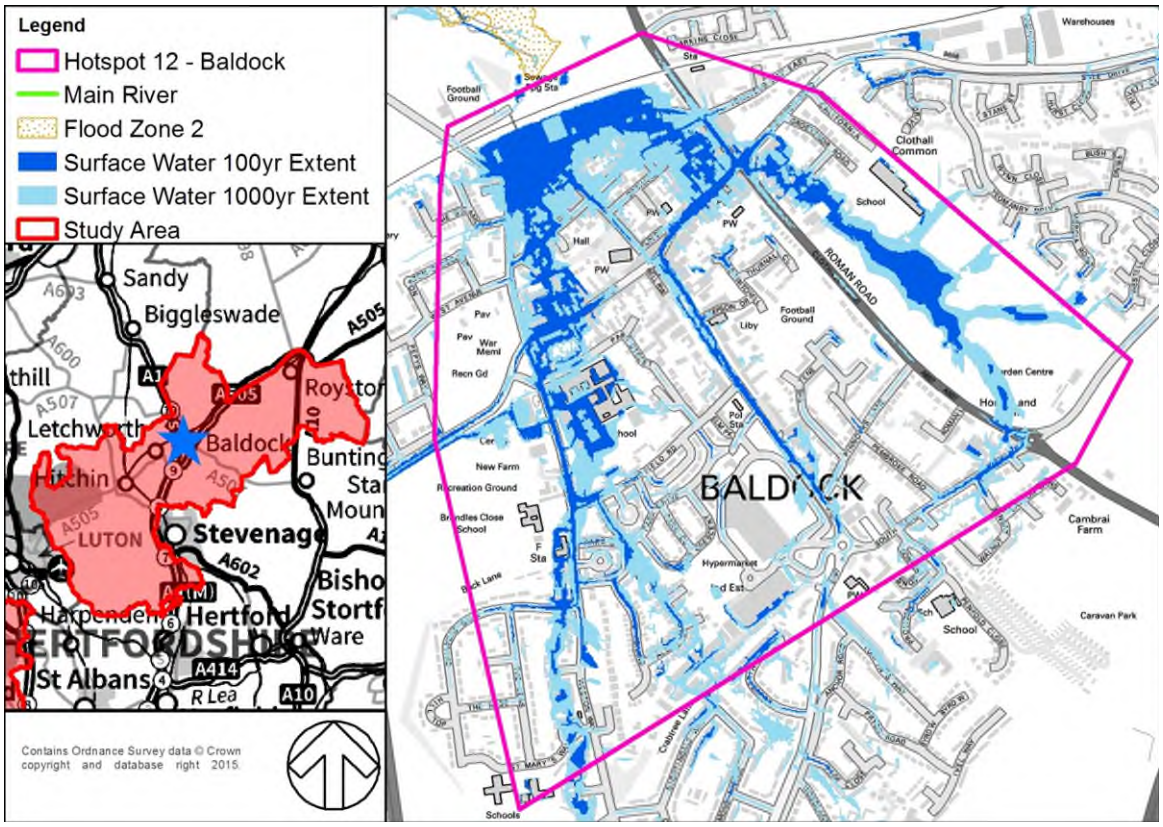
7.5 HOTSPOT 12 - BALDOCK

KEY CONSIDERATIONS

It was decided that Baldock 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 elements (as shown in Figure 13):

- The Environment Agency's Risk of Flooding from Surface Water map which shows:
  - Flooding across the northern part of the hotspot, to the south of the railway track (medium to high risk).
  - Potential flooding along overland flow paths along Weston Way, on High Street (B197) and east of Station Road / Clothall Road (A507).
- LiDAR data is limited for this hotspot. Therefore, this modelling have incorporated the uFMfSW DTM to ensure that flow conveyance routes are incorporated within the model rather than trying to refine the risks, within these areas.

Figure 13: Hotspot 12 - Baldock– extents and baseline information



HYDRAULIC MODEL SUMMARY

The model was developed in ESTRY-TUFLOW with a direct rainfall approach. This model covers both the Baldock and Clothall Common Hotspots as the catchments are adjacent and these are hydraulically linked through the surface water sewer network. Topographical data for the model consisted of the Environment Agency's updated Flood Map for Surface Water (uFMfSW) DTM supplemented with topographical survey data in key locations (see model reports in Appendix C).

Key Constraints

LiDAR data is available for only 38.5% of the catchment (mainly in the downstream area and to the west). NEXTMap data is available for the whole catchment. Considering this and that no more recent LiDAR was flown after the production of the uFMfSW, the uFMfSW DTM have been used in this model. In addition, topographical survey have been undertaken to provide input to the model, in particular to refine the flow paths beneath the railway.

