Appendix C

MODELLING METHODOLOGY REPORT AND MODEL REPORTS

70009115-50604-TN01

MODELLING METHODOLOGY TECHNICAL NOTE

BROXBOURNE BOROUGH SWMP

Public:

MODELLING METHODOLOGY TECHNICAL NOTE

BROXBOURNE BOROUGH SWMP

Hertfordshire County Council

Public

Project no: 70009115
Date: September 2016

WSP | Parsons Brinckerhoff
Unit 9,
The Chase,
John Tate Road,
Foxholes Business Park,
Hertford,
SG13 7NN

Tel: +44(0) 1992 526000
www.wps-pb.com

QUALITY MANAGEMENT

ISSUE/REVISION	FIRST ISSUE	REVISION 1	REVISION 2	REVISION 3
Remarks	First issue	Second Issue		
Date	18/09/15	13/09/16		
Prepared by	Lorena Ramirez	Lorena Ramirez		
Signature				
Checked by	Stephanie Knowles	Andy Smith		
Signature				
Authorised by	Andy Smith	James Berryman		
Signature				
Project number	70009115	70009115		
Report number	50604-TN01	50604-TN01-R02		
File reference	70009115-50604-TN01	70009115-50604-TN01-R02		

CONTENTS

FIGURES

TABLES

APPENDICES

1 OVERVIEW

1.1.1 This technical note sets out the proposed modelling methodology for the highest risk hotspots selected for hydraulic modelling as part of the Strategic and Intermediate Report for the Broxbourne Borough Surface Water Management Plans (SWMPs).

1.1.2 The approach is outlined in terms of the generic approach (Section 2) which will apply to all models and those elements of the approach that are specific to each hotspot (Section 3).

1.1.3 This modelling methodology has been prepared for review and comment to enable agreement to the proposed approach to be reached at the project outset, thereby avoiding unnecessary delay in later stages of the project.

1.1.4 The SWMP hotspots discussed in this Modelling Methodology are:

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

2 GENERIC MODELLING APPROACH

2.1 STAGE 1: DATA COLLATION AND WALKOVER SURVEYS

2.1.1 The first stage in the development of each hydraulic model will be to collate the data necessary for the development of the models. Data required for the development of the models are presented in the specific modelling approaches for each hotspot (Section 3) and summarised in Section 4.

2.1.2 The aim of the data collation and walkover surveys is to collect all the available data/information for the hotspot area and establish what other information is required for the detailed assessment and modelling. This technical note has been informed through the following steps:

- Liaise with Hertfordshire County Council (HCC) and project stakeholders outlining the proposed methodologies for the hydraulic modelling associated with each hotspot;
- Consult with the Environment Agency, Dacorum Borough Council and Thames Water Utilities Ltd to obtain and review the provided flooding and drainage data;
- Identify the extent of the LiDAR available for the study area and review topographical survey requirements for each hotspot;
- Review any appropriate CCTV/manhole/sewer survey data and sewer records available for the vicinity of the study area;
- Undertake site visits to assess flow mechanisms, status of hydraulic structures, physical obstructions to overland flood routes in the vicinity of the site and confirm topographic survey requirements;
- Confirm the hydraulic modelling approach with Hertfordshire County Council and project stakeholders in light of the available data.

2.1.3 This technical note provides the summary of the findings of Stage 1 and any outstanding requests, along with constituting the outline of the proposed hydraulic modelling approach, for confirmation by Hertfordshire County Council and project stakeholders. Following this approval any variations will be identified in the early stages of hydraulic model development and agreement sought.

2.2 STAGE 2: HYDRAULIC MODELLING

HYDRAULIC MODELLING PLATFORM SELECTION

2.2.1 Following a review of the currently available data and the objectives of the modelling studies, WSP propose to preferentially use a direct rainfall methodology (with some inflows for larger watercourses, where relevant) in ESTRY-TUFLOW; using the latest double precision version of TUFLOW (currently 2013_12_AD).

2.2.2 The ESTRY-TUFLOW hydraulic model utilises a two-dimensional (2D) representation of flow across the floodplain and a one-dimensional (1D) representation of flow in the sewers, culverts and watercourses. The 1D and 2D components of the model are dynamically linked, such that water can flow from the channel or sewers into the floodplain, and vice-versa.

2.2.3 ESTRY-TUFLOW is an industry standard hydraulic modelling package, widely used for floodplain modelling in areas also served by arterial drainage networks. ESTRY-TUFLOW has been successfully used by WSP previously for similar SWMP studies. In some areas it may be necessary to extend the model to use Flood Modeller Pro to represent the in-channel flows; however, this is largely likely to be limited to the areas where there is an existing fluvial model. Flood Modeller Pro (which replaces ISIS hydraulic modelling software) is widely used across the industry to model the in-channel flows of fluvial networks. However, it is not as stable as ESTRY for direct rainfall modelling, as the channels cannot run dry (i.e. at the start and end of rainfall events as the flows are conveyed through the catchment).

2.2.4 All the modelling platforms used within this SWMP have been assessed by the Environment Agency as part of their benchmarking exercise[1] and all are considered to be acceptable for this type of study. An advantage of using ESTRY-TUFLOW over ICM is the speed in which multiple mitigation scenarios can be assessed.

2.2.5 The models produced for this SWMP will be developed to facilitate submission to the Environment Agency to update the Risk of Flooding from Surface Water map. This will be undertaken in accordance with Environment Agency guidance "*Updated Flood Map for Surface Water – National Scale Surface Water Flood Mapping Methodology*", May 2013 and "*Submitting Locally Produced Information for Updates to the Risk of Flooding from Surface Water Map"* December 2014.

MODEL GEOMETRY DEVELOPMENT

2.2.6 The approach to the development of geometry for the ESTRY-TUFLOW models is to use the best available data wherever possible. Specifically the 1D and 2D component parts of the hydraulic models will be developed as detailed below.

2.2.7 Model boundaries will be governed by the position of historical flooding sites within the hotspot, and where the hotspot sits within its drainage catchment and the catchment's size. Model boundaries will also be reviewed in terms of their impact on model run times and the objective of maximising model size/coverage. Consideration will also be given to the likely position of potential flood alleviation options for assessment in Stage 3 (Section 2.3).

[1] Environment Agency Research and Analysis: Benchmarking the latest generation of 2D hydraulic flood modelling packages (Published reports available at: https://www.gov.uk/government/publications/benchmarking-the-latest-generation-of-2d-hydraulic-flood-modelling-packages)

2D MODEL COMPONENT

2.2.8 The primary source of topographic data that will be used for construction of the Digital Terrain Model (DTM) element of the 2D component of the hydraulic models will be the Environment Agency's uFMfSW DTM. As this is based upon previously merged LiDAR (Light Detection And Ranging) and where there is Intermap NEXTMap Synthetic Aperture Radar (SAR) dataset for Britain. The benefit of this is that the merger process which includes smoothing and checking for anomalies has already been undertaken. However, given that some time has passed since the completion of this dataset, checks have been undertaken to ensure that there is no more extensive LiDAR coverage, given that this is at a much higher resolution and accuracy than the NEXTMap data. These checks established that LiDAR should be preferentially used for hotspots 24 (Highfield – Hemel Hempstead) and 53 (Kings Langley). The LiDAR will be obtained from the Environment Agency who has a significant programme of checking the data for anomalies and ground truthing.

2.2.9 Where multiple terrain data is to be used the chances of anomalies and differences are increased, in these locations inspections for these will be undertaken. Following a satisfactory review, steps may remain between the data sources, given the varying methods and associated accuracy of data collection, therefore the following approach will be adopted:

2.2.10 In instances where steps in elevation data occur at the boundary of two data sources (i.e. between the boundaries of one or more of LiDAR, NEXTMap (SAR) and topographical survey data) these will be smoothed as far as is practicable within a determined merger area. This will be achieved by generating a TIN over the boundary of the two datasets and averaging/linearly extrapolating elevation data along the junction based on the two datasets.

2.2.11 Where possible the LiDAR and NEXTMap data will be replaced with more detailed topographic survey data to be collected in the field. Predominantly this will be confined to surveying of channel cross sections for watercourses through particular areas of interest and/or hydraulic structures, culverts and weirs etc. In areas where the preferential flow paths are shown to break from flowing along the highway or where properties have low threshold levels, topographical survey data will also be collected. The scope for this is detailed at the individual hotspot level.

2.2.12 The individual hotspot modelling approach summaries (provided in Section 3) identify the likely topographic survey that it is anticipated will be collected; the exact requirements are detailed in a separate specification (Appendix I). Should further site inspections identify additional features and structures that could have an influence on local flooding these will be identified and captured where possible. However, the extents of topographic survey need to be considered against the available budget and the strategic nature of this assessment. In locations where topographic survey is not possible, expert knowledge will be utilised to determine the best approach, if flow conveyance is more important than flow restriction, then watercourse routes/holes in embankments will be enforced by lowering appropriate areas of the DTM. In other instances where flow restriction is more important than structure dimensions, invert levels etc. will be estimated based upon information gained through site visits, local knowledge and engineering judgement.

2.2.13 Model resolution/grid size will be determined on a model by model basis. The highest possible model resolution will be sought whilst considering model complexity, modelling objectives and model run times. Wherever possible model resolution/grid size will be less than 5*5m. In instances where a larger surface water catchment drains into an area of interest, a catchment wide model will be developed with a larger cell size to ensure appropriate run times; flows will then be abstracted from the larger cell size model and entered into the more detailed area of interest model. Multi domain grids will not be used within TUFLOW for surface water modelling due to the potential for inaccuracies to develop at the barrier on significant flow paths. For other modelling platforms such as InfoWorks ICM we would seek to avoid issues between changes in significant cell size by restricting the maximum cell size to around 5*5m and run the model on a high specification server, with GPU, to significantly reduce run times.

2.2.14 Roughness values to be utilised in the 2D component of the models will be determined using Ordnance Survey (OS) MasterMap. Table 1 shows the values proposed.

2.2.15 To ensure the influence of buildings on overland flood flow routes is accounted for building footprints will be raised, however, this is not necessary when using the uFMfSW DTM as these changes have already been implemented. The footprints of buildings will be identified using Ordnance Survey (OS) MasterMap data and will be modelled as ‘stubby’ buildings and raised 300mm above the average ground level (LiDAR bare earth) within the footprint area. An upstand height of 300mm is selected in accordance with the Updated Flood Map for Surface Water National Scale Surface Water Flood Mapping Methodology (May 2013). This guidance states that an upstand height of 300mm is selected because flooding at this depth will certainly exceed the level of any damp-proof course and result in property flooding in many cases. Where property thresholds at specific hotspot sites are known (i.e. as a result of site survey) to be lower than 300mm, this value will be reviewed where appropriate. The Manning’s ‘n’ roughness value within the model shall be increased to 0.3 for the footprint of the building. The use of a higher Manning’s ‘n’ value is used in order to represent the energy dissipation caused by buildings on floodwater[2].

2.2.16 To ensure that the preferential flow routes that frequently operate along the highways will be maintained within the model, the highway will be lowered by 125mm, as recommended in the National Scale Surface Water Flood Mapping Methodology (May 2013). A value of 125mm is selected as it is the height of a British Standard kerb; this ensures the important highway pathway is represented. The highway extent will be identified from OS MasterMap.

2.2.17 Infiltration losses will be assessed within the hydraulic model rather than through hydrological models as variances between soil types and losses can be altered more easily at a local scale. These will be addressed through the Green-Ampt method in ESTRY-TUFLOW

[2] Flooding in Urban Areas – 2D Modelling Approaches for Buildings and Fences (Syme, 2008). (Published article available at: http://www.tuflow.com/Downloads/Publications/2008.09%20-%202D%20Modelling%20Approaches%20for%20Buildings%20and%20Fences.Syme.pdf)

Table 1 – Roughness coefficients by OS MasterMap land use category

OS MasterMap Land Use Category	Manning's 'n' Roughness Coefficient
Buildings	0.3
General surface (residential yards)	0.04
Step	0.025
General surface (unknown)	0.035
General surface (natural)	0.04
General surface (manmade)	0.03
Glasshouse	0.2
Inland water	0.03
Woodland (coniferous/non coniferous trees)	0.06
Manmade surface or step	0.03
Paths (tarmac or dirty tracks)	0.03
Railway surfaces (natural and manmade)	0.035
Roads (tarmac)	0.02
Roadside (natural and manmade)	0.02
Structures	0.3
Unclassified	0.04

1D MODEL COMPONENT

2.2.18 It is understood the following data will be available for construction of the 1D component of the hydraulic models includes:

- Water company GIS Asset data,
- Flood and Water Management Act (2010) asset registers,
- Ordnance Survey MasterMap data,
- LiDAR, and
- Topographic (and channel) survey of key elements of the watercourses and structures.

2.2.19 Where topographic survey data for open channel sections and associated structures is required, this will be collected to the Environment Agency's specification.

2.2.20 It is proposed that the majority of the 1D component of the public surface water sewer element of the hydraulic models will be constructed using data from GIS databases of the local water companies' networks, where these are available.

2.2.21 In the instances where it is important/necessary to incorporate the public surface water sewers (no consideration will be given to the combined or foul sewers – unless there are no surface water network in the area, thus combined will be included and the approach documented in the relevant hotspot), they will be incorporated into the model with the following approach:

- Only pipes greater or equal to 225mm diameter will be incorporated into the 1D component of the hydraulic models. In areas with limited sewer systems the minimum threshold for pipes to be incorporated within the model will be evaluated. This means that the flood maps in certain areas may give a more conservative estimate of the flood depths, as a small amount of storage in the smallest pipes is not being considered. However, as with any form of modelling, the model is a conceptualisation of reality; thus assumptions and simplifications of the real world have to be made, in order for the hydraulic model to be fit for the purpose that it is has been designed to achieve, and in a form where reality is suitably represented.

- Connectivity between the 1D and 2D components of the sewer models will be via manholes pitchannels (zero length channels with no storage associated, where water can flow both ways between the underground 1D pipe network and the above ground 2D domain) where water can flow both ways (i.e. in to and out of the manholes/pipes at ground level) and sewer outfalls (where sewer outfalls have flap valves, pipes representing these flap valve outfalls in the model will be set as one way flow). Flap valves have been assumed at the sewer outfalls to watercourses. No consideration will be given to gully pots as the mechanisms/pipes connecting these to the main sewer are uncertain. Spill levels from the 1D to the 2D and vice versa will be based on asset data provided by the water companies with comparison to topographic data/LiDAR data.
- Roughness values to be utilised for the pipe network, will be 0.013.No CCTV surveys will be undertaken.

2.2.22 It is anticipated that some of the water company sewer asset records will be missing data necessary for the construction of a network model in ESTRY-TUFLOW. Ideally, topographic/sewer/channel surveys would be conducted to collect the missing data; however the time and costs associated with survey for the number of sites under consideration are prohibitive at this time. Therefore, some key engineering judgement principles (set out in Table 2) will be applied in the first instance to address data gaps. Where data gaps are so severe that the degree of engineering judgement applied would give rise to concern regarding the accuracy of hydraulic model results, surveys shall be considered and this noted within the relevant section of the report.

Table 2 – Standard assumptions to address sewer record data gaps

Modelling Parameter	Assumption
Pipe network – Shape	Will be determined from pipe shapes upstream and downstream.
Pipe network – Length	Will be measured in GIS.
Pipe network – Invert levels (upstream & downstream)	Will be interpolated from the inverts of upstream and downstream adjoining pipes / manhole chambers. Where no adjoining pipes were available to interpolate from, invert levels were taken as 1.2m+pipe diameter below ground model. This was then checked and adjusted if necessary to ensure pipe fall gradients were suitable and that pipes were not above ground.
Pipe network – Diameter or width and height	Will be interpolated from the diameter of upstream and downstream pipes. Where different pipe sizes are recorded at the upstream and downstream manhole chamber, the pipe size will be assumed from the nearest pipes with a documented size.
Pipe network – Number of Culverts	Will be interpolated from the characteristics of upstream and downstream manholes in tandem with Sewers for Adoption (7th edition).
Pit Channel – Invert level	The lowest level will be utilised or alternatively it will be interpolated from the inverts of connecting pipes.
Pit Channel – Cover level	Will be interrogated from LiDAR data (in the absence of asset data) and will be used as 2D flood level.
Upstream Pipe Network	Where invert levels are missing at the upstream end of the network, it will be assumed that the pipe is running at 1.2m below ground levels. This will then be checked and

	adjusted if necessary to ensure pipe fall gradients are suitable and that pipes are not above ground.
Downstream Pipe Network	When invert level are missing at the downstream end and where the pipe discharges into a watercourse, it is assumed that the invert level is 300mm above bed level. This will then be checked and adjusted if necessary to ensure pipe fall gradients are suitable and that pipes are not above ground.

2.2.23 Where the hotspot model includes a reach of open watercourse that is considered significant as a control or influence on local flooding, this will be represented in the hydraulic model. Where these watercourses are Main Rivers and the Environment Agency has a river model, the channel geometry will be extracted from the Environment Agency's models for inclusion in the hotspot model. This will be undertaken based on the availability of Environment Agency models.

2.2.24 Where channel geometry data is not available an attempt will be made to collect topographic/channel data, the extent of survey is detailed on a site by site basis in Section 3.

2.2.25 Where the hotspot model includes a reach of open watercourse but this reach is sufficiently distant from the hotspot flooding itself and is also considered insignificant with respect to the influence on local flooding, the river reach will not be represented in the model as a separate reach. In these situations available hydraulic models will be interrogated for flood stage hydrographs which will be used as a downstream boundary condition for all outfalls discharging into the watercourse.

HYDROLOGICAL INPUTS DEVELOPMENT

RIVER FLOWS

2.2.26 In most cases, the area represented in each hotspot hydraulic model extends to encompass the entire upstream catchment, including the watercourses flowing through an area of interest.

2.2.27 In cases where a modelled area includes a watercourse which crosses an upstream boundary and has been previously modelled, the hydraulic model will be interrogated for a flood flow hydrograph which will be used as the upstream boundary condition (i.e. inflow) on the watercourse in the model.

2.2.28 In cases where a modelled area includes a watercourse which crosses an upstream boundary and has not been previously modelled a Flood Estimation Handbook (FEH) Statistical or Revitalised Flood Hydrograph (ReFH) flow boundary will be derived. Instances of where these approaches will be applied are detailed in Section 3.

2.2.29 The concept of Joint Probability is one where the peak of the river flow and the peak of the surface water runoff occur simultaneously. The focus of this SWMP is on surface water (pluvial) flooding rather than fluvial flooding from Main Rivers. Main Rivers frequently have larger (and often more rural) catchments, where flow in the river takes longer to peak (as opposed to surface water catchments, which can be smaller, flashier, more urbanised and quicker to peak). It is not comparable to use design flows/boundary levels for the same event (for the river and the rainfall), as this would provide a significantly conservative estimate of the flood regime. This situation (the concept of same magnitude events, not being comparable) has occurred for many years when modelling tidal and fluvial interactions, in these instances where there is a significant risk, a joint probability analysis to determine the combination of return periods has been undertaken. However, in the instance of this SWMP, the focus is on surface water flooding and therefore an agreed combination of return periods will be used for the assessment for all the return periods for surface water identified in Table 3, and the method for selecting the fluvial return period event to use for joint probability will be assessed via the following method:

- All fluvial boundaries will be preferentially assessed with a 1 in 5 year return period;
- Should the models have not previously been run with a 1 in 5 year return period, a 1 in 20 year return period event will be used (this should be available with any models issued by the Environment Agency, as the definition of a functional floodplain uses this event);
- Existing hydrology in previously built models will be preferentially used (e.g. the 1 in 20 year event), rather than revising flow estimates. This is because, depending on the scale of the model (significant numbers of flow points could be involved) and model age (methodologies regarding flow estimation have changed), altering flow estimates may impact on the model's calibration (in previously calibrated fluvial models).

RAINFALL PROFILES

2.2.30 Hydrological inputs to the models will be derived by extracting the catchment descriptors from the FEH CD-ROM (v3), with revisions made to the URBEXT values and utilisation of the flow estimation tools within ISIS to determine the critical storm duration and the resultant hyetograph (rainfall profiles) with runoff addressed through the use of the Green-Ampt method (detailed in Hydraulic Modelling, Section 2.2.17).