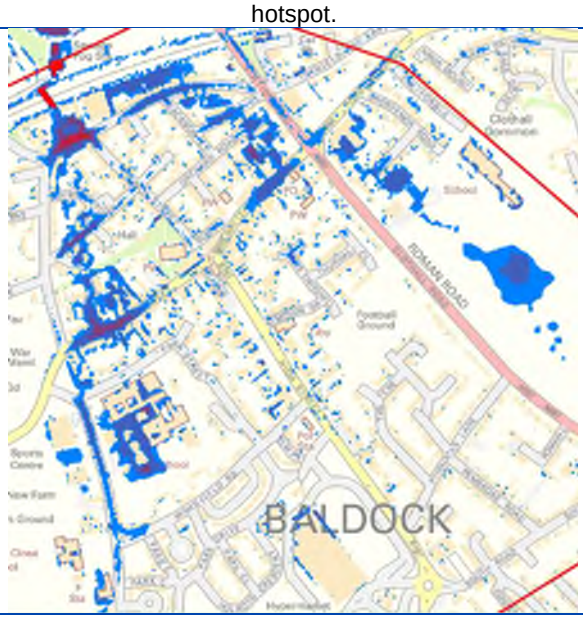
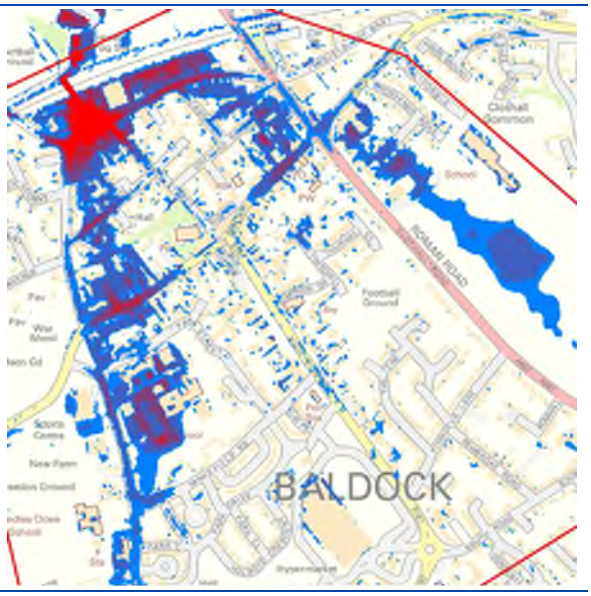
Key limitations

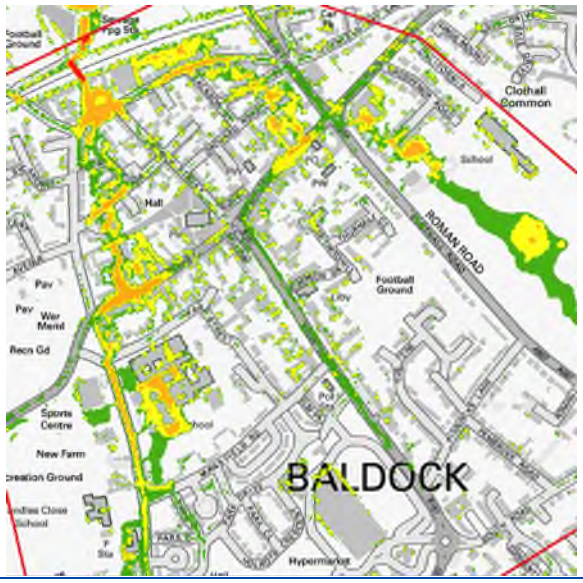
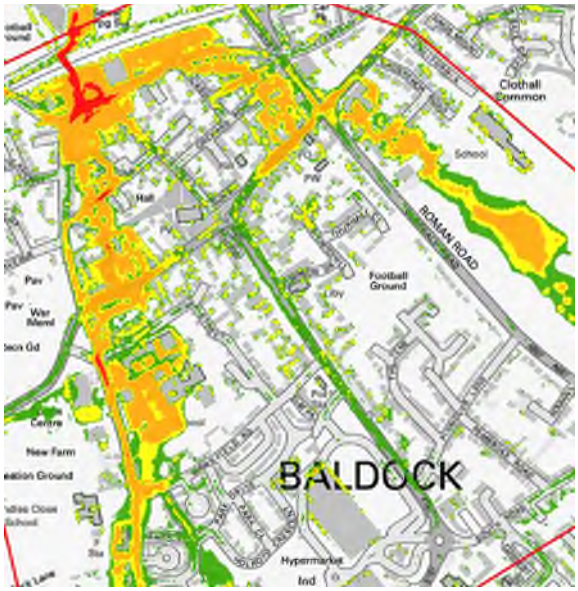
A 4m grid size was used because smaller grid sizes produced prohibitively long model runs due to the model size. Consideration should be given to reducing the grid size if undertaking refined option assessment.

Key Findings

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

Table 8: Key Findings – Hotspot 12 - Baldock

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
Flood Depth	Two flowpaths from the south converge in the north of the hotspot. Deep flooding is predicted on Icknield Way with depths up to 1.2m. Medium to deep flooding is predicted on and around Hitchin Street with depths up to 0.8m. Shallow to medium depth flooding is predicted to affect several roads in the north of the hotspot.	A larger area of deep flooding is predicted around Icknield Way with maximum depths up to 2.4m. Flooding of a greater depth and extent than the 1 in 30 is predicted to affect roads and properties in the north of the hotspot.
		

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
Hazard	There are areas of danger for most to the north of the hotspot (Icknield Way and Hitchin Street). The flowpaths from the southwest and southeast are mainly associated with very low hazard (caution) with some areas of showing danger for some. Danger for all is associated with the footpath under the railway.	Very extensive areas of danger to most in the north of the hotspot. Areas of danger for all on part of Icknield Way and towards the railway line. The flowpaths from the southwest and southeast are mainly associated with danger for most.
		

Sensitivity Testing

As the sensitivity testing of this joint model was undertaken in the Clothall Common section, to assess the impact of a blockage on the culvert that crosses the A505 in the vicinity of Wallington Road, the findings are detailed in the relevant section in 7.6.

POTENTIAL MITIGATION

Potential mitigation measures which could be considered for Hotspot 12 - Baldock are outlined below and shown in Appendix E:

- → Construct a surface water sewer beneath the public footpath in order to increase conveyance under the railway.
- → SuDS retrofit/detention basin/soakaway in playing fields upstream in order to reduce water flowing downstream.
- → Detention/soakaway – Natural FRM along flowpath to the east of the hotspot, as permissions/designation allow – this measure may be restriction because it is in a scheduled monument area.
- → Consider Property Level Measures for properties that have previously experienced flooding and are at high risk.