GENERIC DATA REQUIREMENTS

2.2.31 The data required to develop hydraulic models for each hotspot are detailed in Section 3. In addition, data relating to flood defences and/or flood incidents would be advantageous in development of the hydraulic models, in order to gain an understanding of local flooding issues and for verification of model results.

HYDRAULIC MODEL VERIFICATION

2.2.32 WSP have not been provided with any photographic evidence of recorded surface water flood incidents. Therefore attempts to verify the flood outlines with historical information will be limited to comparison of the flood outlines with:

- Local knowledge (e.g. Section 19 Investigations, flood event extents, flood incident record or DG5 records of flooding, along with Environment Agency rainfall data where available);
- The Environment Agency's Risk of Flooding from Surface Water Map;
- Any other available flood outlines.

SENSITIVITY ANALYSIS

Model Sensitivity: Blockages, coefficients, percentage runoff and inflows

2.2.33 In order to test the robustness of the hydraulic model results, a sample of the models will be subjected to sensitivity analysis.

2.2.34 Sensitivity analysis will be undertaken on one return period event (i.e. the 1 in 100 year, as per current best practice) for each selected model and will include variation of up to three model parameters. This will include testing of the Manning's 'n' roughness coefficients (up to ±20% of the baseline value) and boundary conditions (up to ±20% of the baseline value) applied to the model. The remaining model parameters to be tested will be left to the discretion of the hydraulic modeller based on their appreciation of the data used to develop the hydraulic model. Parameters that may be tested through the sensitivity analysis include:

- Culvert blockage (50 and 75%) – standard practice is to block all culverts, in one or two situations, during the course of the SWMP study, the methodology may be reviewed to only block selected culverts depending on the baseline modelling results and the historic flooding situation at certain hotspots;
- Structural coefficients (up to ±20% of the baseline value);
- Roughness coefficients (Manning's 'n') (±20% of the baseline value);
- Percentage runoff (up to 100% runoff in areas of groundwater emergence); and,
- Inflows (up to ±20% of the baseline value).

Model Sensitivity: Catchment characteristics

2.2.35 Depending upon the outcome of the baseline modelling for Dacorum, at least one hotspot will be adopted for further sensitivity assessment on catchment characteristics. This sensitivity assessment has been chosen to assess the impacts of both the storm duration and antecedent conditions on the chalk catchments (i.e. saturation) and how this alters the flood extents and depths. This will be assessed through running the model with three different initial wetness conditions, through altering the parameters in the Green-Ampt method and running an additional two (longer) storm durations.

2.2.36 A further sensitivity run will be undertaken on a selected hotspot (to be agreed with HCC, following the baseline modelling) to assess the impacts of removing the underground drainage network and representing this through a constant 12mm reduction in the hyetograph (i.e. to facilitate a direct comparison with the approach adopted in the Environment Agency's Risk of Flooding from Surface Water map).

2.2.37 One hotspot model will be selected (in conjunction with HCC) for sensitivity with the fluvial downstream boundary where the 1 in 5 year and 1 in 20 year boundary conditions will be assessed in terms of impact on the surface water flooding regime.

HYDRAULIC MODELLING SCENARIOS

2.2.38 All hydraulic models will be run for the scenarios (storm return period events) presented in Table 3. Justification for these events is provided in the table, in addition to that required to provide input to the economic analysis.

Table 3 – Return periods for hydraulic modelling

Rainfall Probability	Justification
1 in 5 (20% AEP)	■ Of benefit in verifying hydraulic models. ■ Of interest to Hertfordshire County Council.
1 in 30 (3.3% AEP)	■ Of interest to water companies for assessment of benefit for capital investment schemes. ■ Use to define 'very significant' flood risk for assessment of outcome measures. ■ Consistent with Environment Agency Risk of Flooding from Surface Water Map return periods.
1 in 75 (1.3% AEP)	■ Threshold at which insurance for losses from flooding may not feature as part of a standard household or small business insurance policy.
1 in 100 (1% AEP)	■ Typical standard of protection sought for flood alleviation schemes ■ Consistent with NPPF flood zone 3A for fluvial flooding. ■ Used to define 'significant' flood risk for assessment of outcome measures.
1 in 100 +40% (climate change scenario[3])	■ Of interest to the Environment Agency.
1 in 1000 (0.1% AEP)	■ Consistent with NPPF flood zone 2 for fluvial flooding. ■ Of interest to Hertfordshire County Council.

HYDRAULIC MODEL OUTPUTS

2.2.39 The results of the hydraulic models will be utilised to generate maps of the modelled domain, with due consideration to the minimum depth represented illustrating the following:

- Maximum flood extent;
- Peak flood depth bands;
- Peak flood water velocity bands; and
- Flood hazard maps.

2.2.40 Where model sensitivity testing is undertaken and results documented in a simple tabular form for these scenarios to demonstrate the differences in:

- Maximum flood extent; and
- Peak flood depth bands.

[3] Flood and coastal risk guidance: Climate change allowances (Published guidance available at: https://www.gov.uk/government/publications/flood-and-coastal-risk-guidance-climate-change-allowances)

2.2.41 In the areas where parts of the model are developed using NEXTMap data or there are uncertainties over the accuracy of the input data, this may result in limited parts of the model having a lower degree of accuracy. These areas may potentially be comparable to the Environment Agency's Risk of Flooding from Surface Water map, where NEXTMap data was used for areas missing LiDAR coverage). Regarding the results of this SWMP, to ensure that any areas which may have a lower degree of accuracy are considered in future use and interpretation of the maps, polygons covering these areas will be provided to HCC as part of the GIS delivery. Any PDF maps produced which show these areas of uncertainty will be clearly marked to ensure that this uncertainty is conveyed such as overlying this area with a polygon with reduced transparency.

2.2.42 Hydraulic model outputs will be issued to HCC as GIS files (ESRI compatible).

HYDRAULIC MODEL REVIEW AND ACCEPTANCE

2.2.43 The development of all hydraulic models will be captured in a 'baseline' hydraulic model build report for each hotspot. Due to the data limitation, calibration of the model may not be possible. However, attempts will be given to use historic data upon availability to validate the model results, see Model Verification Section 2.2.32.

2.2.44 Each hydraulic model will be subject to an independent internal review at specific points in the modelling process by a member of WSPs hydraulic modelling team who will not be involved with the development of the model.

2.2.45 The hydraulic models with their accompanying build reports will be submitted to Hertfordshire County Council for their review and acceptance. This will follow an internal review by WSP | Parsons Brinckerhoff; all models will be reviewed by our lead modeller on this project to ensure consistency. This review will be documented in an audit sheet that will be submitted as a standalone element with the report and models.

2.3 STAGE 3: OPTIONS ASSESSMENT

2.3.1 Following completion of the baseline modelling, results will be reviewed and flood alleviation scheme options identified for discussion with stakeholders.

2.3.2 Should it be agreed with HCC that flood alleviation options for selected hotspots are to be assessed within the hydraulic model, either the approach will be discussed or a technical note will be prepared to accompany the baseline model build reports describing how the baseline model will be amended to reflect the preferred options. In this instance, the option modelling technical note will be submitted for review, comment and acceptance by Hertfordshire County Council and stakeholders (where appropriate) prior to commencing with option analysis.

3 SPECIFIC MODELLING APPROACHES

3.1 INTRODUCTION

3.1.1 The following sections detail the hotspots identified for assessment through hydraulic modelling.

3.1.2 The following sections document the justification for proceeding (or not proceeding) with hydraulic modelling of each hotspot and the modelling aims and objectives.

3.1.3 The location and extent(s) of the hydraulic models are defined (based on understanding from the currently available data).

3.1.4 The availability of the data required to develop the hydraulic models are identified along with the anticipated topographic survey requirements for each site.

3.1.5 The hotspots should not be viewed solely as the area within which hydraulic model results are required or desired.

3.1.6 For each hotspot, the proposed hydraulic modelling methodology has been developed to ensure the area for which a refined understanding of flood risk is required is adequately represented.

3.2 RYE HOUSE / NORTH HODDESDON (SITE 9)

FLOOD RISK OVERVIEW

3.2.1 This is a relatively flat catchment, where the Environment Agency's Flood Map for Surface Water outlines that surface water is predicted to flow through a residential area. However, this water is largely constrained to the highway network for lower order events, although, in localised areas and in larger magnitude events there are expected to be areas where several properties could be inundated.

3.2.2 In the downstream area of the hotspot (to the south) the surface water and fluvial flood plains are combined within Rye Park (as shown by the Environment Agency's Flood Map for planning). The fluvial flooding is from Woollens Brook which is a Main River.

3.2.3 The Environment Agency's Risk of Flooding from Surface Water map shows isolated areas of surface water flooding within the eastern sections of the hotspot. Inclusion of the surface water drainage infrastructure within the hydraulic model of the hotspot area may show a reduction of surface water ponding in these areas.

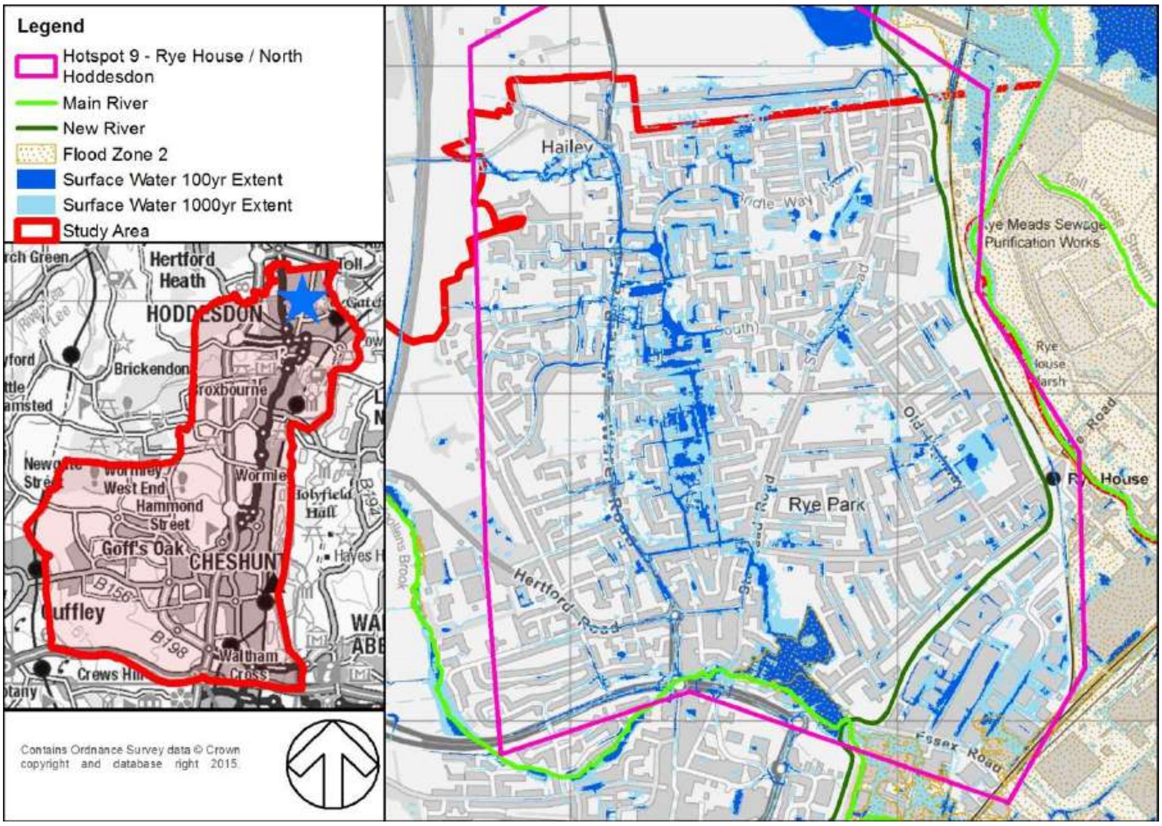

Figure 1 : Rye House / North Hoddesdon - Site 9

AVAILABLE INFORMATION AND DATA GAPS

The topographical data for the model will consist of LiDAR data where available. LiDAR is available for the majority of the catchment. NEXTMap data will be used where LiDAR data is missing. LiDAR data is missing in the north western part of the hotspot (mainly to the west of Ware Road (A1170)); in this location an understanding of flow conveyance rather than risk identification is required. UFMfSw DTM will be used for this hotspot as these data sets have already been merged by the Environment Agency's specialists.

Thames Water data has been obtained for this hotspot site, and consultation was undertaken with Network Rail to establish the presence of any further culverts under the railway. This established that there are culverts, however, these are located on the other side of the river, which is used as downstream boundary. Therefore these have not been modelled.

3.2.4 The Environment Agency's hydraulic models are available for the Woollens Brook and Upper River Lee/River Lee Navigation running to the south and east of the hotspot respectively. These are ISIS-TUFLOW models and can be used as downstream boundaries in the Rye House / North Hoddesdon hotspot model.

3.2.5 The purpose of utilising the Environment Agency's hydraulic modelling is that the topographical survey requirements will be significantly reduced, making this an economically feasible model. These models have been used to extract the 1 in 50 year flood level to be used as the downstream boundary.

3.2.6 Additional topographical survey will include road levels to be taken at various locations across the hotspot to ensure that the flow paths along and at the highway junctions are accurately represented.

PROPOSED MODELLING APPROACH

3.2.7 The focus of this modelling is the flow path to the east of Ware Road (A1170), which is flowing south. There are additional surface water flooding areas further to the east of the defined flow path that have been included in this hotspot, as from initial inspections they are likely to be contributing areas to the drainage infrastructure. The River Lee Navigation forms the eastern boundary of the hotspot, but the fluvial outlines are not shown to extend into the hotspot (separated from the hotspot by the railway), the New River, is within the hotspot, however this a controlled watercourse and thus there is a low risk of flooding and not included within the model. Therefore these will only be considered as a flow restriction on the surface water infrastructure. The southern boundary is formed by Woollens Brook and, if possible the Environment Agency's model will be utilised for the downstream boundary, at this location.

3.2.8 The proposed modelling will be undertaken in accordance with Section 2.2 and will use ESTRY-TUFLOW with a direct rainfall approach. Topographical data for the model will consist of uFMfSW DTM.

3.2.9 The surface water pipe network as detailed on the Thames Water asset records will be utilised as detailed in Section 2.2, with topographical survey data used to enhance the representation of key surface features. The downstream boundaries of the model will be derived from the existing Environment Agency models of the Woollens Brook and Upper River Lee.

3.3 CHESHUNT (SITE 52)

FLOOD RISK OVERVIEW

3.3.1 The Environment Agency's Flood Map for Surface Water and Flood Map for Planning show that surface water flood risk in this hotspot is compounded by the fluvial flood waters during the 1 in 1,000 year event. In lower order magnitude events the surface water flow path runs eastwards along Church Lane, across the crossroads with Great Cambridge Road (A10) and further eastwards towards Church Lane's junction with High Street (B1176) and Turners Hill. It is at this point that the surface water flood water leaves the highway and flows across the residential area towards the Small River Lea or Lee, the River Lee Navigation, River Lee Country Park and marshes.

3.3.2 Flooding was recorded on 20th June 2015 on College Road (B198) on the southern boundary of the hotspot. There is College Brook, a largely culverted Main River located within this area, as shown, in the figure below, by the green line on the southern boundary of the hotspot, in this area the river is partly culverted.

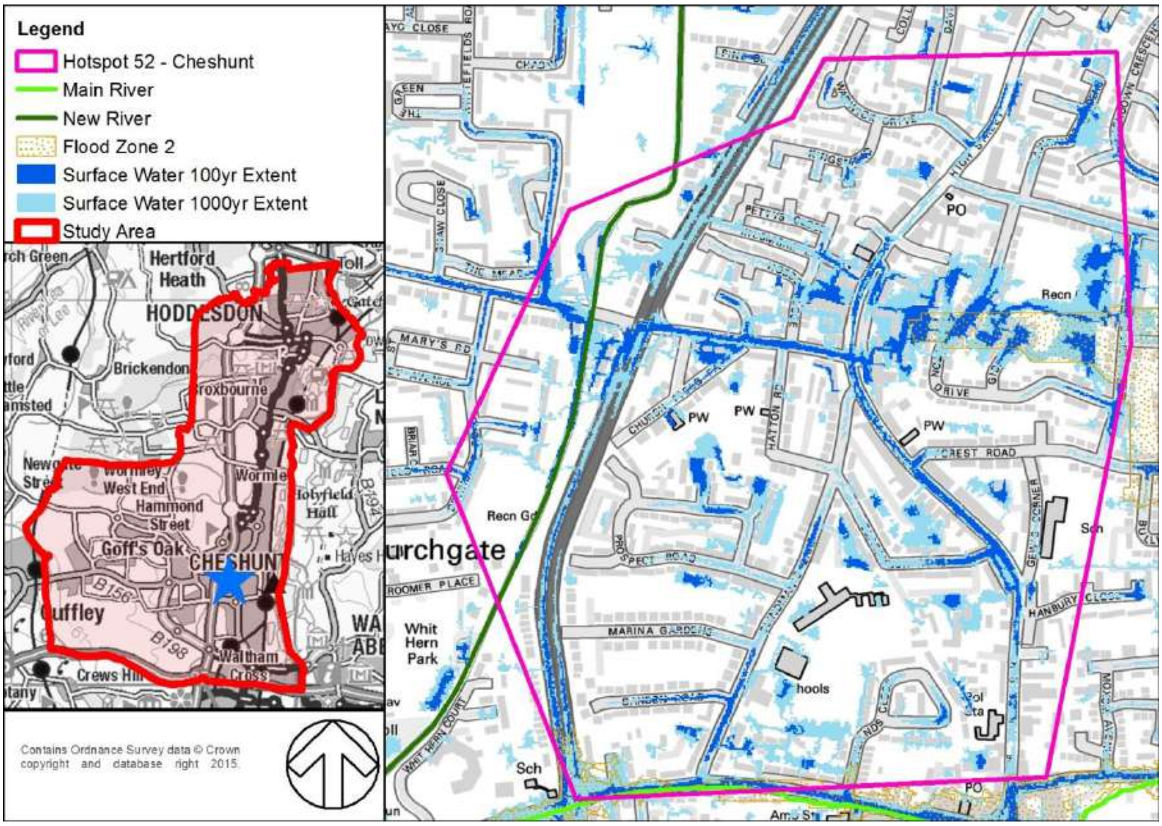

Figure 2: Cheshunt - Site 52

AVAILABLE INFORMATION AND DATA GAPS

3.3.1 LiDAR data is available for 100% of the catchment.

3.3.2 Thames Water asset data has been obtained and covers the full hotspot.

3.3.3 It is anticipated that additional topographical survey may be required to provide input to the model. In particular, it is expected that topographical data may include road levels to be taken at various points on the section of Great Cambridge Road (A10) and High Street (B176). Surveyed levels may also be required on the flow pathways shown in the Risk of Flooding from Surface Water map to ensure that these flow pathways are accurately represented.

PROPOSED MODELLING APPROACH

3.3.4 This model will be extended to combine with the model for the Rosedale North and South Hotspots due to the linkages of the surface water drainage network.

3.3.5 The hydraulic model will be developed as a direct rainfall ESTRY-TUFLOW model with the surface water sewers incorporated in accordance with Section 2.2. The basis of the direct rainfall model will be the topographical data, which will be based upon LiDAR data (as provided within the uFMfSW DTM) for the whole hotspot, supplemented with topographical survey where required, in localised areas.

3.3.6 Although College Brook runs west to east in the south of the hotspot, this will not be included in the model as the focus for this model is the central area, and thus not in the vicinity of this watercourse. Additionally it is also largely culverted (there are two major flow constrictions upstream of the hotspot), therefore the watercourse will not be used as a downstream boundary to ensure that modelling of this hotspot remains economically viable without large topographical survey requirements. Instead, the downstream boundary will be represented as a Head Time (HT) boundary based upon the slope in the relevant area.

3.4 COZENS LANE EAST, WORMLEY (SITE 55)

FLOOD RISK OVERVIEW

3.4.1 Flow paths on the Environment Agency's Risk of Flooding from Surface Water map show water flowing from north of the New River (Broxbourne town) and into the Cozens Lane East area, Wormley (hotspot 55). Site visit inspections indicate that the Risk of Flooding from Surface Water map is considered to be over predicting the flow into the hotspot and not taking into account the cut-off provision of the New River.

3.4.2 Surface water is also shown to pond in the housing estate bounded by the railway. It is considered that localised hydraulic modelling, with the inclusion of Thames Water sewers and any drainage infrastructure under the railway, will provide an increased understanding of the flow pathways and thus flood risk within this hotspot.

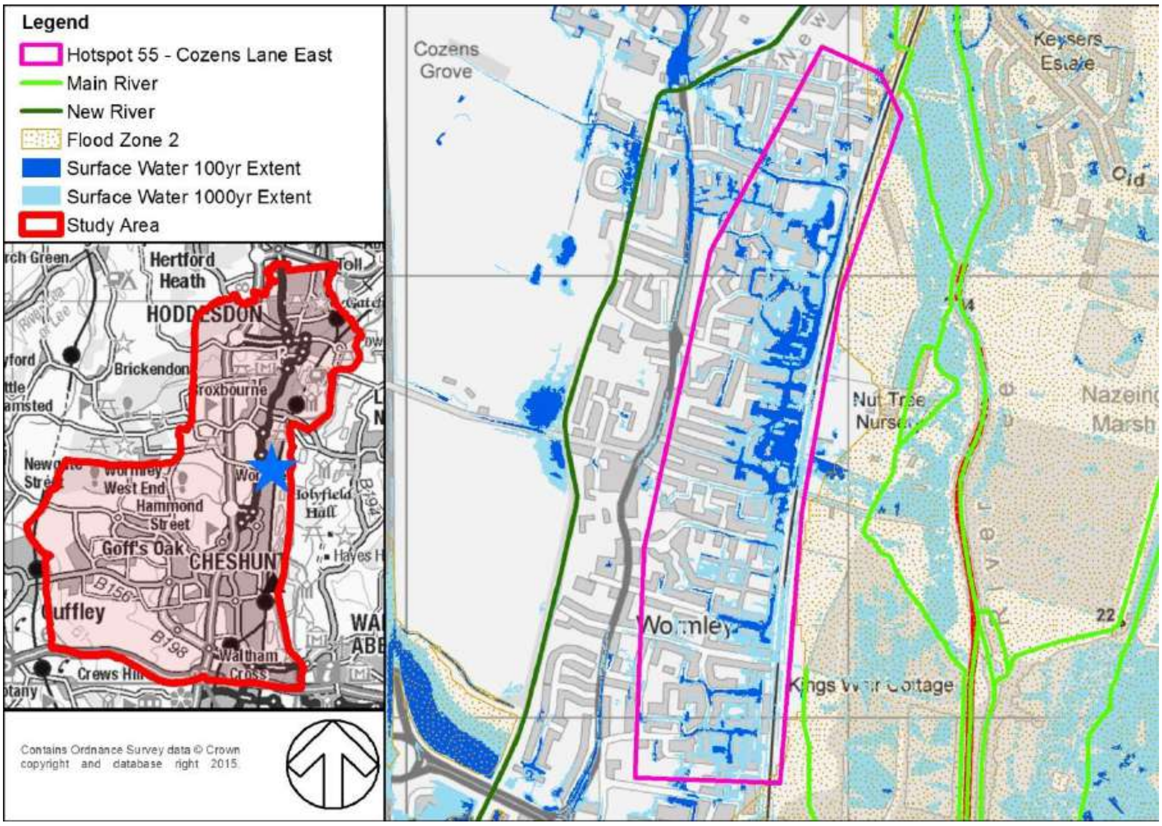

Figure 3 : Cozens Lane East, Wormley - Site 55

AVAILABLE INFORMATION AND DATA GAPS

3.4.3 LiDAR data is available for 100% of the catchment.

3.4.4 Thames Water asset data has been obtained and covers the full hotspot.

3.4.5 We hold some information from Network Rail on the culverts crossing the railway in the east of the hotspot. It may be that this information (largely including pipe diameter but excluding soffit, invert and other information) is all the detail that we can obtain, without the need for track closures which are outside of the realms of the study.

3.4.6 It is anticipated that additional topographical survey may be required to provide input to the model. In particular, it is expected that topographical data may include further details on the culverts under the railway. Surveyed levels may also be required on drains that have not been detected in the LiDAR data.

PROPOSED MODELLING APPROACH

3.4.7 Topographical data for the model will consist of LiDAR data for the whole site, supplemented with topographical survey where required. However, the topographical survey will not incorporate the drainage infrastructure under the railway, as this is within land owned by Network Rail and is track side of the fence. Therefore, survey could only be undertaken with Network Rail's permission and possibly with closure of the line. As assumptions on grade can be made based upon cross sections up and downstream of the culverts, it is considered that this approach will be suitable for the strategic level of this study. To ensure that topographical survey is only obtained where necessary, and to ensure all hotspots can be developed to the most appropriate level within the available budget, the field drains to the east of the railway will be represented by lowering the DTM along the channels (as shown by the OS Mapping of the banks). It may be that later studies will need to undertake further survey to refine these assumptions, should this hotspot be progressed to a funding application.

3.4.8 Although this forms part of a larger catchment, the site visit identified that the New River would act as a catchment boundary, by intercepting the flows and conveying them within its channel. However, there is drainage infrastructure beneath the New River, which will convey surface water runoff into the hotspot. These flows will be incorporated within the model as a point source inflow based upon the likely flows that could be conveyed by the pipe. These will be assessed through the use of spreadsheet based flow conveyance calculations, combined with an assessment on the length of time the pipe (under the New River) could be expected to run full.

3.4.9 This model will be developed as a direct rainfall ESTRY-TUFLOW model with the surface water sewers network as detailed on the Thames Water records (in accordance with Section 2.2) and where necessary, topographical data obtained for key sections downstream of the railway to ensure that the flows conveyed out of the hotspot are suitably represented..

3.4.10 The downstream boundary of the model will be set on the floodplain downstream of the outfalls from the culverts under the railway. The boundary will be a Head Flow (HQ) boundary based on the slope of the ground.

3.5 ROSEDALE NORTH & ROSEDALE SOUTH – FLAMSTEAD END (SITES 62 & 63)

FLOOD RISK OVERVIEW

3.5.1 The flood risk mechanisms and pathways within these two hotspots (Rosedale North and Rosedale South) and Hotspot 52 (Cheshunt) are considered to be interlinked, the later through the drainage network; therefore they will be modelled together.

3.5.2 The flooding in these hotspots extends across a relatively flat area, with the Environment Agency's Risk of Flooding from Surface Water mapping demonstrating an interaction between surface water and the two Main Rivers, Rags Brook to the north and a College Brook (which is largely culverted to the south, with a third preferential flow path (along Goff's Lane) in the central area of Hotspot 63.

3.5.3 The available mapping indicates that the event magnitude, severity and flood depth determine which catchment/hotspot (62 or 63) the surface water drains towards. However, further inspection as part of the stakeholder site visits indicated that the current national Risk of Flooding from Surface Water map is likely to be over estimating the complexity and associated risks. This is because Rags Brook is within a relatively deep incised channel throughout the majority of this hotspot, which is unlikely to be incorporated within the LiDAR.

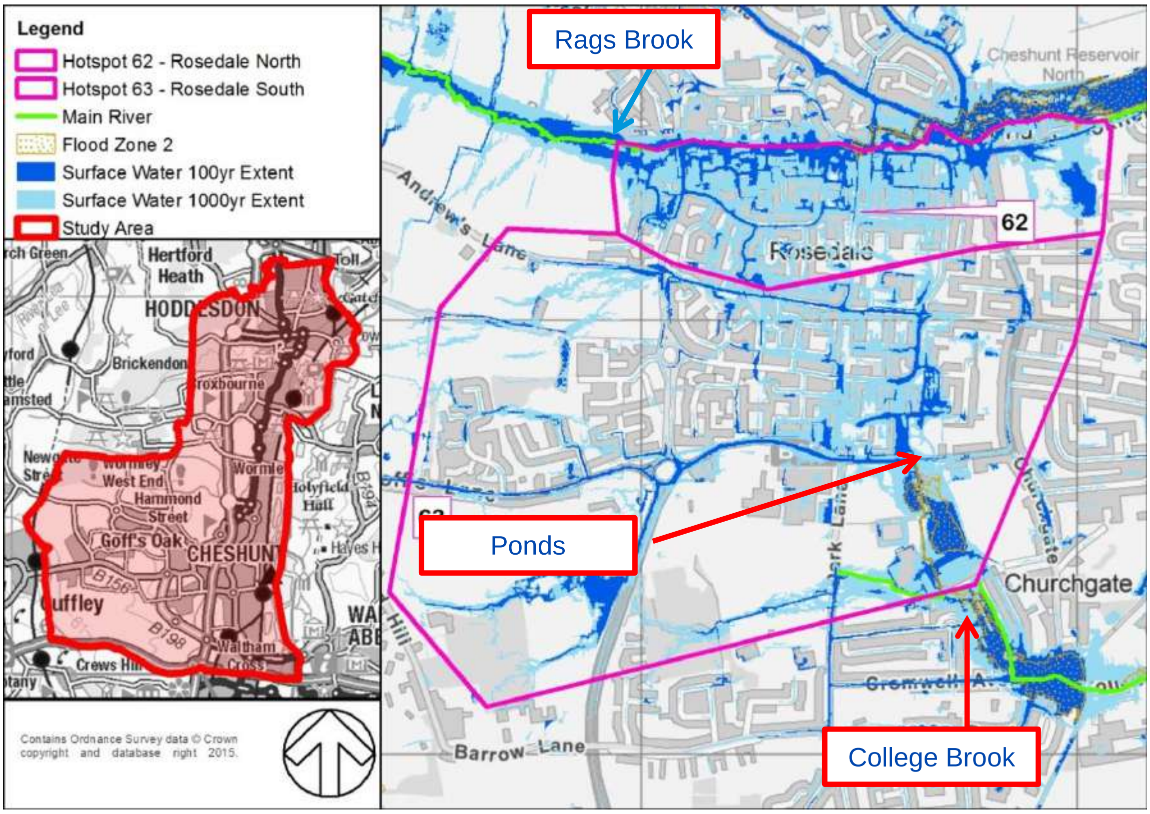

Figure 4 : Rosedale North & Rosedale South – Flamstead End – Sites 62 & 63

AVAILABLE INFORMATION AND DATA GAPS

3.5.4 LiDAR data is available for 100% of the hotspot to ensure best data is used across the whole area which is required within the model, the uFMfSW DTM, which incorporates the LiDAR is to be utilised.

3.5.5 Thames Water asset data has been obtained and covers the full hotspot.

3.5.6 Rags Brook to the north and College Brook to the south, run west to east of hotspot 62 and hotspot 63 northern and southern boundaries respectively.

3.5.7 It is anticipated that additional topographical survey may be required to provide input to the model. In particular, it is expected that topographical data will need to include cross sections on the watercourses and may also include road levels to be taken at various points on the section of Goff's Lane (B156) and B198. Surveyed levels may also be required on drains and ponds within the catchment.

PROPOSED MODELLING APPROACH

Phase 1

3.5.8 An initial assessment of the fluvial and surface water flood risk was undertaken by lowering a chain of cells within the 2D model along the course of Rags Brook, to provide a representation of the channel and its associated conveyance. This was undertaken to determine the need for more extensive modelling. This phase of the assessment demonstrated similar flood extents as included within the Environment Agency's Risk of Flooding from Surface Water and therefore, it was deemed that more detailed modelling was required.

Phase 2

3.5.9 This model will be developed as a direct rainfall ESTRY-TUFLOW model, using the surface water sewer network as detailed on the Thames Water records (in accordance with Section 2.2) and topographical data obtained for key sections as detailed above (3.5.7).

3.5.10 This model is to be developed in conjunction with Hotspot 52, due to linkage of surface water drainage network.

3.5.11 Topographical data for the model will consist of uFMfSW DTM for the whole site, supplemented with topographical survey where required.

3.5.12 Rags Brook has been modelled by the Environment Agency downstream of the hotspot, information from this model will be used as a downstream boundary condition. In other locations along the north, south and east of the model where the Rags Brook forms the boundary, sections of Head Time (HT) boundary conditions will be adopted. This approach is required to ensure economic viability of the model, appropriate flows out of the model into the watercourse and removing the need for a catchment wide model, given the complexity of trying to adjust the Environment Agency's fluvial model into a pluvial/fluvial model with interest only on one bank.

3.5.13 In common with other hotspots which bound the New River, this will not be included and assumed to be a pathway in which water can be conveyed once it has entered it, subject to topographic controls. However, a culvert beneath Church Lane has been included, as detailed on the infrastructure plans.

3.5.14 The 2D model will include a representation of the ponds, if connectivity of the ponds with the drainage network is confirmed, and information on the inlet/outlet features is available, pond features will be linked to the modelled network as appropriate.

4 SUMMARY OF DATA REQUIREMENTS

4.1.1 Table 4 provides a summary of the availability of the data required to progress the hydraulic modelling for each hotspot.

Table 4 - Summary of data availability and requirements

Hotspot	LiDAR	Network data	Railway data	Existing hydraulic model availability
Rye House / North Hoddesdon (site 9)	Missing in the north west	Available	Railway to the east	Woollens Brook and Upper River Lee/River Lee Navigation
Cheshunt (site 52)	100%	Available	No railway crossing	None required
Cozens Lane East, Wormley (site 55)	100%	Available	Railway to the east, some information available, considered to be best available	None required
Rosedale North & Rosedale South, Flamstead End (site 62 & 63)	100%	Available	No railway crossing	Rags Brook

Key

Colour	Definition
(green)	Most/all available
(orange)	Some available
(red)	Little/none available
(grey)	Not required
(yellow)	To be confirmed

Appendix I

TOPOGRAPHICAL SURVEY REQUIREMENTS

SURVEY BRIEF COVERSHEET

TO	Prospective Surveyors
FROM	Lorena Ramirez
COPIES TO	Project File
DATE	22/12/2015
REF	70009115 – East Hertfordshire and Broxbourne SWMP

Kings Orchard
1 Queen Street
Bristol
BS2 0HQ
Tel: +44 (0)117 930 3789
www.wspgroup.co.uk

SURVEY REQUIREMENTS

Introduction

Hertfordshire County Council in their role as Lead Local Flood Authority commissioned WSP | Parsons Brinckerhoff to undertake a surface water management plan for East Hertfordshire District and Broxbourne Borough as part of their programme of undertaking such studies across the county.

To enable hydraulic modelling to be undertaken at the key locations across East Hertfordshire District and Broxbourne Borough, watercourse survey and road level survey is required at a number of locations as detailed in the accompanying figures.

There is potential for minor variations in this brief as the Environment Agency are currently providing copies of their hydraulic models, of which some modification is expected to be required.

Survey is required at the following locations:

- Rye House, North Hoddesdon (Site 9)
- Cheshunt (Site 52)
- Rosedale North and Rosedale South, Flamstead End (Sites 62 and 63)
- Cozens Lane East, Wormley (Site 55)
- Buntingford (Site 1)
- Hadham Road, Benhooks Avenue and Potter Street / South Street, Bishop's Stortford (Sites 43, 44 and 60)
- Raynham Road, Bishop's Stortford (Site 47)
- Bengeo, Hertford (Site 40)

This document outlines the key requirements of the survey for which we require a competitive quotation for your services. It must be read in conjunction with WSP standard specifications for watercourse survey (in particular refer to the accompanying document named "*WSP RICS Jan 2013 ISSUED - Annex K only.pdf*"), which accompanies this document and provides more explicit instructions of the survey requirements. It is worth noting that this survey should also be undertaken to Environment Agency standards, of which I believe you are familiar.

The specific requirements for each location are detailed below, with indicative locations shown in the relevant figures.

Key - Legend

Levels will be needed for some roads, the kerb levels are represented in the figures below as grey thick lines with blue outline, and the central line of road with a grey dotted line. The properties where threshold levels are required are represented as red polygons. River banks are represented as pink polylines.

The locations of cross sections in ditches are indicated by yellow points. In some instances OS mapping and Water Company records provide contradictory information as to the presence/absence of a watercourse, in these instances the potential location of the ditch is represented by a blue dotted line. The locations of pipes to be surveyed are indicated with red arrows whereas manholes are indicated with purple dots; note that this is based on Thames Water information not a site inspection. The approximate NGR of these is provided.

Rye House, North Hoddesdon (Site 9)

The approximate grid reference for the central area is NGR 537300, 210000.

- Road levels of Bridle Way (South), Danemead, and Glenster Close, including kerb levels and levels of the central line – as indicated in Figure 1 – in order to confirm the flowpaths. These should include the levels of the kerbs around the roundabout and underneath the roundabout located in Bridle Way, and kerb levels to the south of Beyers Gardens.
- Kerb levels to the east of Ware Road (A1170), as indicated in Figure 1, Figure 2 and Figure 3.
- Threshold levels of the properties indicated in Figure 1.

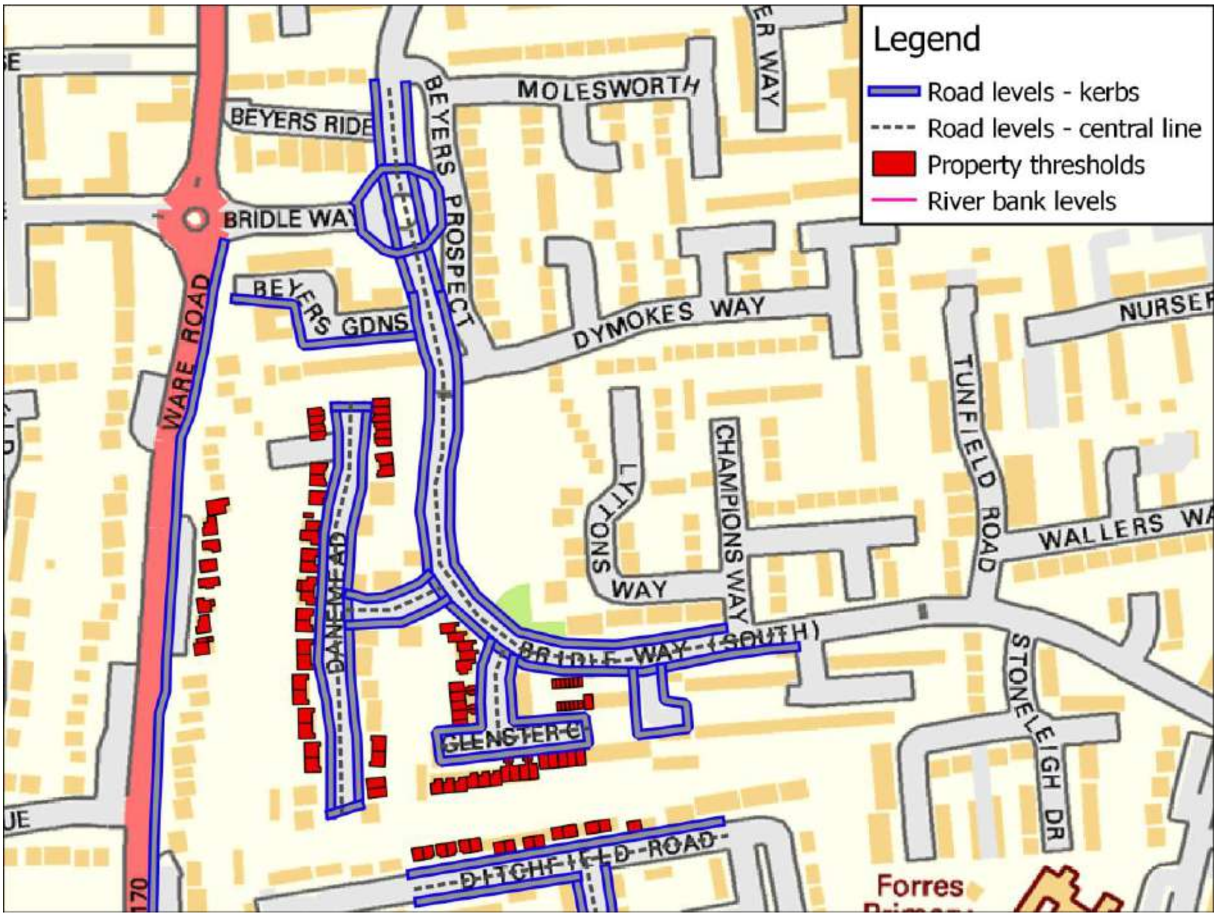

Figure 1

- Road levels of Ditchfield Road, Tregelles Road, Dorchester Avenue, Tovey Avenue and Thurgood Road, including kerb levels and levels of the central line – as indicated in Figure 2– in order to confirm the flow paths.
- Threshold levels of the properties indicated in Figure 2.