RECOMMENDATIONS

The following recommendations are made for further consideration of this site and for inclusion within the action plan:

- Construct a new culvert under the railway to increase conveyance in the long term (historical records of flooding required to support business case).
- Work with developers/planners to ensure suitable land use as warehousing redeveloped over the longer term.
- Consider purchasing one or more of the empty warehouses adjacent to the railway and the associated underpass to provide space for flood storage.

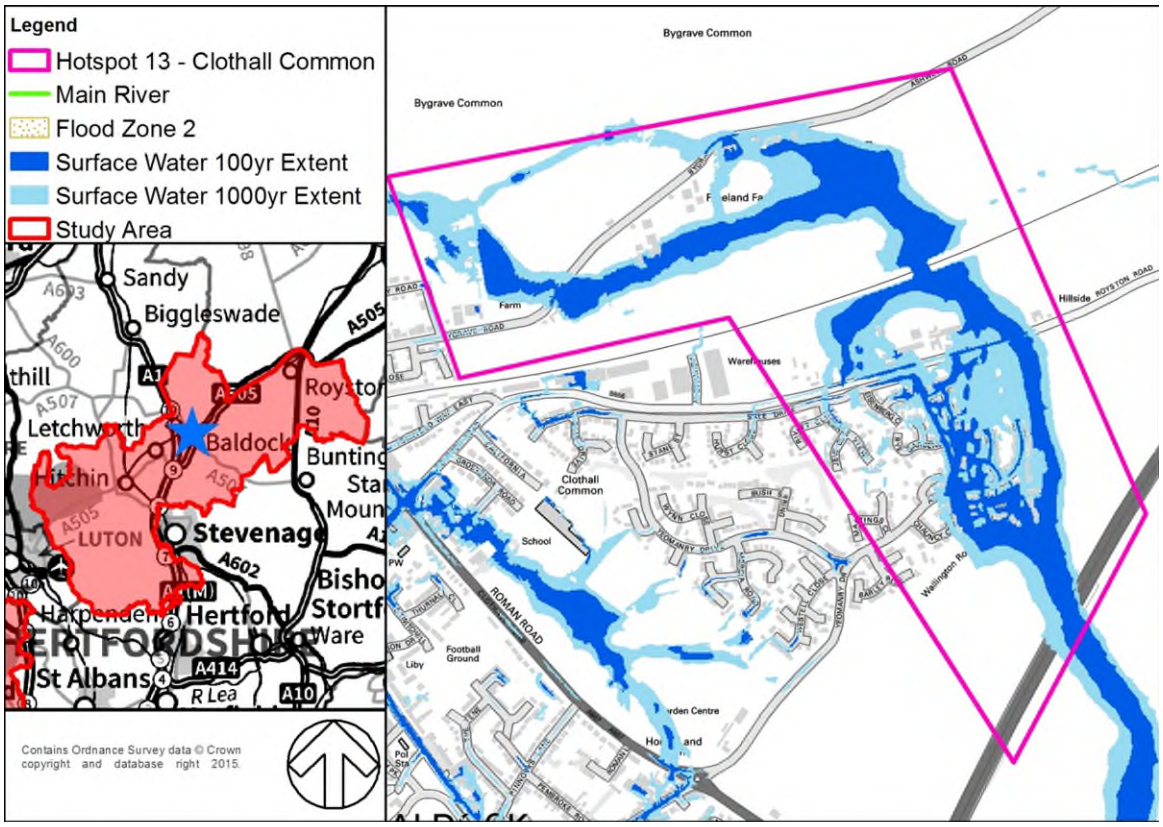
7.6 HOTSPOT 13 - CLOTHALL COMMON, BALDOCK

KEY CONSIDERATIONS

It was decided that Clothall Common, Baldock 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 elements (as shown in Figure 14):

- The Environment Agency's Risk of Flooding from Surface Water map which shows:
  - An extensive area at medium to high risk of surface water flooding to the eastern part of Clothall Common.
  - Flooding along an overland flowpath across the A505 dual carriageway highway to the south (medium to high risk)
  - Two further flowpaths are shown from the east and west which converge to the south and east of Icknield Way (B488).
- Local Knowledge which suggests that the Environment Agency's Risk of Flooding from Surface Water map is unrealistic because
  - The A505 is in a cutting at this location which is not included within the DTM.
  - Although the flowpath across the A505 would be diminished, it is thought that a risk to the residential properties to the north and the proposed future development (which being considered in the agricultural area between the existing residential area, Royston Road and the A505) would remain.

Figure 14: Hotspot 13 - Clothall Common – extents and baseline information



HYDRAULIC MODEL SUMMARY

The model was developed in ESTRY-TUFLOW with a direct rainfall approach. This model covers both the Baldock and Clothall Common Hotspots as the catchments are adjacent and these are hydraulically linked through the surface water sewer network. Topographical data for the model consisted of the Environment Agency's updated Flood Map for Surface Water (uFMfSW) DTM supplemented with topographical survey data in key locations (see model reports in Appendix C).

Key Constraints

A preliminary investigation of the Environment Agency LiDAR demonstrates that coverage is less than 20% of the proposed model extents with this being limited to a small area to the north-west corner. Considering this and that no more recent LiDAR was flown after the producing of the uFMfSW, the uFMfSW DTM have been used in this model.

The drainage connection from the A505 attenuation/infiltration ponds which are located to the north of the A505 has been represented by a constant inflow under full bore conditions. This is unlikely to be fully representative and this conservative assumption may need to be revised.