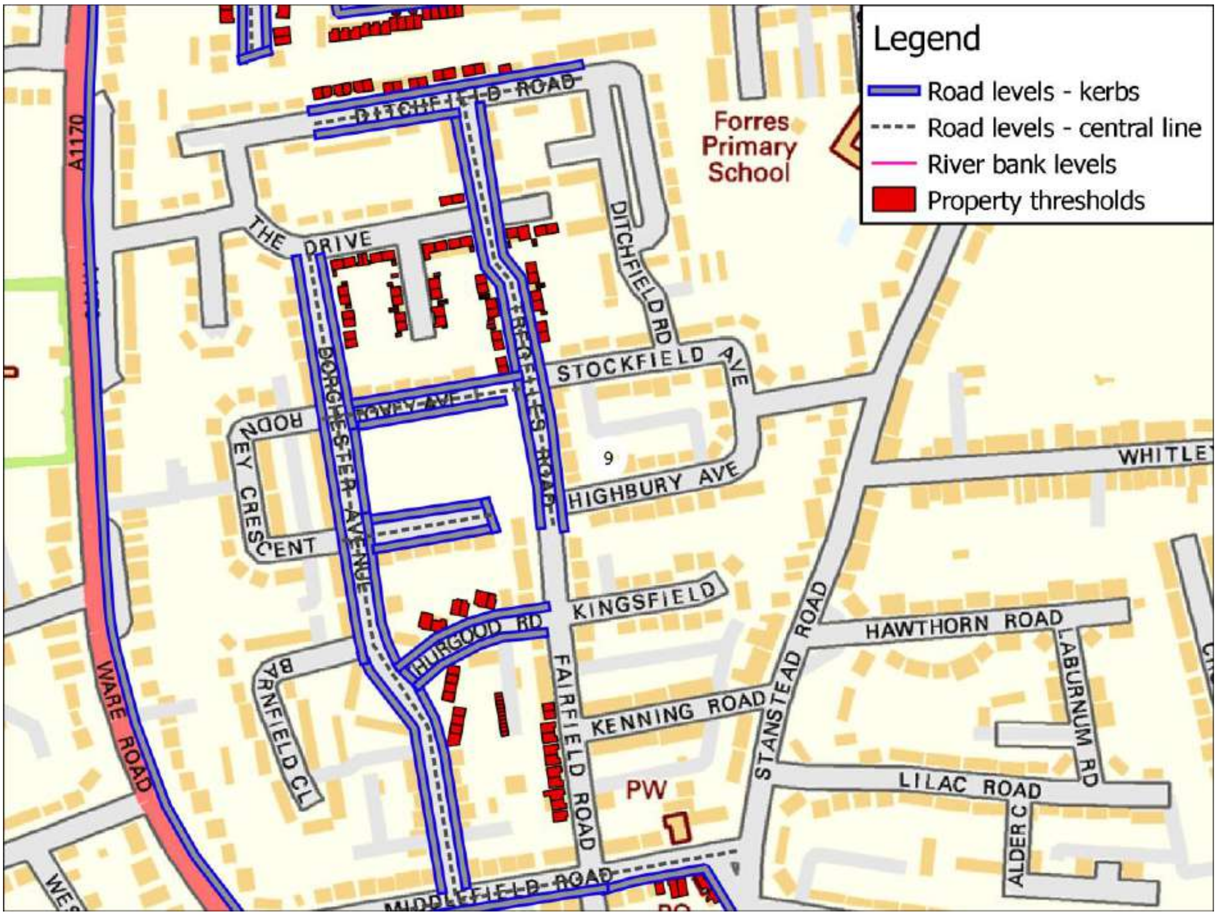

Figure 2

Survey Brief Continuation

- Road levels of Middlefield Road, Essex Road, Marston Road and Parrotts Field, including kerb levels and levels of the central line for the locations indicated in Figure 3, in order to confirm the flow paths.
- Threshold levels of the properties indicated in Figure 3.
- Levels of the north bank of Woollens Brook for the reach of watercourse running to the west of Parrotts Field, as indicated in Figure 3.
- Levels of both north and south banks of Woollens Brook for the reach of watercourse running to the east of Parrotts Field, as indicated in Figure 3.

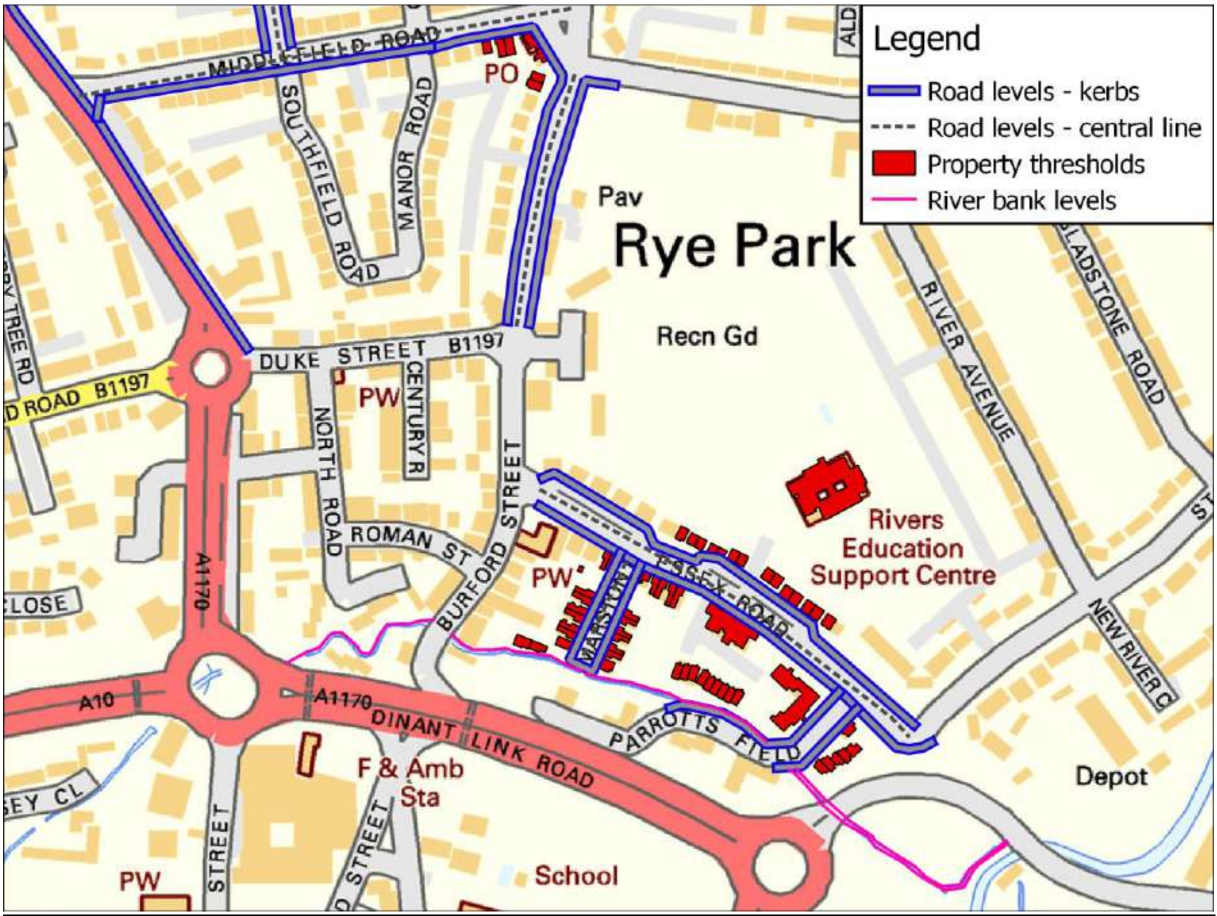

Figure 3

Cheshunt (site 52)

The approximate grid reference for the central area is NGR 535300, 202900.

- Kerb levels to the south of Church Lane, as indicated in Figure 4, in order to understand the level of the road in relation to the watercourse running underneath.
- Cross section in the location indicated in Figure 4, in order to compare them against the road level.

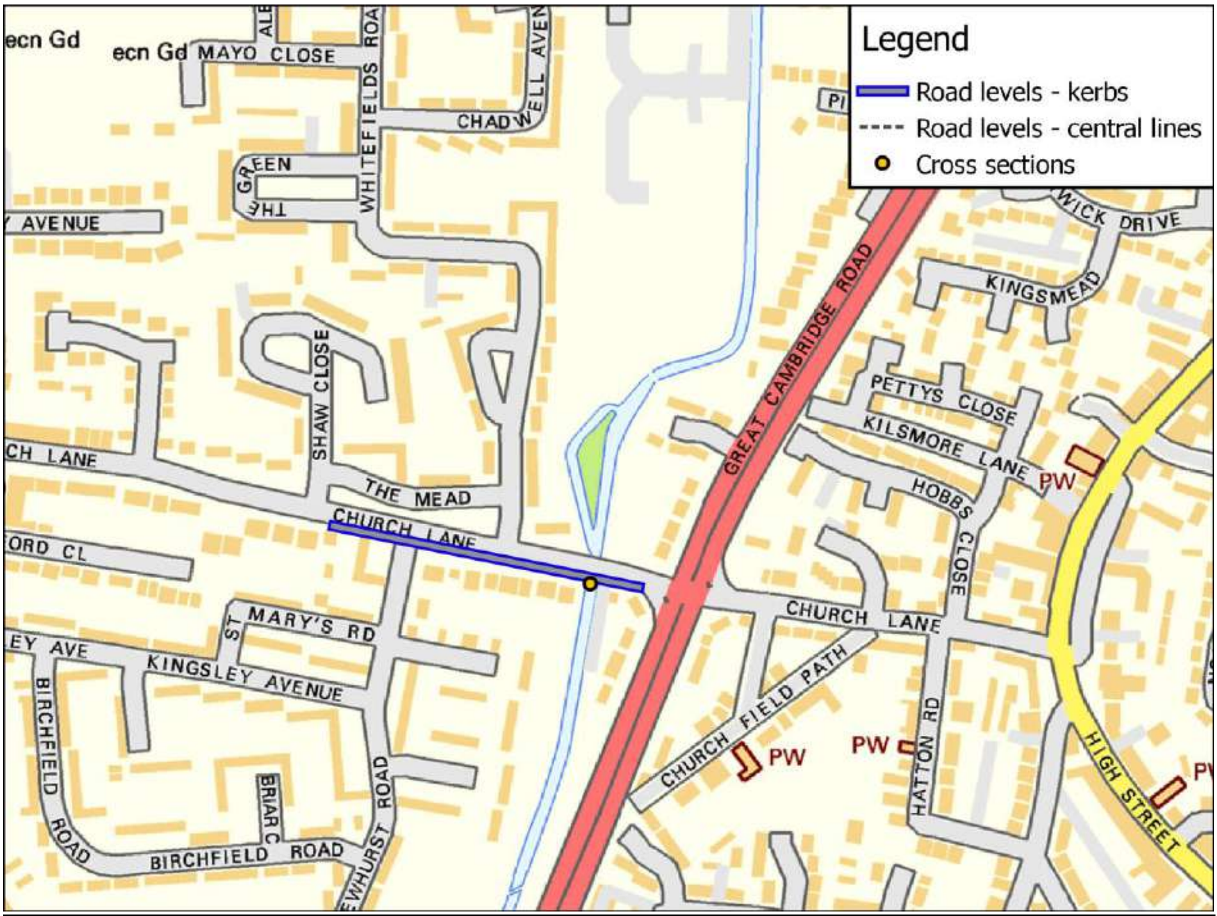

Figure 4

<u>Rosedale North and Rosedale South, Flamstead End (Sites 62 & 63)</u>

The approximate grid reference for the central area is NGR 534300, 202900.

- Road levels of Rosedale Way and Andrew's Lane and Andrew's Lane footpath, including kerb levels and levels of the central line – in the locations indicated in Figure 5 – in order to confirm the flow paths. Dimensions of the underpass under Rosedale Way leading to Andrews Lane footpath.
- Two cross sections in the ditch running across the Recreation Ground if access is possible, from analysis in Google Street View, the area of the Recreation Ground looks to be undergoing development (residential house building). The two cross sections should be approximately in the locations indicated by yellow points in Figure 5.

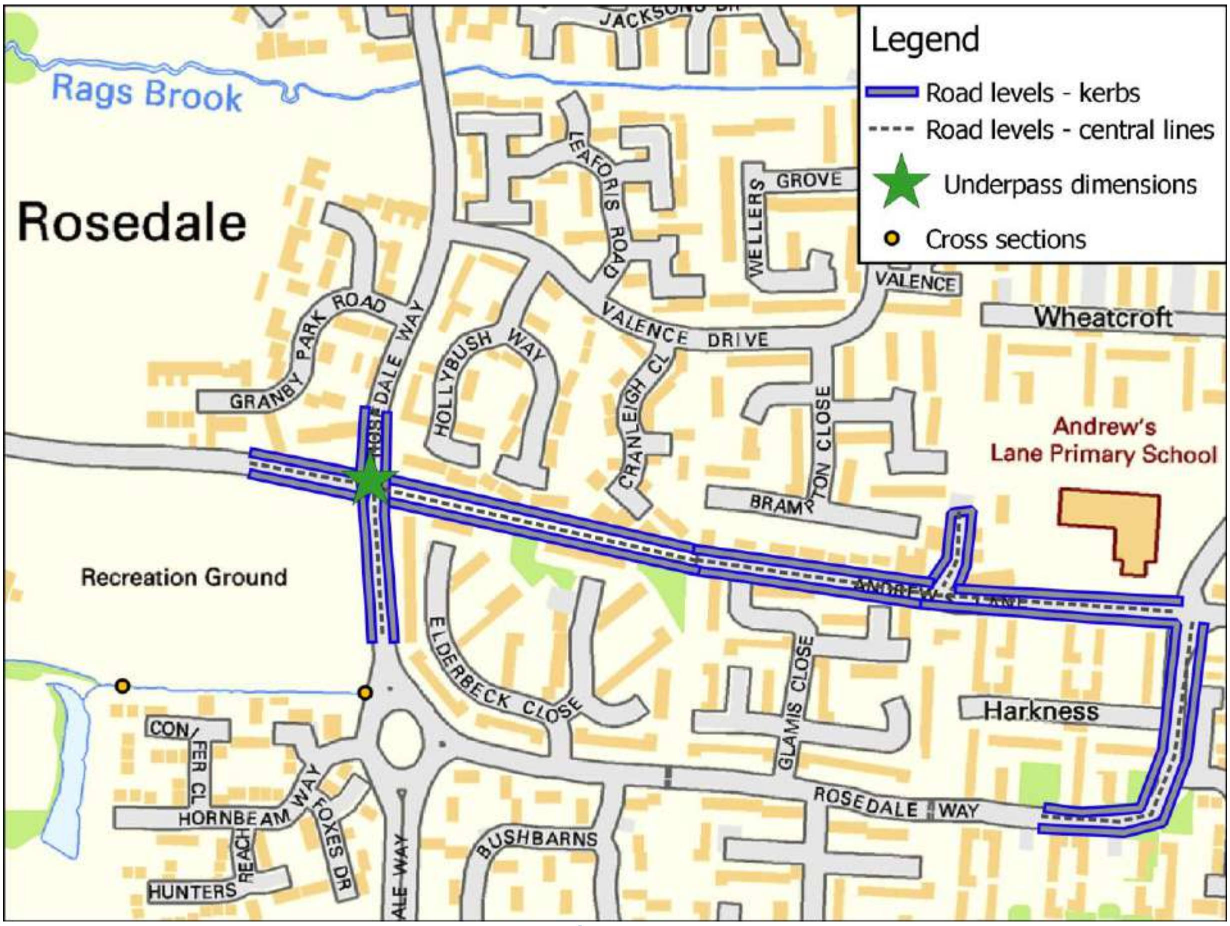

Figure 5

- Cross sections in the locations indicated by yellow points in Figure 6.

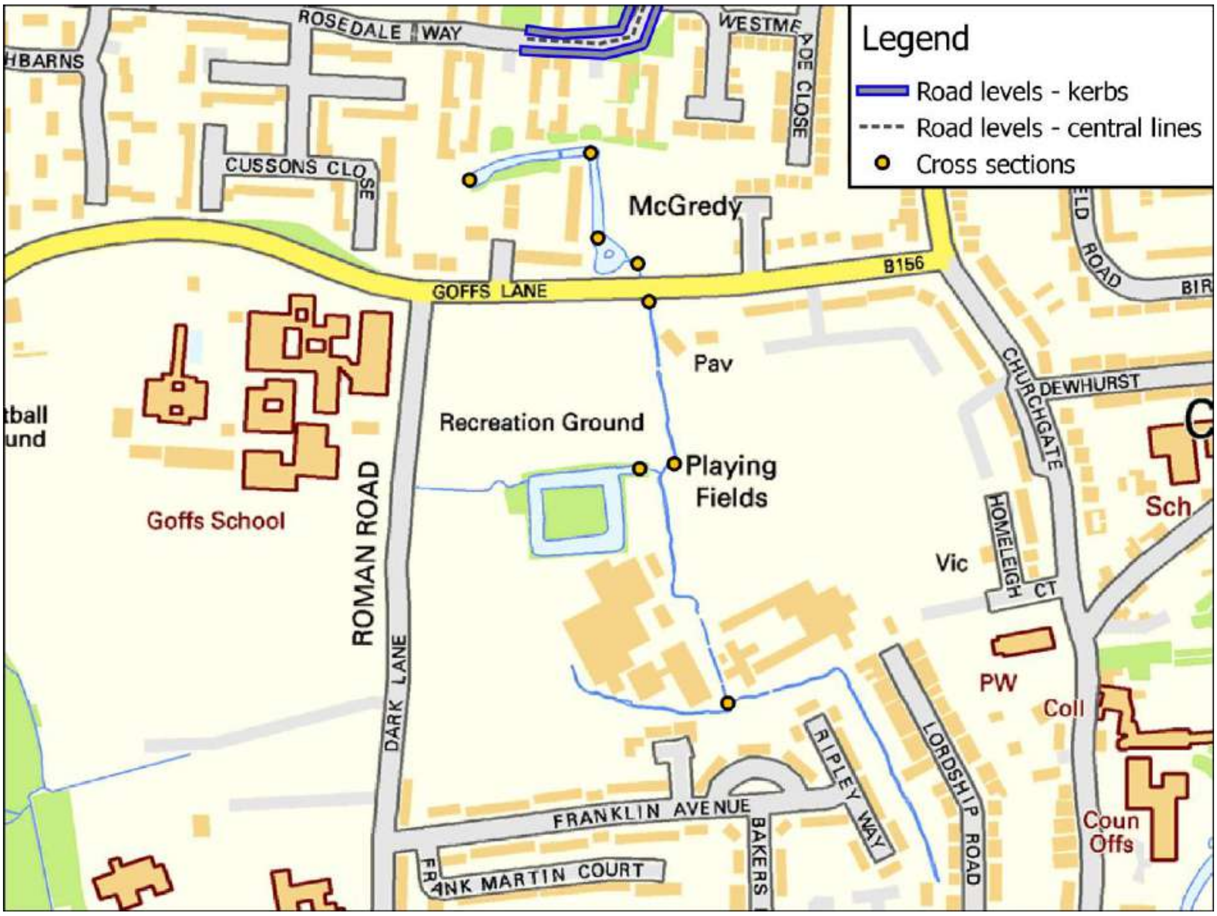

Figure 6

Additional cross sections may be required at a later stage for other watercourses in the area. We are currently unable to confirm the scope as we are waiting for the Environment Agency to provide us with their models for review.

Cozens Lane East, Wormley (Site 55)

The approximate grid reference for the central area is NGR 536700, 205700.