Key limitations

A 4m grid size was used because smaller grid sizes produced prohibitively long model runs due to the model size.

The location where the watercourse crosses the railway is outside of the hotspot boundary and so it was decided that the study limit for this model was to be the B656 Royston Road. There is no information on this culvert, which has therefore not been included into the model. When interpreting the results outside the hotspot/study area consideration needs to be given to this constraint.

If the model is to be adapted to support a planning or funding application, then consideration should be given to sensitivity testing on the soil infiltration characteristics, informed by a site specific ground investigation, in the instance of a planning application. In addition in this scenario an improved representation of the swale which separates the agricultural land to the north from the residential area should be incorporated.

Key Findings

The key findings of the hydraulic modelling are detailed in Table 9 below for the critical 1 in 30 and 1 in 100 year events, snap shots of the key flooding extents are provided; mapping of the whole hotspot is in Appendix D, which provides a better resolution and colour key.

Table 9: Key Findings – Hotspot 13 - Clothall Common

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
Flood Depth	The model predicts an area of shallow to medium depth flooding to the east of Clothall Common, northwest of the A505, with depths up to 0.5m.	The model predicts a larger area of shallow to medium depth flooding northwest of the A505 with depths up to 0.6m.
		
Hazard	There is an area of danger for some to the east of Clothall Common, northwest of the A505.	The area of danger for some has increased, and includes a small area of danger for most.
		

Sensitivity Testing

Sensitivity was undertaken to assess the impact of a blockage on the culvert that crosses the A505 in the vicinity of Wallington Road in Baldock. An inflow was applied in the model just downstream this culvert, therefore the flow applied has been reduced to 75% and 50% of the flow applied in the baseline scenario. Results (flood model summary report in Appendix C) show that

flood levels are not very sensitive to the inflow reduction, as the mean differences between baseline and sensitivity scenarios are 1mm and 0.5mm.

POTENTIAL MITIGATION

Potential mitigation measures which could be considered for Hotspot 13 - Clothall Common are outlined below and shown in Appendix E:

- Ensure that a preferential flow path exists along the highway network.

RECOMMENDATIONS

The following recommendations are made for further consideration of this site and for inclusion within the action plan:

- Work with the scheme promoter/developer to ensure that formalised attenuation/detention/soakaways are included in the master plan (if required following development drainage proposals).
- Work with the landowners adjacent to the railway to ensure awareness of wet areas and methods of discharge under the railway and in the downstream ditch network.

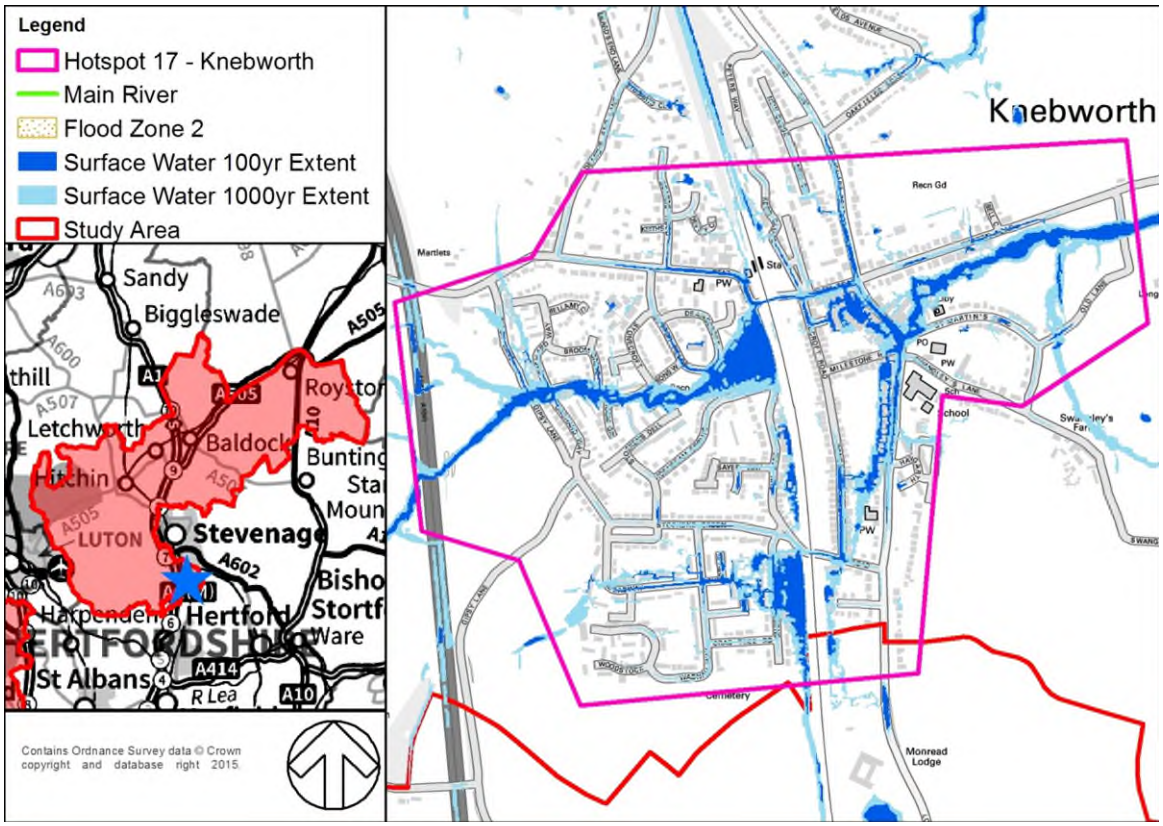
7.7 HOTSPOT 17 - KNEBWORTH

KEY CONSIDERATIONS

It was decided that Knebworth 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 elements (as shown in Figure 15):

- The Environment Agency's Risk of Flooding from Surface Water map, which shows:
  - Flooding along the eastern and western side of the railway track, a large area just south of Station Road and a second area behind properties on Gun Road Gardens (medium to high risk).
  - A flow route across the A1(M) motorway to the west. However, the A1(M) is above the surrounding ground levels, a culvert exists that is not included in the maps, which discharges to an infiltration pond, so this flowpath would be less significant.
- A Section 19 Flood Investigation, together with local knowledge, indicated that the occurrence of historical flooding events is associated with several storms in short succession. As a result of this, it is estimated that a suitable runoff coefficient for the larger events is likely to be around 85% for the chalk agricultural land.

Figure 15: Hotspot 17 - Knebworth– extents and baseline information



HYDRAULIC MODEL SUMMARY

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

There are not any open watercourses within this catchment and Thames Water asset records show no surface water sewers in the area. Therefore the model consists of a direct rainfall model with topographical data obtained for key sections under the railway.

Following discussions on the implications of the wet antecedent soil conditions the baseline model was run with loam and clay loam soil types, whilst the sensitivity analysis was run as a loamy sand to represent the chalk conditions.

Key Constraints

LiDAR data was only available for 78% of the area, with the remainder covered by NEXTMap. Therefore, the DTM used to produce the updated Flood Map for Surface Water (uFMfSW) DTM was used in this model, as there was no most recent LiDAR available for the catchment.

Given that Thames Water asset records show no surface water sewer in the area, no drainage network has been included into the model.

Key limitations

A grid size of 2.5 m was used, as model run times were prohibitively long when using smaller grid sizes.

Access to the Highways England land was not possible to enable the topographical surveyor to provide information on the pipes associated with the infiltration pond downstream of the A1(M).

Key Findings

The key findings of the hydraulic modelling are detailed in Table 10 below for the critical 1 in 30 and 1 in 100 year events, snap shots of the key flooding extents are provided, mapping of the whole hotspot is in Appendix D, which provides a better resolution and colour key.

Table 10: Key Findings – Hotspot 17 - Knebworth

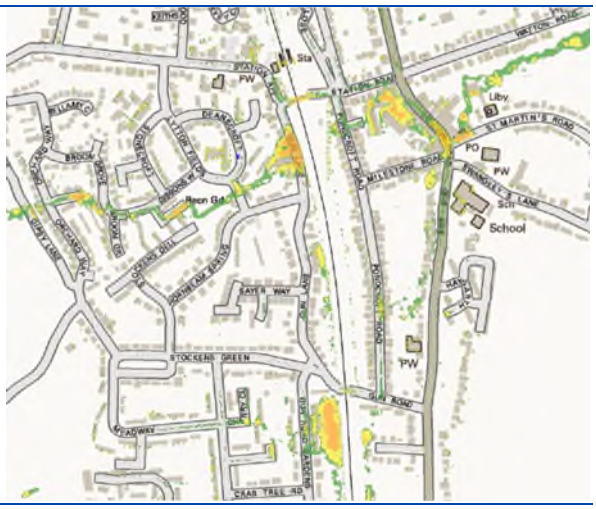
MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
Flood Depth	Deep flooding may affect properties on Gun Lane and Gun Road Gardens. Deep flooding is predicted on Gun Lane with a maximum depth of up to 2m. A maximum flood depth of 1.4m is predicted to the east of Gun Road Gardens. Medium to deep flooding is predicted on London Road with depths up to 0.8m.	Deep flooding may affect properties on Gun Lane and Gun Road Gardens. Deep flooding is predicted on Gun Lane with depths up to 2.5m. A maximum flood depth of 1.6m is predicted for flooding to the east of Gun Road Gardens. Medium to deep flooding is predicted on London Road with depths up to 0.95m.
		
Flood Hazard	Large areas of danger for most including Gun Lane, Gun Road Gardens and London Road.	Large areas of danger for most, including Gun Lane, Gun Road Gardens and London Road. An area of danger for all is predicted on part of Gun Lane.
		

Sensitivity Testing

Sensitivity testing was undertaken on roughness coefficients and soil type. The flood levels were not deemed to be overly sensitive to the changes in roughness (mean difference is 1mm). Flood levels were deemed to be more sensitive to changing the soil type to loamy sand, with a reduction in flood levels of approximately 3mm. Figures of sensitivity analysis can be found in the individual model report in Appendix C.

The sensitivity test using a loamy sand soil was undertaken as a way of representing the conditions which could be expected during drier periods or for individually occurring storms where the soils have not reached saturation and facilitate infiltration to the underlying more permeable geology as opposed to wet antecedent soil conditions. This shows a significant reduction in flood extents, especially for the small return periods, key extracts are contained below in Table 11, with full flood maps showing the extents for both soils can be also found in Appendix C.

Table 11: Sensitivity Findings – Hotspot 17 - Knebworth

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
Flood Depth	Limited flooding predicted across the hotspot Shallow to medium depth flooding may affect properties off Gun Lane, London Road and Gun Road Gardens. Medium depth flooding is predicted around Gun Lane with a maximum depth of approximately 0.7m.	More extensive flooding was observed with medium depth to deep flooding affecting properties on Gun Lane, with depths up to 1.2m. Medium depth flooding predicted further south, to the west of the railway line on Gun Road Gardens. Medium depth to deep flooding was also shown south of Station Road and into London Road with depths up to 0.7m.
		