Confirmation on the presence of a sewer shown by the red arrow in Figure 7, crossing the railway near Boat House (approx. NGR 537134, 206513). Details should include soffit and invert levels of the culvert, dimensions, shape, material and the presence of any flap valves. Where access to Network Rail land is not possible, estimates of the culvert characteristics (i.e. dimensions and soffit level) along with photographic evidence should be provided in order to help with the assumptions.

- Cross sections of the ditch crossing the railway at this point, approx. every 30 metres as per the locations indicated by yellow points in Figure 7.

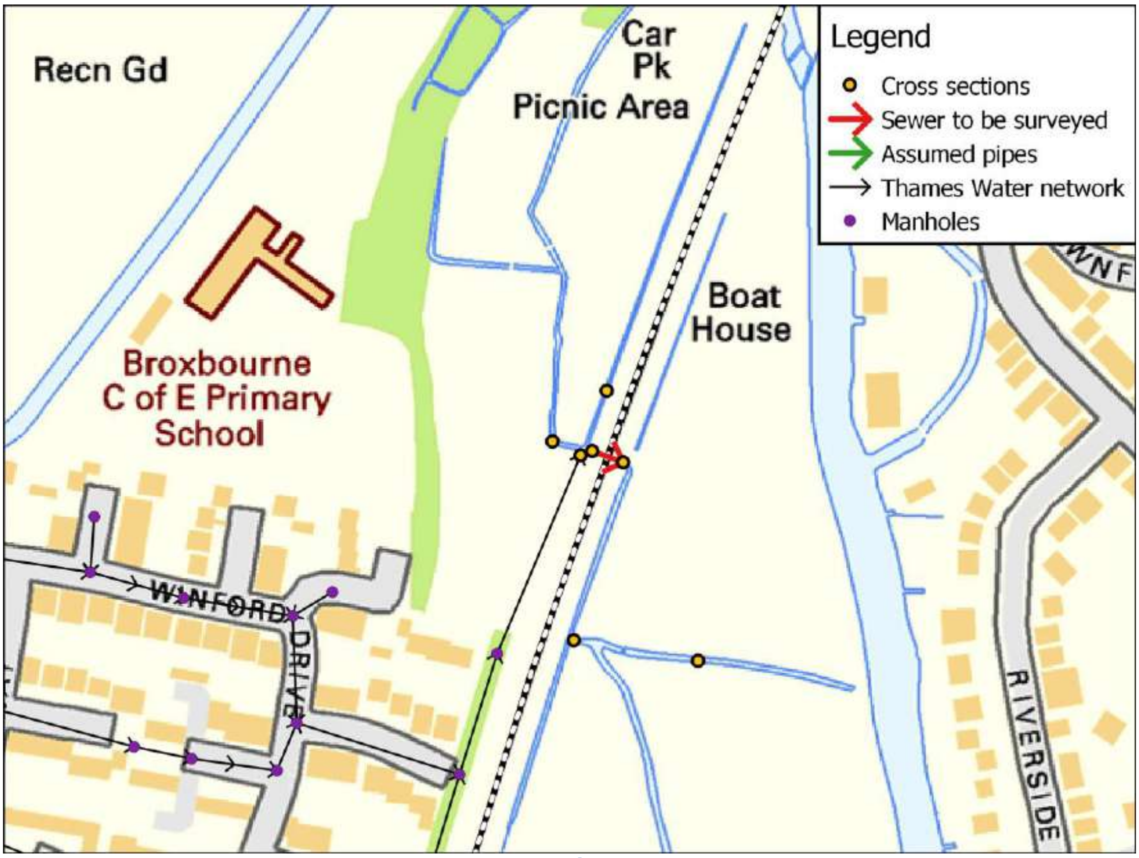

Figure 7

Survey Brief Continuation

- Confirmation on the presence of a surface water sewer crossing the railway near Cozens Lane East (approx. NGR 536932 205782), as indicated in Figure 8. Details should include downstream soffit and invert levels of the culvert, dimensions, shape, material and the presence of any flap valves. Where access to Network Rail land is not possible, estimates of the culvert characteristics (i.e. dimensions and soffit level) along with photographic evidence should be provided in order to help with the assumptions.

- Details of the Thames Water sewer crossing the railway (approx. NGR 536897 205600) as detailed in Figure 8. Details should include downstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves. Visual confirmation of the existence of a culvert crossing underneath the path running parallel to the railway (approx. NGR 536918, 205592). If existing, details on this culvert, including downstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves. Where access to Network Rail land is not possible, estimates of the culvert characteristics (i.e. dimensions and soffit level) along with photographic evidence should be provided in order to help with the assumptions.

- Details of the Thames Water sewer crossing the railway (approx. NGR 536865 205389), as detailed in Figure **8**. Details should include downstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves. Where access to Network Rail land is not possible, estimates of the culvert characteristics (i.e. dimensions and soffit level) along with photographic evidence should be provided in order to help with the assumptions.

- Cross section on the ditches where these three sewers discharge into, in the locations indicated by yellow points in Figure 8.

- Road levels of Wharf Road, including kerb levels and levels of the central line in order to confirm the flow paths, in the section of road indicated in Figure 8.

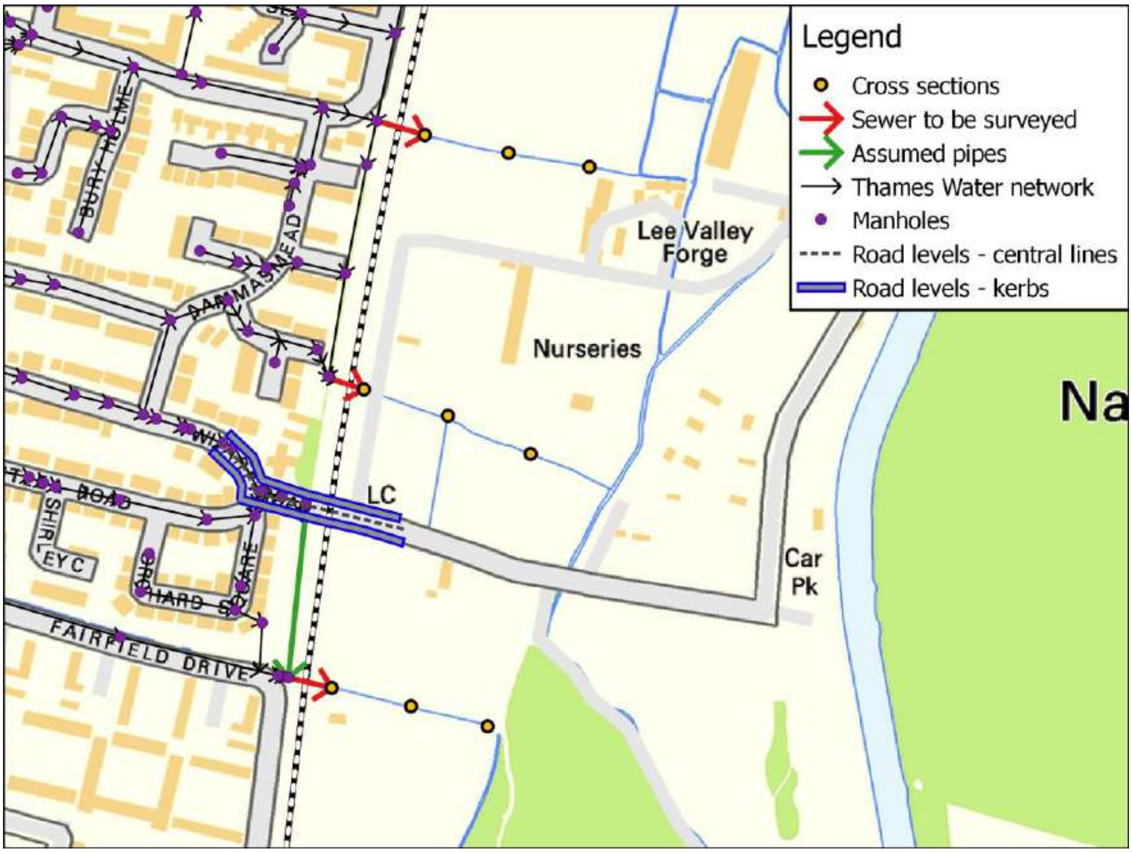

Figure 8

Survey Brief Continuation

- Details of the Thames Water sewer crossing the railway near Sorbus Road (approx. NGR 536818 204777), as detailed in the Figure 9. Details should include downstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves. Where access to Network Rail land is not possible, estimates of the culvert characteristics (i.e. dimensions and soffit level) along with photographic evidence should be provided in order to help with the assumptions.

- Visual confirmation on the presence of a surface water sewer (blue arrow in Figure 9) immediately downstream from the Thames Water sewer mentioned above (approx. NGR 536838, 204774). If existing, details on this sewer including soffit and invert levels of the culvert, dimensions, shape, material and the presence of any flap valves.

- Cross sections on the ditch where this sewer discharges into, in the locations indicated by yellow points in Figure 9.

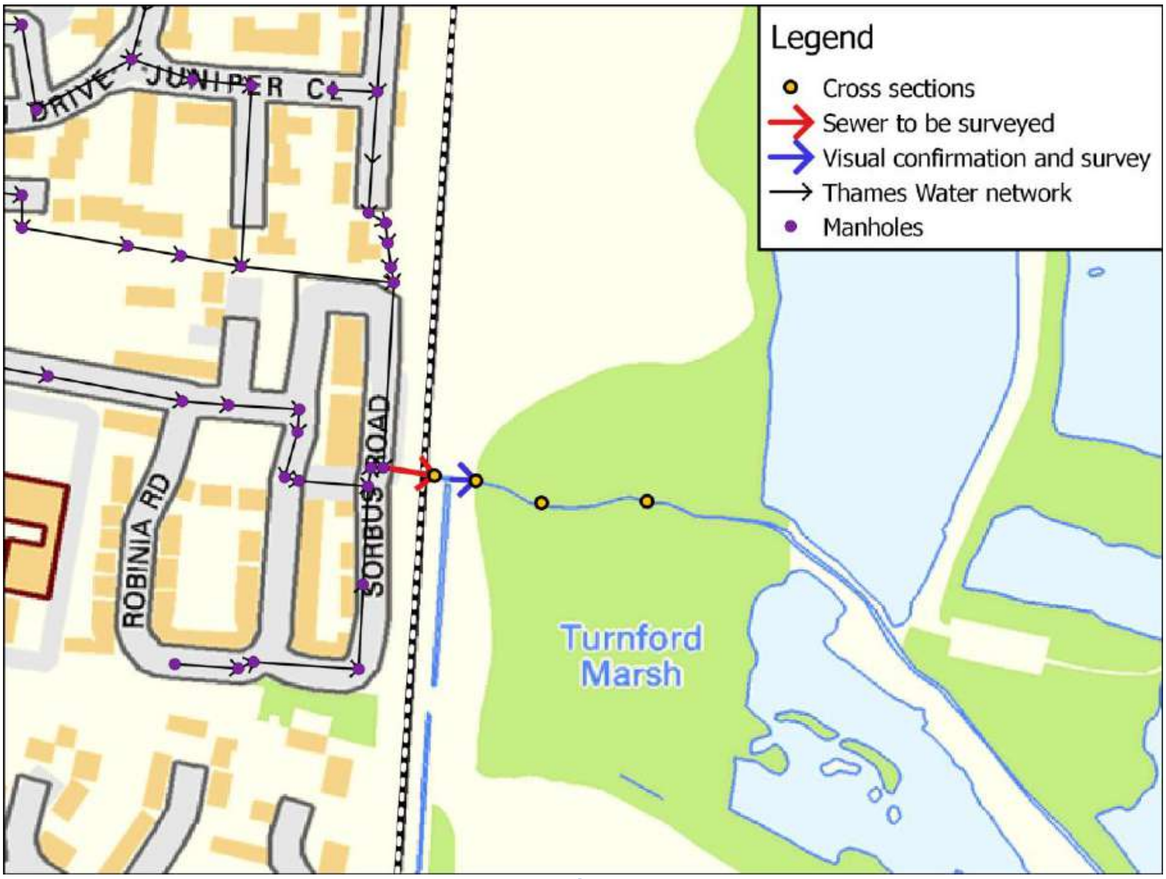

Figure 9

<u>Buntingford (Site 1)</u>

The approximate grid reference for the central area is NGR 536030, 229400.

- Cross sections on the ditch running across Monks Walk, in the locations indicated by yellow points in Figure 10. These cross sections are needed to estimate the slope of the ditch acting as a flow path rather than detailed cross sections of the ditch.

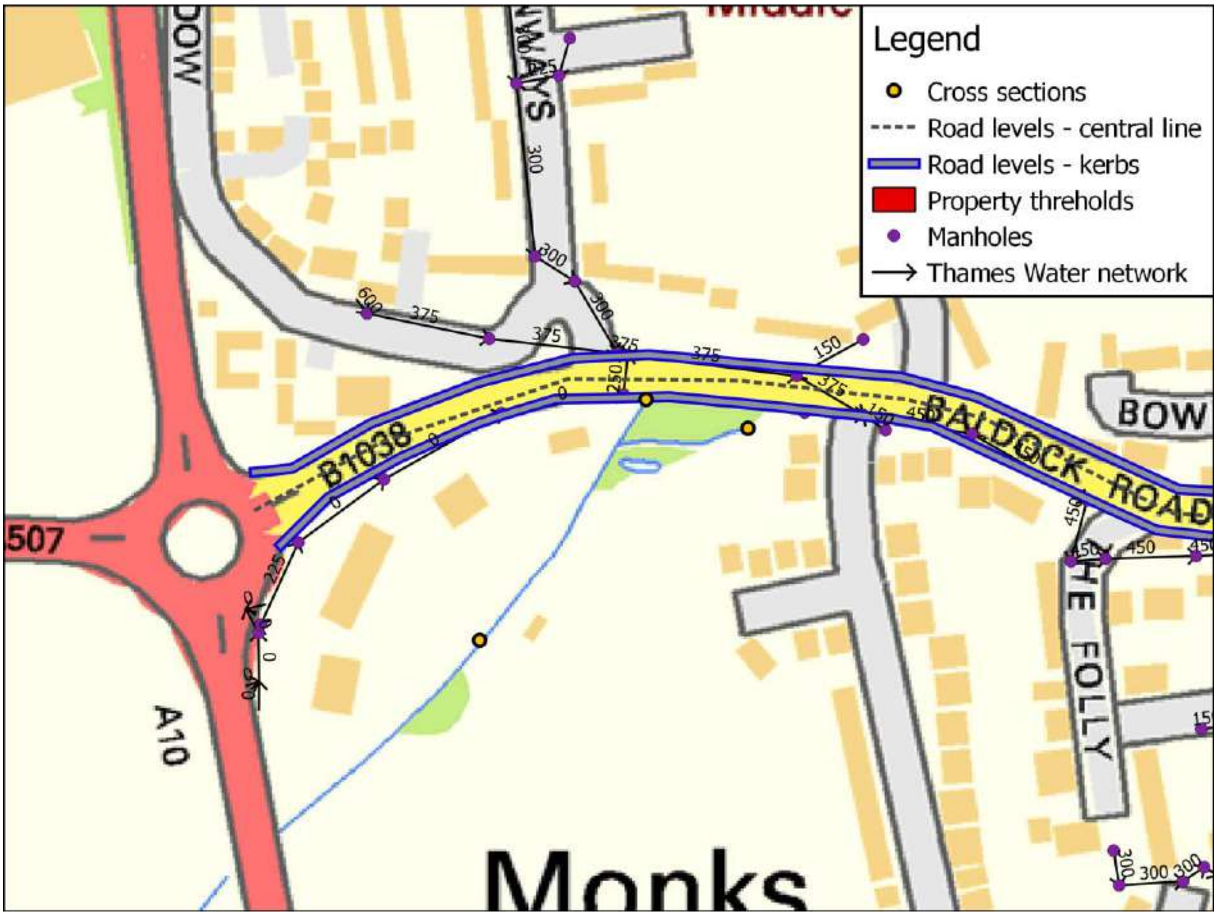

Figure 10

Survey Brief Continuation

- Road levels of Baldock Road (B1038), Chapel End, Monks Walk and High Street, including kerb levels and levels of the central line in order to confirm the flow paths in the locations indicated in Figure 11.

- Threshold levels of the properties indicated in Figure 11.

- Details on the width of the alleyways as indicated by green stars in Figure 11. Details of the location of these are provided in the list below, starting from the south west of the street, up north and back to the south east of the street.
    - Alleyway next to 41 High Street.
    - Alleyway between Vanilla Boutique Ltd and Skin Deep stores, opposite to Days of Ashwell bakery.
    - Alleyway between 59A High Street and Animal Attraction Ltd, opposite to Touch of Glamour.
    - Alleyway between The Buntingford Coffee Shop and The Dentist.
    - Alleyway between Brunel's restaurant and 71 High Street.
    - Alleyway next to Damian's Barber Shop.
    - Alleyway between Isabel Hospice Shop and Country Properties estate agents
    - Alleyway between 30 High Street and Days of Ashwell bakery
    - Alleyway between Days of Ashwell bakery and Interior Solutions
    - Alleyway next to 22 High Street
    - Alleyway for Trax cycles, next to The Black Bull pub

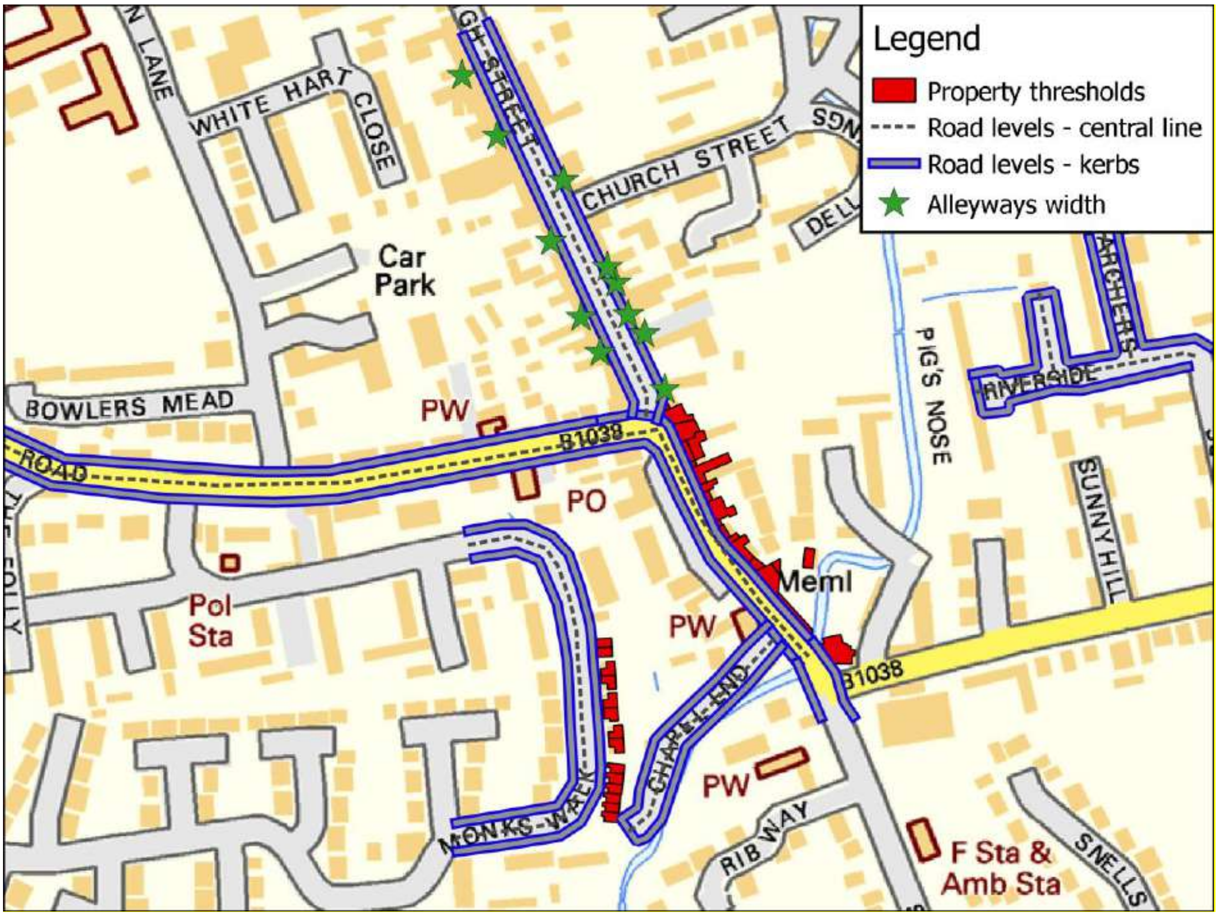

Figure 11

Survey Brief Continuation

- Road levels of Archers and Riverside, including kerb levels and levels of the central line – as indicated in Figure 12 – in order to confirm the flow paths.

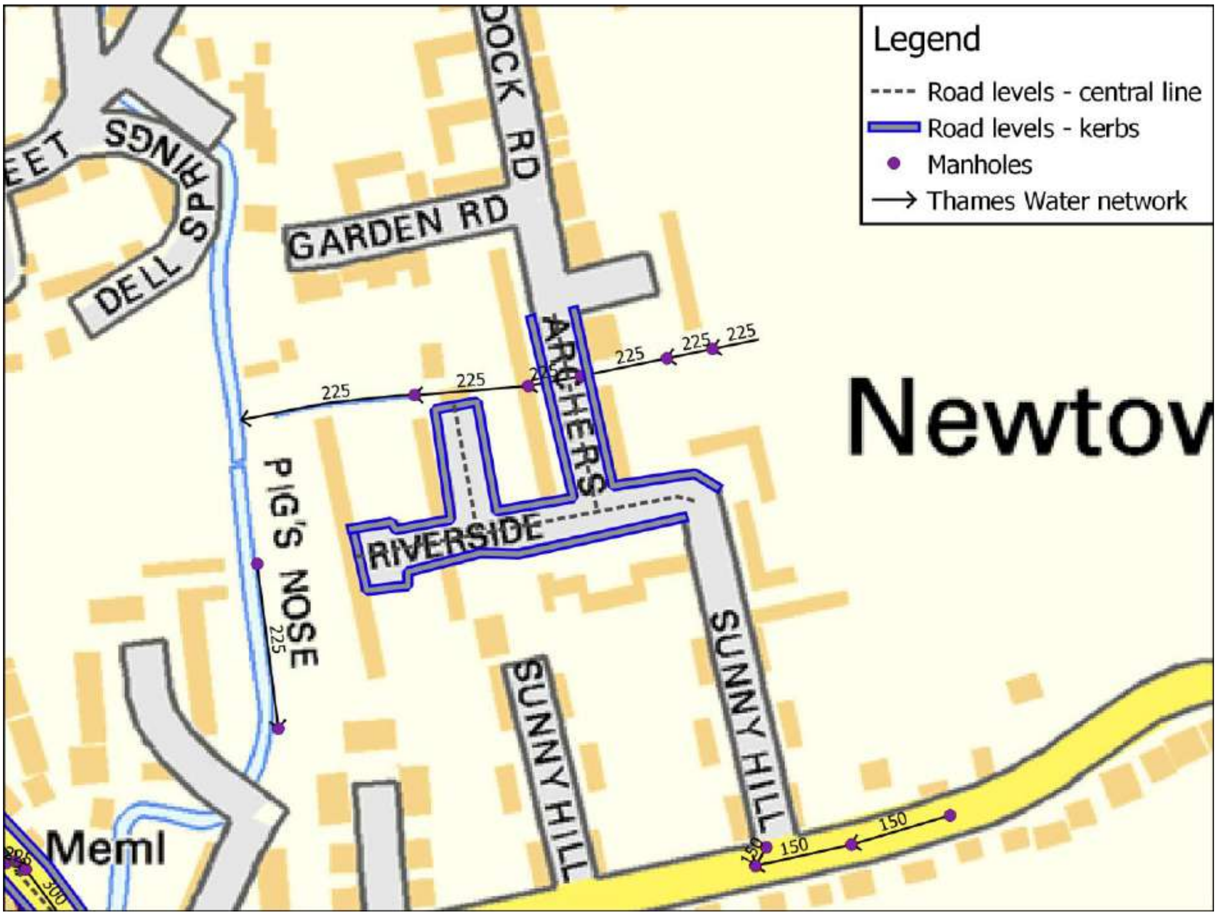

Figure 12

Survey Brief Continuation

- Road levels of Vicarage Road including kerb levels and levels of the central line – as indicated in Figure 13 – in order to confirm the flow paths.

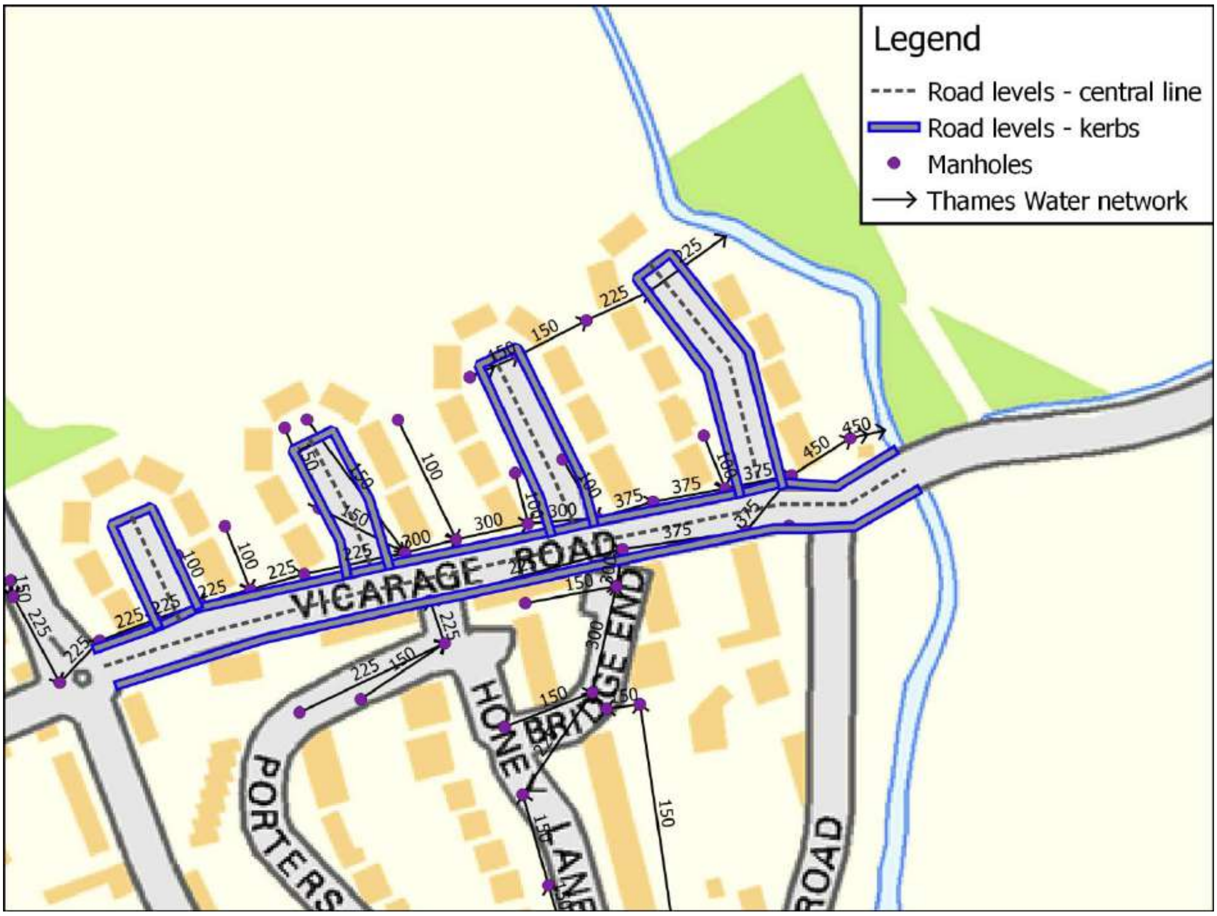

Figure 13

Hadham Road, Benhooks Avenue and Potter Street / South Street, Bishop's Stortford (Sites 43, 44 & 60)

The approximate grid reference for the central area is NGR 548300, 221200.

- Road levels of Dane Park, Maple Avenue and Matching Lane including kerb levels and levels of the central line – as indicated in Figure 14 – in order to confirm the flow paths.
- Threshold levels of the properties indicated in Figure 14.

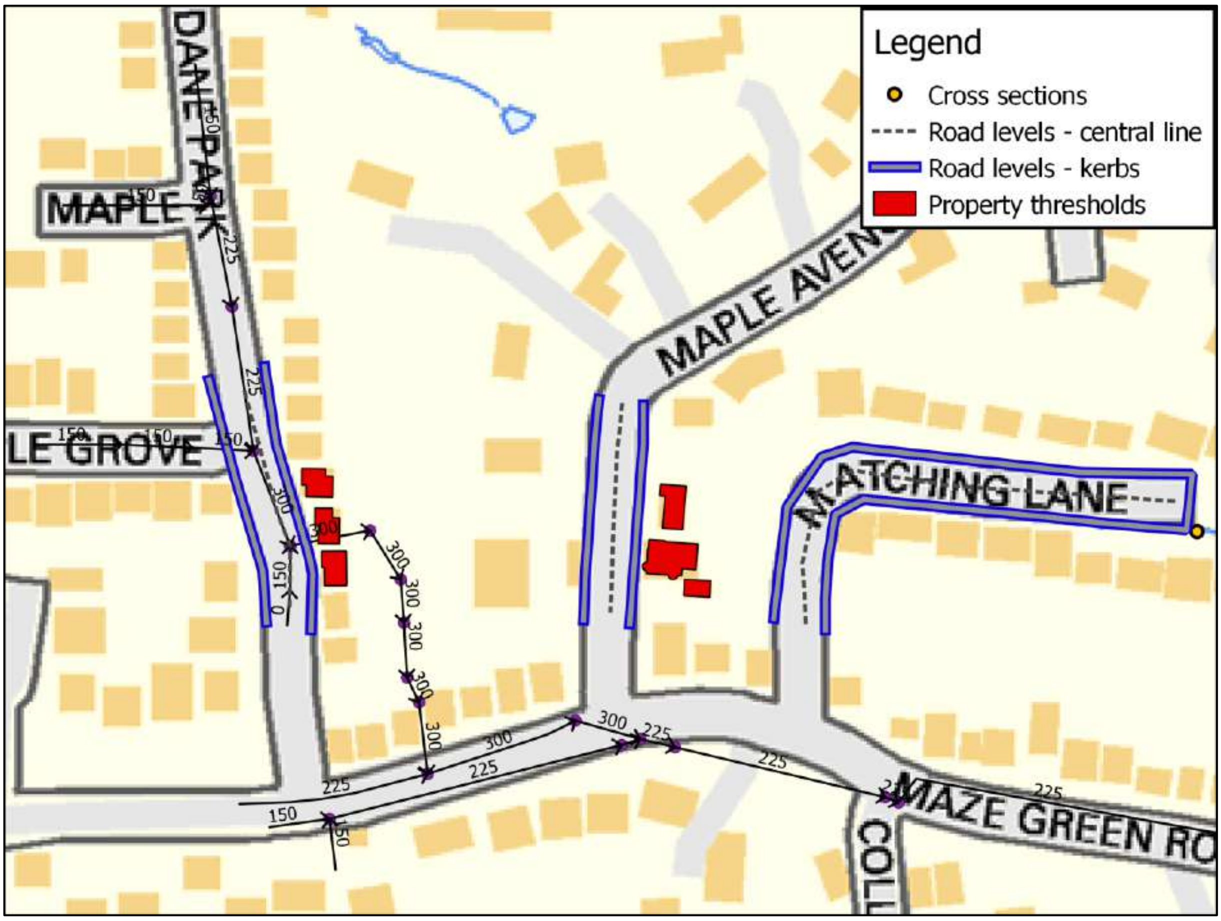

Figure 14

Survey Brief Continuation

- Cross sections on the ditches running between Matching Lane, Maze Green Road and Pye Gardens, in the locations indicated by yellow points in Figure 15.

- Details on the Thames Water sewer discharging into this drain (visual confirmation on this connectivity) from Maze Green Road (approx. NGR 547948, 221436), as detailed in Figure 15. Details should include downstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves.

- Details on the Thames Water sewer linking this drain to the Thames Water network (visual confirmation on this connectivity) running along Hadham Road (A1250) (approx. NGR 548596, 221132), as detailed in Figure 15. Details should include upstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves.

- Two cross sections on the ditch running across Saint Mary's Catholic School, in the locations indicated in Figure 15.

- Details on the Thames Water sewers linking this ditch (visual confirmation on this connectivity) to the Thames Water network, indicated by red arrows (approx. NGR 548290 221295 and 548283 221336) in Figure 15. Details should include downstream and upstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves.

- Visual connectivity of the drain running in an eastern direction to the west of Saint Mary's Catholic School, which seems to connect to the Thames Water network (approx. NGR 548200 221253).

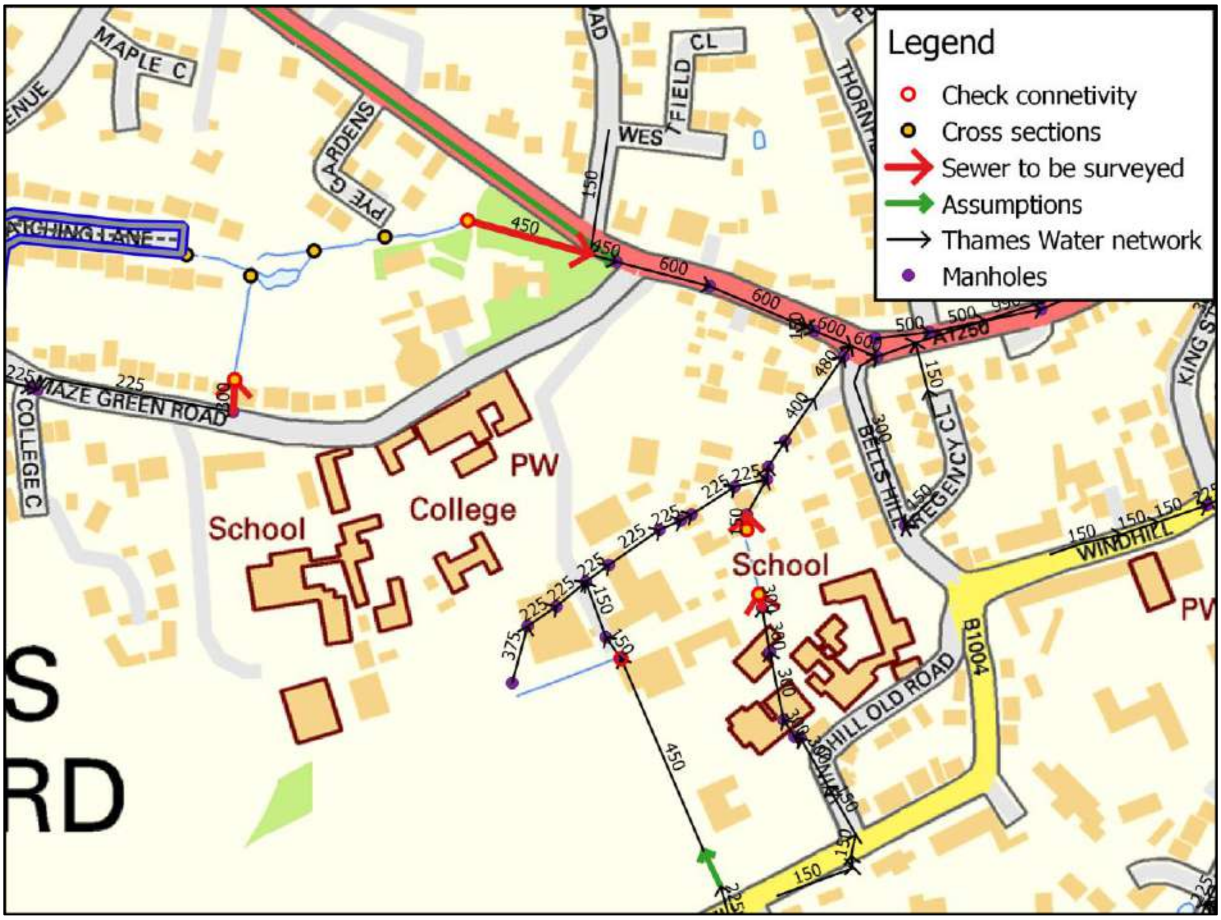

Figure 15

Survey Brief Continuation

- Visual confirmation of the connectivity of the ditch running between Beechlands and The Chase, with the Thames Water network as indicated in Figure 16.
- If the ditch and Thames Water network are connected, cross sections on the two locations indicated in Figure 16.
- Details on the Thames Water sewer discharging to this drain from Beechlands (approx. NGR 548621, 220477), as detailed in Figure 16. Details should include downstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves.

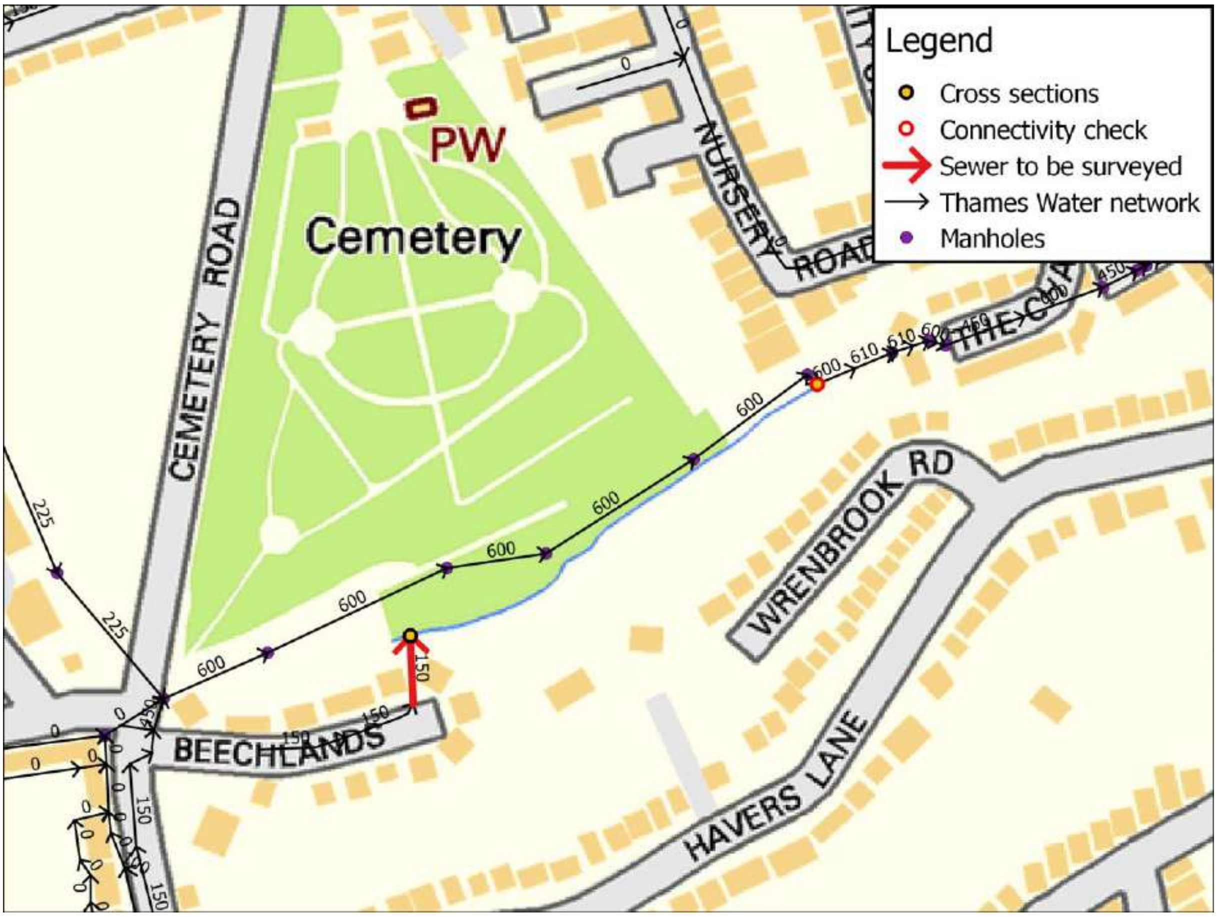

Figure 16

Raynham Road, Bishop's Stortford (Site 47)

The approximate grid reference for the central area is NGR 550100, 221500.