Hazard	There are small areas showing danger for some between Station Road and London Road. Deeper flooding at Gun Lane is associated with danger for most.	Hazard ranges from danger to some to danger to most adjacent to Gun Lane and London Road. An area of danger for most is predicted adjacent to Gun Road Gardens.
		

POTENTIAL MITIGATION

Potential mitigation measures which could be considered for Hotspot 17 - Knebworth are outlined below and shown in Appendix E:

- Enhance the cut off drain for both of the flow paths that flow from the west in order to attenuate them in the short term, prior to development of the allocated sites.
- Implement attenuation/soakaway in the recreation ground adjacent to Lytton Fields.
- Ensure preferential flow paths exists along the highways, as required.
- Implement an upstream rural attenuation area to the south of Gun Road Gardens.
- Ensure that the highway drainage and associated downstream attenuation/infiltration area that were installed when the B197 was part of the strategic road network (i.e. pre A1(M) construction) are suitably maintained and fully utilised.

RECOMMENDATIONS

The following recommendations are made for further consideration of this site and for inclusion within the action plan:

- Increase connectivity to the more permeable geology which underlies the top soils.
- Work with planners and developers to ensure exceedance pathways and soakaways/detention areas are in place to attenuate the flow paths from the west, as the allocated sites come forward for development.
- Liaise with Highways England to ensure that a suitable maintenance regime is in place for the A1(M) highway drainage infrastructure.
- Consider the implications of installing conveyance pathways with infiltration elements along Gun Lane and the path behind Gun Road Gardens on the railway.
- Consider increasing flow conveyance to the Station Road underpass and then utilising Watton Road to convey the flows to the open fields beyond.
- Improve drainage and connectivity, as required, preferentially utilising highway drainage.

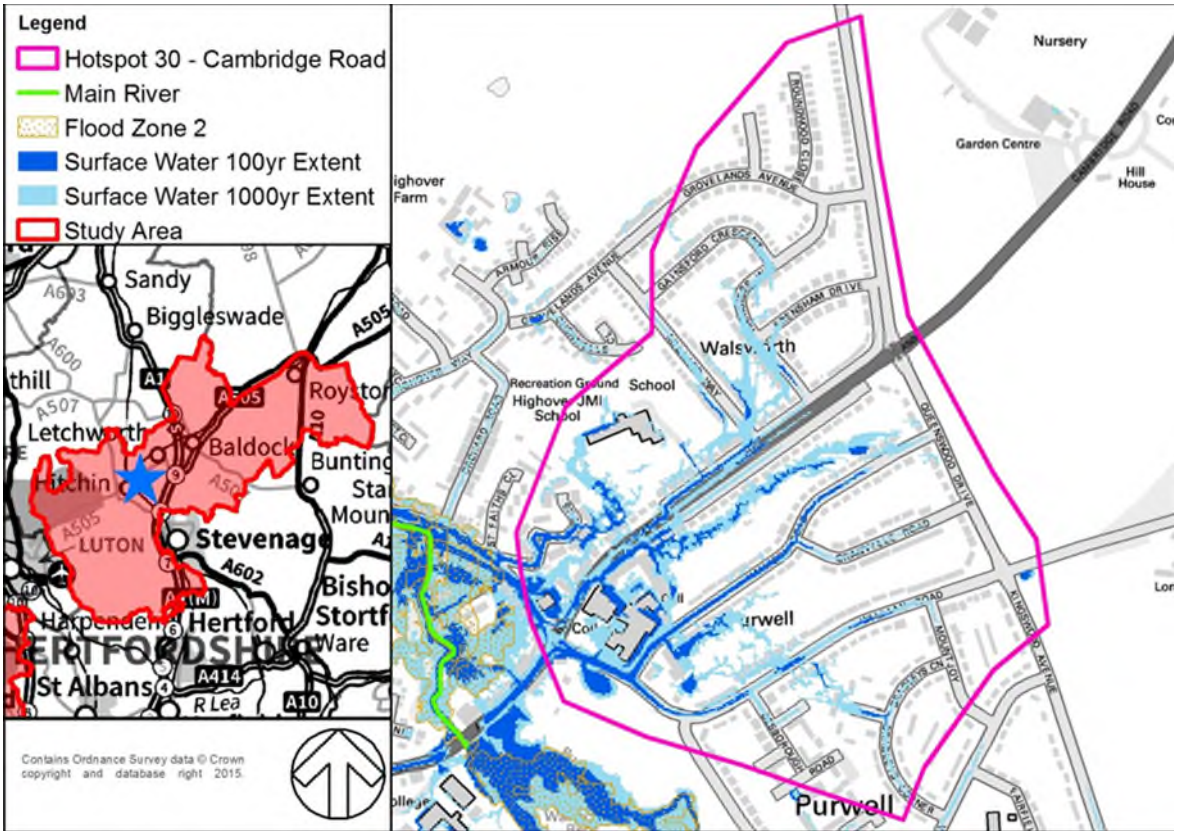
7.8 HOTSPOT 30 - CAMBRIDGE ROAD – A505 HITCHIN

KEY CONSIDERATIONS

It was considered that Cambridge Road and the surrounding area of Hitchin 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 (as shown in Figure 16) and mechanisms were:

- Historical flood records
  - There are records of several historical flooding incidents for the residential properties that front the southern side of Cambridge Road, between Queenswood Drive and the garage.
- The Environment Agency's Risk of Flooding from Surface Water map which shows:
  - Medium to high risk areas at the downstream part of the hotspot.
  - Surface water flood risk appears to be mainly in relation to an overland flowpath along Cambridge Road (A505) and there is an additional overland flowpath to the south.
- Local Knowledge
  - This indicates that the capacity of gullies and the surface water sewer network are likely to fail in heavy rainfall, with the worst effects near the property where two flowpaths meet on Cambridge Road (A505), and the Walsworth crossroads (Cambridge Road, Willian Road and Woolgrove Road junction).

Figure 16: Hotspot 30 - Cambridge Road (A505), Purwell and Walsworth areas of Hitchin – extents and baseline information



HYDRAULIC MODEL SUMMARY

The model has been developed in ESTRY-TUFLOW with a direct rainfall approach using the uFMfSW DTM. The downstream boundaries of the model have been defined as the 20% AEP fluvial boundary; based on the level outputs for the River Purwell, for 1 in 5 year event provided by the Environment Agency from their Ivel model on 1st March 2016.

Key Constraints

Anglian Water data shows a surface water sewer running down Cambridge Road and ending around The Anchor Inn, with no information on connections. Site investigations were undertaken to confirm connectivity and connections but to no avail, therefore it was necessary to assume that the surface water drainage connects to the culverted watercourse via a 450mm surface water culvert and drains to the River Purwell.

Key limitations

The key limitations of this hydraulic model is the uncertainty on the connection of the surface water sewer in Cambridge Road, which will require further investigations if a detailed mitigation model is to be developed.

Key Findings

The key findings of the hydraulic modelling are shown in Table 12 for the 1 in 30 and 1 in 100 year events, snapshots of the key flooding extents are provided in this table; mapping of the whole hotspot is in Appendix D, which provides better resolution maps and a legend.

Table 12: Key Findings – Hotspot 30 - Cambridge Road, Hitchin

MAP	1 IN 30 YEAR EVENT	1 IN 100 YEAR EVENT
Flood Depth	Flooding is predicted along Cambridge Road (depths up to 0.3 m) and properties to the south of the road (depths up to 0.6m). Flooding is predicted at College where depths go up to 0.9m.	Greater flood extents are observed during the 1 in 100 year event, and depths go up to 0.6 m along the road and up to 1.2m in the College.
		
Hazard	The flow path along Cambridge Road is associated mainly with area of danger for some, with some localised areas of danger for most.	Flood hazard increased generally, including some areas of danger for most and danger for all.
		

Sensitivity Testing

Sensitivity testing was undertaken on roughness coefficients. The flood levels (m) were not deemed to be overly sensitive to the changes in roughness (mean difference is 1mm). Figures of sensitivity analysis can be found in the individual model report in Appendix C.

POTENTIAL MITIGATION

Potential mitigation measures which could be considered for Hotspot 30 - Cambridge Road are outlined below and shown in Appendix E, these measures focus on providing attenuation upstream in the catchment and keep the highway is as a preferential flowpath.

→ Construct swales along the north west of Cambridge Road (A505) (between the garden centre and Stotfold Road) and east of Stotfold Road (to capture the flow paths north of the urban area and channel them to the low point at the Cambridge Road junction). An attenuation area should be incorporated at the Cambridge Road, Stotfold Road junction in order to reduce the volume of water flowing down Cambridge Road.

- Construct a swale along the east of Queenswood Drive and provide attenuation at the Cambridge Road, Queenswood Drive junction in order to reduce the water flowing down Cambridge Road.
- Provide attenuation and bund in the green triangle area located at the junction between Queenswood Drive and Cambridge Road, in order to reduce the water flowing down the side road of Cambridge Road. In addition, a speed bump (or similar barrier to flow) in the northern access to the side road would be required to contain the overland flows on the A505 and reduce the water flowing down the side road.
- Potential attenuation, through a swale or similar, can be investigated on the green strip located in Cambridge Road to the south of the junction with Queenswood Drive.
- Further investigation on the potential flow containment to highways and potential installation of property level measures along Hampden Road.
- HCC to undertake a site inspection to confirm the permeability of barriers along the flow path in the gardens of properties located between Hampden Road and Cambridge Road.
- Options would be to contain water on the A505 and keep it from entering the parallel side road. This could provide the opportunity to relocate accesses onto the side road to reduce flows into the curtilage of properties.

RECOMMENDATIONS

The following recommendations are made for further consideration of this site and for inclusion within the action plan:

- Ensure a suitable maintenance plan is in place for the highway drainage and gullies along this section of the A505, as this will remain as the preferential flowpath. This plan should take into account the flood risk in this area.
- Further assessment/secure financing of mitigation measures outlined above to enable their implementation.

8 VIABILITY SUMMARY

The results of the baseline economic analysis for each hotspot are summarised in Table 13. This illustrates the number of properties currently at risk of internal flooding, in line with the Environment Agency's bands for economic assessment.

Table 13: Number of Properties at Risk of Flooding

HOTSPOT	PROPERTIES AT RISK OF FLOODING		
	VERY SIGNIFICANT (>5% AEP)	SIGNIFICANT (5% – 1.33% AEP)	MODERATE (1.33% – 0.5% AEP)
6 - Hitchin	20	74	411
7 - Oakfield	0	0	0
12 - Baldock	21	151	209
13 - Clothall Common	0	0	3
17 - Knebworth	17	26	84
30 - Cambridge Road	4	34	58

The results of the mitigation option economic analysis for each hotspot are summarised in Table 14. 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 and the associated benefit cost ratio will 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 associated 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. The area which would benefit from the mitigation scheme, the 'benefit area' is identified in the Option Maps (Appendix E).