- Kerb levels of Raynham Road, Stortford Hall Park road and Parsonage Lane as indicated in Figure 17, in order to confirm the flow paths.
- Threshold levels of the properties indicated in Figure 17.

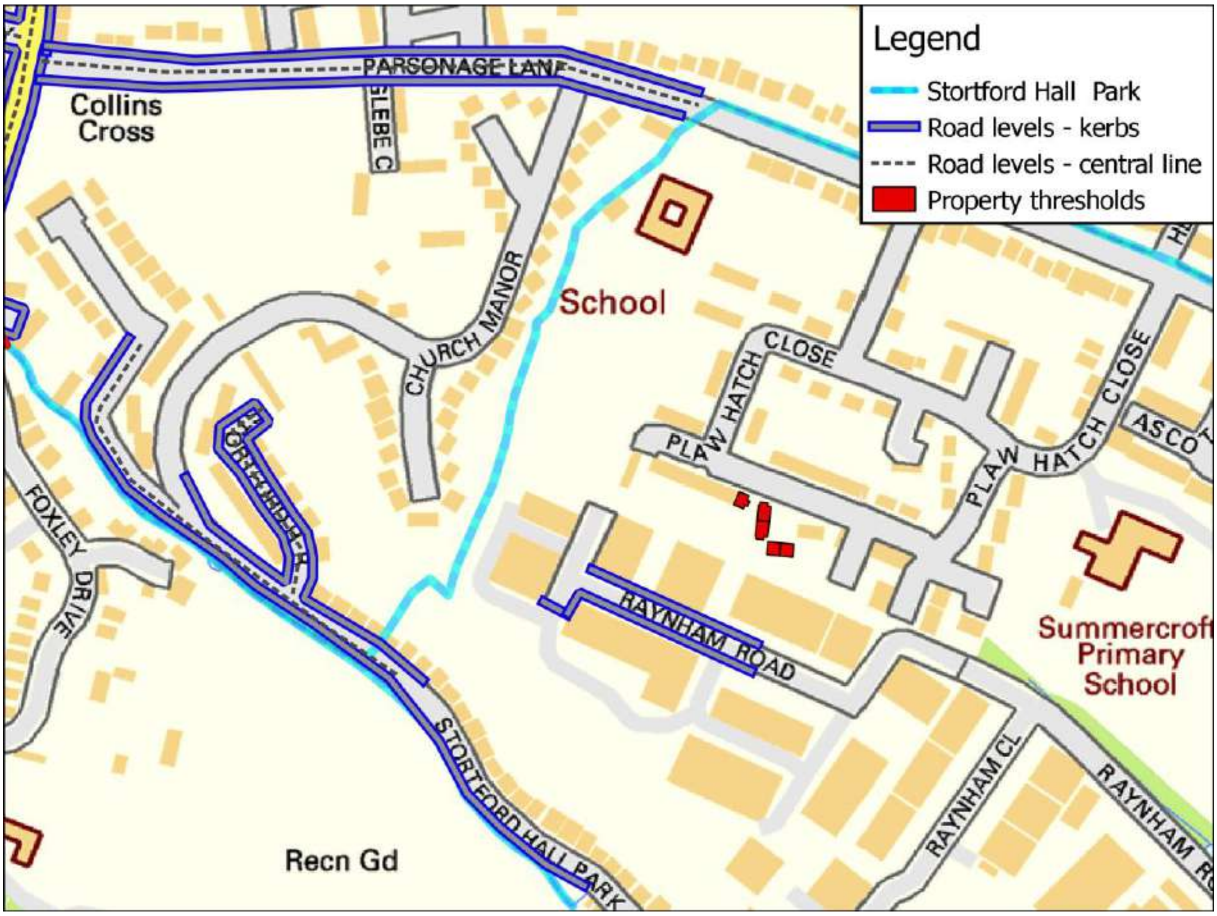

Figure 17

- Details on the culvert connecting Parsonage Lane Ditch to the Thames Water network (approx. NGR 549490, 221776). Details should include downstream and upstream soffit and invert levels, dimensions, shape, material and confirmation of the presence of any flap valves.
- Road levels of Legions Way and Stansted Road (B1383) – including kerb levels and levels of the central line – as indicated in Figure 18 – in order to confirm the flow paths.

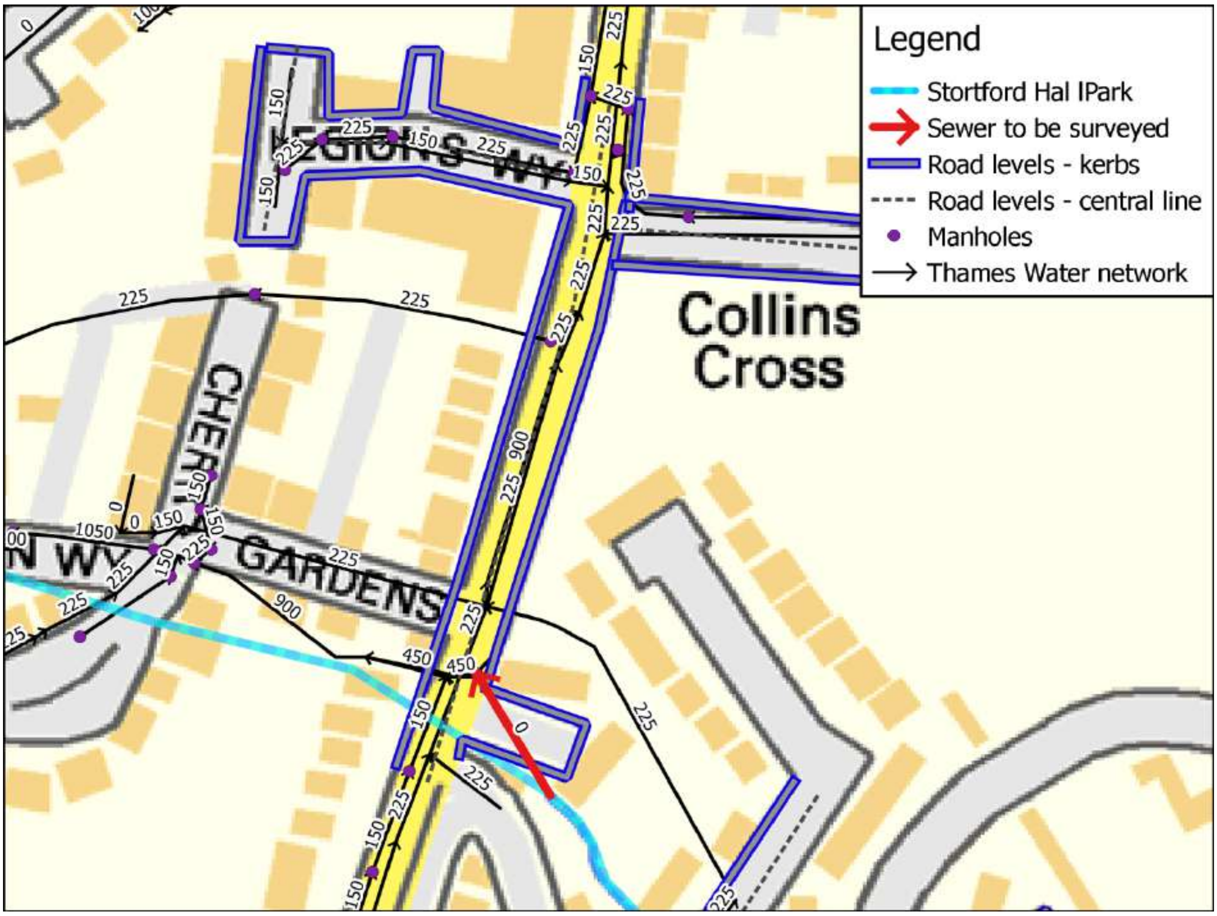

Figure 18

Survey Brief Continuation

- Cross sections on the ordinary watercourse running parallel to the disused railway, which acts like a flowpath, in the locations indicated in Figure 19 by yellow points.
- Cross sections on the drain running to the south west of Brooke Gardens, in the locations indicated in Figure 19 by yellow points.

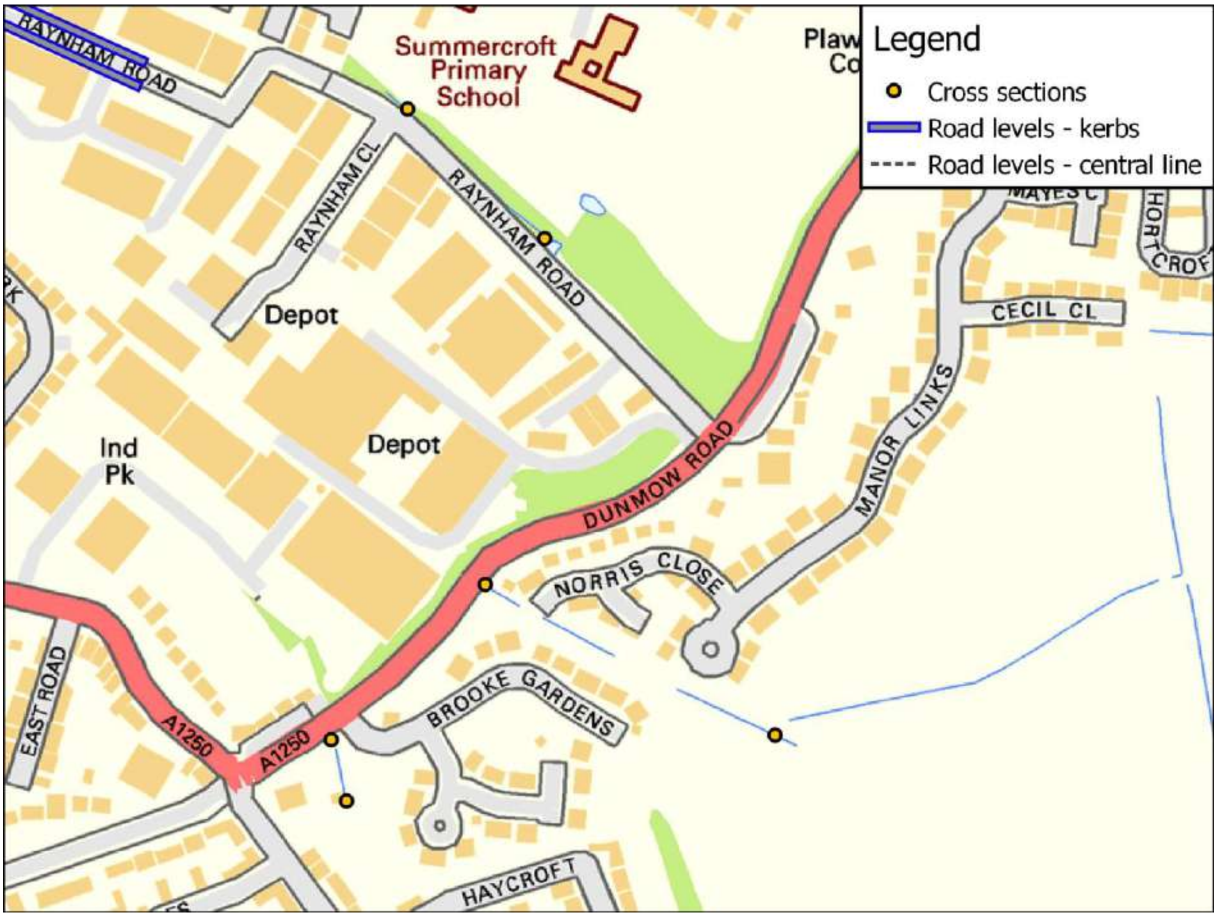

Figure 19

- Details on the sewers represented by red arrows in Figure 20 (approx. NGR 549162, 221863 and NGR 549227, 221848). Details should include downstream and upstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves. Where access to Network Rail land is not possible, estimates of the culvert characteristics (i.e. dimensions and soffit level) along with photographic evidence should be provided in order to help with the assumptions.

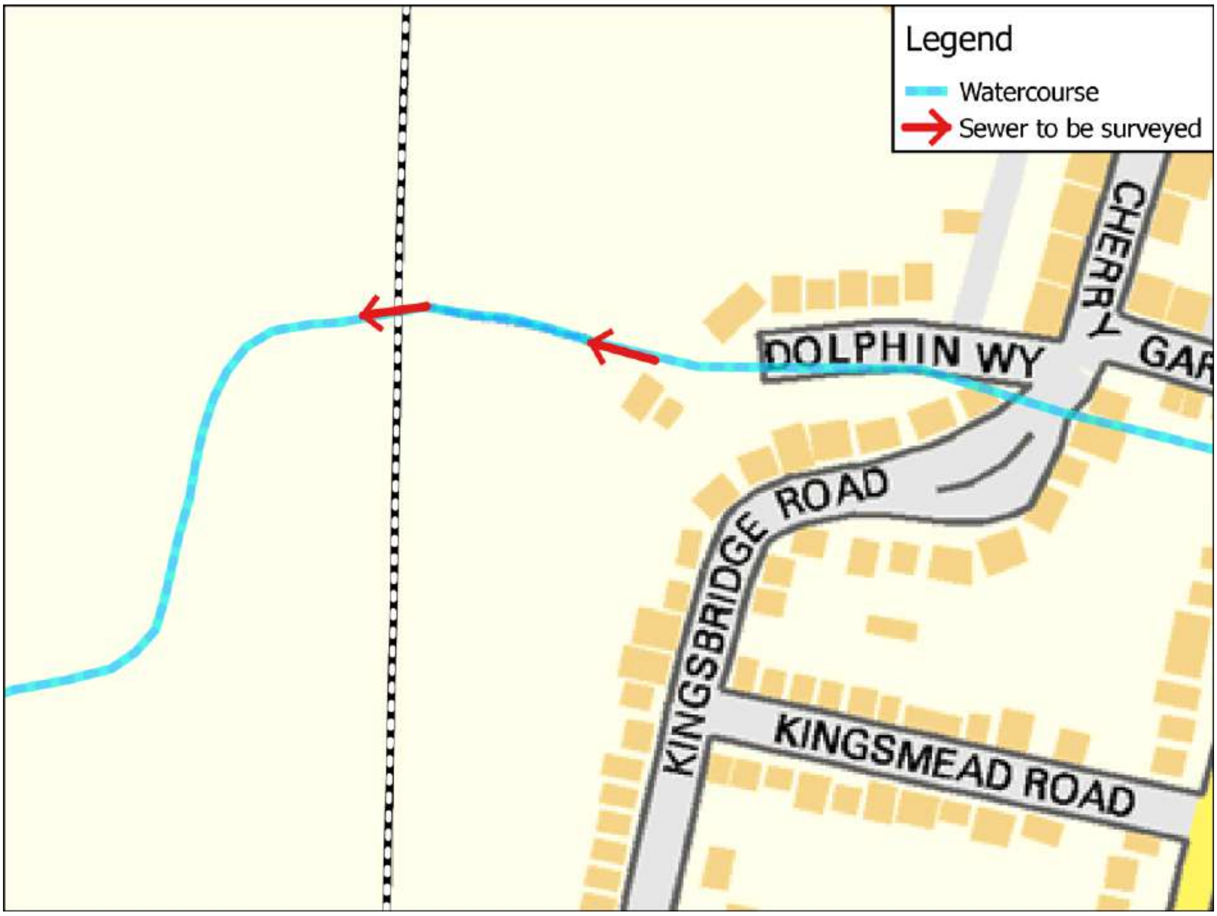

Figure 20

- Visual confirmation on a pipe running under the footpath (Figure 21) and if existing, details including downstream and upstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves.

Figure 21

<u>Bengeo, Hertford (Site 40)</u>

The approximate grid reference for the central area is NGR 532400, 213800.

- Road levels of Bengeo Street, Sacombe Road, Palmer Road, Revels Road, Glebe Road, Watermill Lane, Rib Vale, Ware Park Road, including kerb levels and levels of the central line in order to confirm the flow paths in the locations indicated in Figure 22.
- Threshold levels of the properties at Globe Court and surrounding properties as indicated in Figure 22.

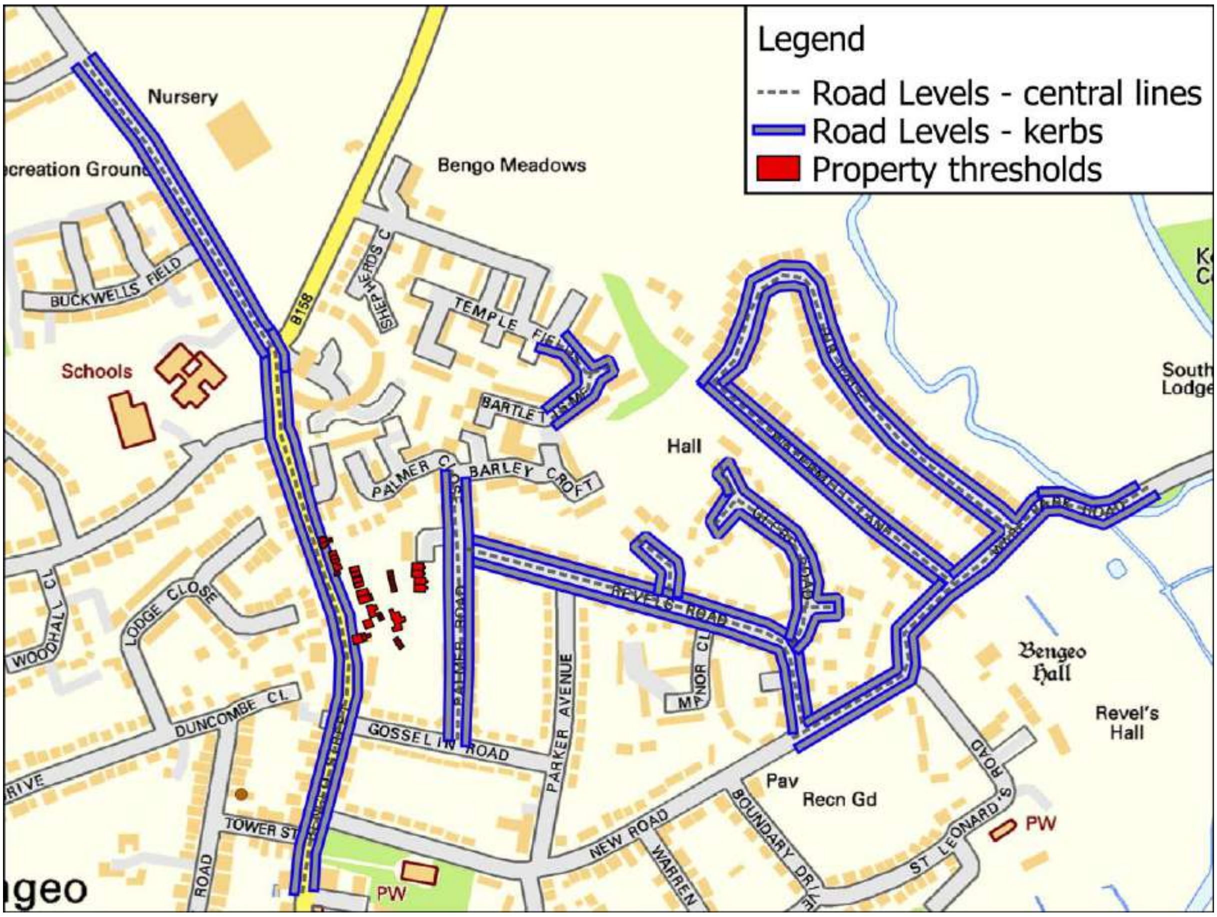

Figure 22

Watercourse survey requirements

The locations of the required highway and watercourse cross sections have been indicated in the attached plans. The WSP standard specifications for watercourse survey provide details of how these should be surveyed, which includes example cross sections of river sections, structures and long sections. Please allow for the survey of additional cross sections where changes occur in cross section geometry and/or channel slope, which may not be captured by the locations specified.