Table 14: Baseline and Mitigation Options Economic Damages

HOTSPOT	MITIGATION OPTION	PRESENT VALUE DAMAGES [£]	PRESENT VALUE BENEFITS [£]	PRESENT VALUE COSTS	BC RATIO
6 - Hitchin	Baseline	66,570,000	-	-	-
	75yr SoP for all benefit areas	60,000,000	6,570,000	4,000,000	1.7
7 - Oakfield	Baseline	190,000	-	-	-
	No options identified	N/A	-	-	-
12 – Baldock	Baseline	48,850,000	-	-	-
	30yr SoP for all benefit areas	27,000,000	21,820,000	2,810,000	7.8

HOTSPOT	MITIGATION OPTION	PRESENT VALUE DAMAGES [£]	PRESENT VALUE BENEFITS [£]	PRESENT VALUE COSTS	BC RATIO
13 - Clothall Common	Baseline	N/A	-	-	-
	No options identified	N/A	-	-	-
17 - Knebworth	Baseline	14,470,000	-	-	-
	30yr SoP for all benefit areas	7,370,000	7,110,000	770,000	9.2
30 - Cambridge Road	Baseline	19,560,000	-	-	-
	30yr SoP for all benefit areas	11,170,000	8,390,000	510,000	16.5

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

To secure FCERM GiA funding then a benefit cost ratio of 10-14 would normally be expected, however, this is dependent upon the competing schemes. This combined with the current funding process which aims to get third party funding (which could be from Local Levy) then the majority of the schemes will not be viable without attracting additional 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, are likely to 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 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 will 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[16]:

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

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

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 and therefore other measures could be explored in the future if necessary.

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.

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 the Figure 17[17] below as "Payment for Outcomes (anticipated)".

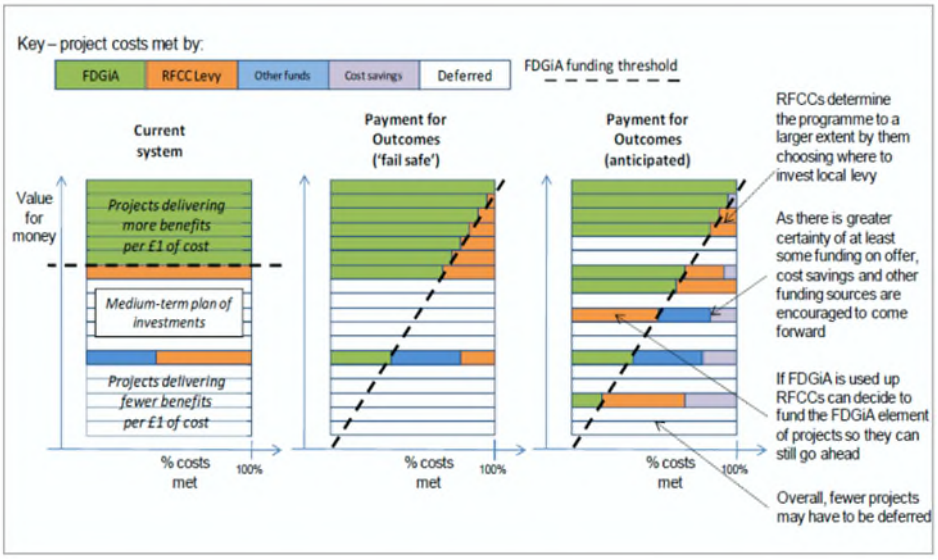


Figure 17: Combination of possible different funding sources to cover costs of flood risk management schemes

9.5 FUNDING CONCLUSIONS

The economic assessment finds that all four of the recommended schemes are 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 (Project Appraisal Report). For all these schemes HCC will need to work with key stakeholders in Hertfordshire to secure additional third party funds to enable 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.

[17] 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 to be 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.

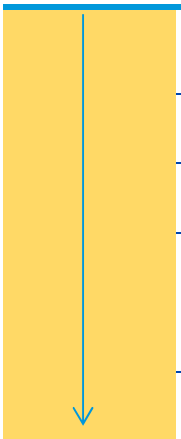
10.1 ACTION PLAN

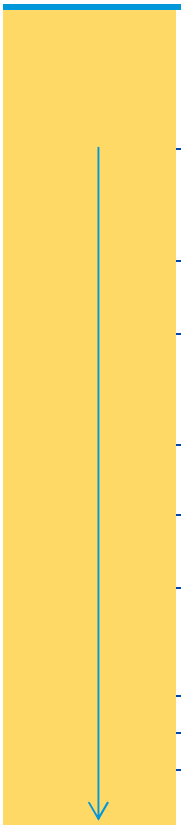
The Action Plan for each hotspot details recommendations for options to be explored further. This is then accompanied by the actions that will be needed as part of the further investigation, after the completion of this SWMP. The Action Plan is targeted towards each of the assessed hotspots and provides 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.

The further investigation for any options involving construction works will likely 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 Table 15, during this process community involvement should be considered at each stage to ensure that they have a greater stake in project design and delivery at an early stage of flood risk management schemes and ownership of the final solution. Other elements which will run throughout are consideration of how the scheme will be funded and how to maximise the environmental benefits and reduce the impacts of flooding.

Table 15: 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, NHDC, TW, AW and other stakeholders.
	Appoint Project Team	Consult with stakeholders involved. This should include, if necessary, consultants.

TIME	ACTION	REASON/WHAT IS NEEDED FOR THIS?
	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, NHDC, TW, and AW).
	Economic Viability	Undertaken 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, stakeholders 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 detail design of proposed mitigation 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. 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 workstream 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 District of North Hertfordshire 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 North Hertfordshire District 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[18]. 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 six 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 flood plain 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 North Hertfordshire District 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

[18] 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 North Hertfordshire District 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 District.