Some of the cross sections are located at in-channel culvert structures, which have been informed through a site visit and/or desk based analysis. Further detail on the specifications is below:

- The cross sections must be surveyed in accordance with WSP and Environment Agency standard specifications for watercourse survey, as must all of the remaining cross sections.
- For culverts: Survey data will include culvert type (including material), culvert dimension, invert and soffit level at inlet/outlet location, road/deck levels, parapet levels, culvert conditions and approximate estimation of silt if present. For a culvert inlet, it must include survey of the watercourse cross section immediately upstream of the culvert inlet. For a culvert outlet, it must include survey of the watercourse cross section immediately downstream of the culvert outlet;
- For bridges: Survey data will include type, dimension, invert and soffit level at inlet/outlet location, road/deck level, parapet levels, condition and approximate estimation of silt if present. Surveyed cross sections must be provided at each location identified being both the watercourse cross section immediately upstream or downstream (as marked) of the bridge feature;
- For weirs: Survey data will include length of the structure, angle with respect to direction of flows, upstream and downstream bed level, weir level; two surveyed cross sections may be required to define the weir accurately. An indication of whether the weir is natural or manmade would also be useful.

It is possible that key information was not identified during our site visit, such as additional culverts, weirs, ditches, so please ensure that any additional features that may be relevant are also captured during the survey.

The survey should be undertaken in accordance with the WSP standard specifications for watercourse survey (refer to the accompanying document named "*WSP RICS Jan 2013 ISSUED - Annex K only.pdf*"). Any major deviation from these standards may result in deliverables being rejected, where this is not possible this should be identified in your quote.

<u>Access</u>

The surveyor will be responsible for arranging access to any third party land and any consents/licences that are required (i.e. Thames Water).

We trust this information is useful and if you have any queries please do contact us.

Survey Contact
Lorena Ramirez
Graduate Hydrologist

WSP UK, Kings Orchard, 1 Queen Street, Bristol, BS2 0HQ
Tel: +44(0)117 930 2055
Email: Lorena.ramirez@wspgroup.com

Appendix II

FLOOD MODELLING SUMMARY REPORTS

FLOOD MODELLING SUMMARY REPORT

HOTSPOT 9

RYE HOUSE/NORTH HODDESDON

Modeller:	M Näslund	17-06-2016
Reviewer:	A Chowdhury	21-06-2016

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
1. General	
1.1 Variations to agreed Methodology	The downstream boundary of the model has been set using the draft levels outputs of the Environment Agency's River Lee Model and Woollens Brook. The updated Flood Map for Surface Water (uFMfSW) DTM was used as there was no more recent LiDAR flown after the production of the uFMfSW.
1.2 Scenarios used in TUFLOW model	The following naming convention has been used for developing the Scenarios: • Models labelled as Hotspot9_Broxbourne_~s1~_~e1~_~e2~_v16.tcf • Scenario ~s1~ = Baseline: Model baseline conditions • Event ~e1~ = 1.1hr: 1.1 hr critical storm duration • Event ~e2~ = 4 digit reference for return period (plus additional for climate change): Q1000; Q0100CC; Q0100; Q0075; Q0030; Q0020; Q0005. • Model results, logs, checks labelled using above convention, eg. "Hotspot9_Broxbourne _Baseline_1.1hr_Q0100_v26"

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
2. 2D Reference data	
2.1 Final DEM	The Environment Agency's updated Flood Map for Surface Water (uFMfSW) DTM was used – tiles tl31se and tl30ne.
2.2 Changes to DEM	Grid and Z shape polygons based on surveyed levels were used to modify ground levels in specific areas of roads: • survey_roads_hotspot9_new.asc • 2d_zsh_Wareroad_Hotspot9_BR_v11_R.shp • 2d_zsh_Wareroad_Hotspot9_Broxbourne_v11_P.shp Threshold levels for surveyed buildings: • 2d_z_THL_Hotspot9_Broxbourne_v01_R.shp Z line was used to raise the elevation of 2D cells along the extent of the bank wall in Wollens Brook to the south of the site: • 2d_z_bank_wall_Hotspot9_Broxbourne_v01_L.shp • 2d_z_bank_wall_Hotspot9_Broxbourne_v01_P.shp
3. 1D Reference data	
3.1 Sewer network	The surface water drainage network has been based on data provided by Thames Water. Surface Water Network Layers: • 1d_nwk_TW_pipes_Hotspot9_Broxbourne_v09.shp • 1d_nwk_TW_pitchannels_Hotspot9_Broxbourne_v09_P.shp • 1d_nwk_underpass_Hotspot9_Broxbourne_v01.shp Any changes to the 1d nwk have been included into the 'Assumption' column in the layers above.

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
3.2 Watercourse Structures	No 1d watercourse represented within the model.
4. Hydrology	
4.1 Inflow boundaries	FEH CD ROM (not web based FEH) was used to extract catchment characteristic which was later used in ISIS FEH module to derive rainfall hyetographs for a critical storm duration.

AEP	20.0%	5.0%	3.3%	1.3%	1.0%	1%+40%	0.1%
Peak rainfall intensity (mm/hr)	56	89	101	135	148	208	307
Total rainfall (mm)	19	30	35	46	51	71	106
Storm duration (hr)	1.1						

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
4.2 Downstream boundaries	The downstream boundaries have been defined as the 20% AEP fluvial boundary for the River Rive Lee and Woollens Brook model.
4.3 Historical records of flooding	Basement flooding was reported in Padick Close due to ground water from gravel overlaying London Clay. Environment Agency Recorded Flood Outlines show no recorded events in the area.
5. Materials and Soils	

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
5.1 2D Manning's n	The Manning's n values used for the floodplain areas (2D domain) are specified in the modelling methodology report.
5.2 1D Manning's n	No channel manning's values needed as no 1d open channel have been modelled.
5.3 Soil loss definition	The soil types in the study area have been defined based on National UK Soils Maps. The table below shows the National UK Soil type classification and all the Green-Ampt Soil Type used in the TUFLOW model for this hotspot.

National UK Soil Maps Classification	Description	Green-Ampt Soil Type
Loamy	Freely draining slightly acid loamy soils	8 – Loam
Loamy and Clayey	Slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils	4 – Clay Loam
Loamy and clayey	Loamy and clayey floodplain soils with naturally high groundwater	4 – Clay Loam

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
5.4 Changes to coefficients from normal	No
6. Software	
6.1 Version	TUFLOW version 2016-03-AA-W64
6.2 Precision	Double precision used for direct rainfall modelling
6.3 Defaults	Cell wet/dry depth changed to 0.0002 from default of 0.002 for direct rainfall modelling
6.4 Outputs	DAT – d v q h ZUK0
6.5 Hazard	UK Hazard Land Use - Conservative
7. Modelling Log	
7.1 Model duration	2.3 hours
7.2 Grid size	2 m
7.3 Timestep	0.5 seconds

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
7.4 Mass balance check	Peak Cumulative Mass Balance errors (Qi+Qo > 5%) in different event scenarios range between -0. 19% and -0.26% for all scenarios.
7.5 Number of messages / warnings etc.	255 warnings/ 1606 checks relating to invert levels interpolation, SX ZC lowering, null shapes etc.
8. Sensitivity testing	
8.1 Culvert blockage	
8.2 Structural coefficients	
8.3 Roughness coefficients	
8.4 Runoff coefficients	
8.5 Inflows	

The model review is complete and this model meets WSP|Parsons Brinckerhoff requirements and it is suitable for mapping and release.	✓

FLOOD MODELLING SUMMARY REPORT

HOTSPOT 52, 62 & 63

CHESHUNT/ROSEDALE NORTH & SOUTH – FLAMSTEAD END

Modeller:	M Näslund	13-06-2016
Reviewer:	A Chowdhury	28-06-2016

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
1. General	
1.1 Variations to agreed Methodology	The downstream boundaries of the model have been set using the levels outputs of the Environment Agency's Small River Lea or Lee, Rags Brook, Turnford Brook, Model and College Brook, for the north, south and east boundaries. The updated Flood Map for Surface Water (uFMfSW) DTM was used as there was no more recent LiDAR flown after the production of the uFMfSW.
1.2 Scenarios used in TUFLOW model	The following naming convention has been used for developing the Scenarios: • Models labelled as Hotspot52_62_63_Broxbourne _~s1~_~e1~_~e2~_v13.tcf • Scenario ~s1~ = Baseline: Model baseline conditions • Event ~e1~ = 2.8hr: 2.8 hr critical storm duration • Event ~e2~ = 4 digit reference for return period (plus additional for climate change): Q1000; Q0100CC; Q0100; Q0075; Q0030; Q0020; Q0005. • Model results, logs, checks labelled using above convention, eg. "Hotspot52_62_63_Broxbourne_Baseline_2.8hr_Q0100_v13"

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
2. 2D Reference data	
2.1 Final DEM	The Environment Agency's updated Flood Map for Surface Water (uFMfSW) DTM was used – tiles tl30sw and tl30se.
2.2 Changes to DEM	Z shape polygon to correct road topography at those locations where DTM is picking up levels on the by-pass culverts underneath the road • 2d_zsh_road_fill_Hotspot52_62_63_v08_R.shp • 2d_zsh_road_corr_Hotspot52_62_63_v01_R.shp • 2d_zsh_road_corr_Hotspot52_62_63_v01_P.shp Z shape polygons based on surveyed levels were used to modify ground levels in specific areas of the roads: • 2d_zsh_Hotspot52_62_63_Broxbourne_v08_R.shp • 2d_zhp_Hotspot52_62_63_Broxbourne_v08A_P.shp Z shape polygon to correct topography near the culvert underneath Rosedale Way; modification is based on lowering ground levels upstream of the culvert inlet (both sides) in accordance with survey data • 2d_zsh_bypass_Hotspot52_62_63_v01_R.shp • 2d_zsh_bypass_Hotspot52_62_63_v01_P.shp Z lines (HX) and points to represent banks: • 2d_banks_Hotspot52_62_63_Broxbourne_v01_L.shp • 2d_banks_Hotspot52_62_63_Broxbourne_v01_P.shp Z line and point to represent channel downstream of pond: • 2d_z_channel_Hotspot52_62_63_Broxbourne_v01_P.shp • 2d_z_Hotspot52_62_63_Broxbourne_v01_P.shp The channel between the pond and the culvert under the road was modelled as a 1d with a xz table, and the area of the channel was made inactive : • 1d_tab_xz_Hotspot52_62_62_Broxbourne_v08_L.shp. • 2d_code_inactive_Hotspot52_62_63_Broxbourne_v08_R.shp

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
3. 1D Reference data	
3.1 Sewer network	The surface water drainage network has been based on data provided by Thames Water. Surface Water Network Layers: • 1d_nwk_TW_pipes_Hotspot52_62_63_Broxbourne_v13_L.shp • 1d_nwk_pitchannel_Hotspot52_62_63_Broxbourne_v12_P.shp • 1d_nwk_culverts_Hotspot52_62_63_Broxbourne_v13_L.shp • 1d_nwk_road_bypass_Hotspot52_62_63_Broxbourne_v01_L.shp Any changes to the 1d nwk have been included into the ‘Assumption’ column in the layers above.
3.2 Watercourse Structures	N/A
4. Hydrology	
4.1 Inflow boundaries	FEH CD ROM (not web based FEH) was used to extract catchment characteristic which was later used in ISIS FEH module to derive rainfall hyetographs for a critical storm duration.

AEP	20.0%	5.0%	3.3%	1.3%	1.0%	1%+40%	0.1%
Peak rainfall intensity (mm/hr)	34	53	61	80	87	122	175
Total rainfall (mm)	25	38	44	58	63	88	126
Storm duration (hr)	2.8						

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
4.2 Downstream boundaries	Levels for the 20% AEP event of the Environment Agency's mode for Small River Lea or Lee, Rags Brook, Turnford Brook, Model and College Brook been used as a downstream boundary to the north, south and east of the 2D model.
4.3 Historical records of flooding	The S&I report indicates that flooding occurs frequently IN Flamstead End Road due to surface water runoff from the fields to the north. Solutions are being considered, including resurfacing the road. Environment Agency Recorded Flood Outlines show no recorded events in the area.
5. Materials and Soils	
5.1 2D Manning's n	The Manning's n values used for the floodplain areas (2D domain) are specified in the modelling methodology report.
5.2 1D Manning's n	No channel manning's values needed as no 1d open channel have been modelled.
5.3 Soil loss definition	The soil types in the study area have been defined based on National UK Soils Maps. The table below shows the National UK Soil type classification and all the Green-Ampt Soil Type used in the TUFLOW model for this hotspot.

National UK Soil Maps Classification	Description	Green-Ampt Soil Type
Loamy	Freely draining slightly acid loamy soils	8 – Loam

MODEL ELEMENT	ACTION TAKEN DURING MODELLING		
	Loamy and Clayey	Slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils	4 – Clay Loam
	Loamy and clayey	Loamy and clayey floodplain soils with naturally high groundwater	4 – Clay Loam
5.4 Changes to coefficients from normal	No		
6. Software			
6.1 Version	TUFLOW version 2016-03-AA-W64		
6.2 Precision	Double precision used for direct rainfall modelling		
6.3 Defaults	Cell wet/dry depth changed to 0.0002 from default of 0.002 for direct rainfall modelling		
6.4 Outputs	DAT – d v q h ZUK0		
6.5 Hazard	UK Hazard Land Use - Conservative		

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
7. Modelling Log	
7.1 Model duration	4.2 hours
7.2 Grid size	2 m
7.3 Timestep	0.5 seconds
7.4 Mass balance check	Peak Cumulative Mass Balance errors (Qi+Qo > 5%) in different event scenarios range between -0. 43% for 1 in 5 year event to -4.04% for 1 in 1000 year event.
7.5 Number of messages / warnings etc.	446 warnings/ 2287 checks relating to invert levels interpolation, SX ZC lowering, null shapes etc. 6267 warnings are related to the presence of negative depths in the underpass X, but this is not impacting the results.
8. Sensitivity testing	
8.1 Culvert blockage	See table below

Change in levels (m)		
Pipes blockage	50%	75%
Max	0.321	0.349
Mean	0.000	0.000
Min	-0.047	-0.083
Standard Deviation	0.008	0.012

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
	Sensitivity was undertaken to assess the impact on levels (m) of blocking all the pipes, culverts and underpasses in the model by 50% and 75%. The table above indicates the maximum, minimum and mean difference in levels between baseline and sensitivity scenarios for the 1 in 100 year event, and the standard deviation.
8.2 Structural coefficients	
8.3 Roughness coefficients	
8.4 Runoff coefficients	
8.5 Inflows	

The model review is complete and this model meets WSP|Parsons Brinckerhoff requirements and it is suitable for mapping and release.	✓

FLOOD MODELLING SUMMARY REPORT

HOTSPOT 55

COZENS LANE EAST, WORMLEY

Modeller:	L Ramirez	20-06-2016
Reviewer:	A Chowdhury	27-06-2016

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
1. General	
1.1 Variations to agreed Methodology	N/A
1.2 Scenarios used in TUFLOW model	The following naming convention has been used for developing the Scenarios: • Models labelled as Hotspot55_CozensLn_East_v35_~s1~_~e1~_~e2~.tcf • Scenario ~s1~ = Baseline: Model baseline conditions • Event ~e1~ = 3.08hr: 3.08hr critical storm duration • Event ~e2~ = 4 digit reference for return period (plus additional for climate change): Q1000; Q0100CC; Q0100; Q0075; Q0030; Q0020; Q0005. • Model results, logs, checks labelled using above convention, eg. “Hotspot55_CozensLn_East_v35_Baseline_3.08hr_Q0100”
2. 2D Reference data	
2.1 Final DEM	The final DTM is based on 1m EA & PGA2a LIDAR DTM – tile TL3504

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
2.2 Changes to DEM	The following changes have been made to the DTM in the baseline model: Z line and points were used to define drains downstream the railway: • 2d_z_openchannels_CozensLn_East_v35_L.shp • 2d_z_openchannels_CozensLn_East_v35_P.shp Zshape were used to lower roads by 0.125m (the height of a British Standard kerb) to better delineate the important pathways and ensure that the principal flood pathways along roads are better represented in the 2m model grid. The buildings polygons were also raised by 300mm. These are consistent with the approach adopted to produce the uFMfSW. • 2d_z_roads_CozensLn_East_v18_R.shp • 2d_z_buildings_CozensLn_East_v18_R.shp Z shape polygons based on surveyed levels were used to modify ground levels in specific areas of the roads: • 2d_zsh_road_levels_CozensLn_East_30_R.shp • 2d_zsh_road_levels_CozensLn_East_32_L.shp • 2d_zsh_road_levels_CozensLn_East_32_P.shp
3. 1D Reference data	
3.1 Sewer network	The surface water drainage network has been based on data provided by Thames Water. Surface Water Network Layer: • 1d_nwk_TW_CozensLn_East_v30_L.shp • 1d_nwk_culverts_CozensLn_East_30_L.shp • 1d_nwk_pitchannels_CozensLn_East_30_P.shp Any changes to the 1d nwk have been included into the ‘Assumption’ column in the layers above.
3.2 Watercourse Structures	N/A

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
4. Hydrology	
4.1 Inflow boundaries	FEH CD ROM (not web based FEH) was used to extract catchment characteristic which was later used in ISIS FEH module to derive rainfall hyetographs for a critical storm duration.
4.2 Downstream boundaries	The downstream boundary has been defined as a free flow HQ boundary based on the slope.
4.3 Historical records of flooding	Environment Agency Recorded Flood Outlines show a recorded event in March 1947 due to exceedance f channel capacity of the River Lee.
5. Materials and Soils	
5.1 2D Manning's n	The Manning's n values used for the floodplain areas (2D domain) are specified in the modelling methodology report.
5.2 1D Manning's n	N/A

Table for 4.1 Inflow boundaries:

AEP	20.0%	5.0%	3.3%	1.3%	1.0%	1%+40%	0.1%
Peak rainfall depth (mm/hr)	27	42	47	62	67	94	134
Total rainfall (mm)	26	40	45	60	65	91	129
Storm duration (hr)	3.08						

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
5.3 Soil loss definition	The soil types in the study area have been defined based on National UK Soils Maps. The table below shows the National UK Soil type classification and all the Green-Ampt Soil Type used in the TUFLOW model for this hotspot. <table><tr><th>National UK Soil Maps Classification</th><th>Description</th><th>Green-Ampt Soil Type</th></tr><tr><td>Loamy</td><td>Freely draining slightly acid loamy soils</td><td>8 – Loam</td></tr></table>
5.4 Changes to coefficients from normal	No
6. Software	
6.1 Version	TUFLOW version 2016-03-AA-W64
6.2 Precision	Double precision used for direct rainfall modelling
6.3 Defaults	Cell wet/dry depth changed to 0.0002 from default of 0.002 for direct rainfall modelling
6.4 Outputs	DAT – d v q h ZUK0

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
6.5 Hazard	UK Hazard Land Use - Conservative
7. Modelling Log	
7.1 Model duration	4.58 hours
7.2 Grid size	2 m
7.3 Timestep	0.5 seconds
7.4 Mass balance check	Peak Cumulative Mass Balance errors (Qi+Qo > 5%) in different event scenarios range between 0. 21% and -0.40% for all scenarios.
7.5 Number of messages / warnings etc.	174 warnings/ 1099 checks relating to invert levels interpolation, SX ZC lowering, null shapes etc.
8. Sensitivity testing	
8.1 Culvert blockage	Sensitivity was undertaken to assess the impact of blockage on the culverts crossing the railway. The table above indicates the maximum, minimum and mean difference in levels between baseline and sensitivity scenarios for the 1 in 100 year event, and the standard deviation.

Change in levels (m)		
Blockage of culvers crossing railway	50%	75%

MODEL ELEMENT	ACTION TAKEN DURING MODELLING		
	Max	0.104	0.220
	Mean	0.003	0.006
	Min	-0.049	-0.083
	Standard Deviation	0.014	0.030

8.2 Structural coefficients

8.3 Roughness coefficients

8.4 Runoff coefficients

8.5 Inflows

The model review is complete and this model meets WSP|Parsons Brinckerhoff requirements and it is suitable for mapping and release.	✓