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BMT WBM

Leiston Surface Water Management Plan Update

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Leiston Surface Water Management Plan Update

Prepared for:	Suffolk County Council
Prepared by:	BMT WBM Pty Ltd (Member of the BMT group of companies)

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Synopsis:	**The following report outlines the scope of works undertaken by BMT WBM in updating the Surface Water Management Plan hydraulic model developed for Leiston. The results of the models will be used in future assessments for the development of capital schemes and to secure funding for more detailed surface water studies.**	

REVISION/CHECKING HISTORY

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Executive Summary

BMT WBM were commissioned by Suffolk County Council to update the Leiston Surface Water Management Plan Modelling. The purpose of the update is to incorporate new data to create a more accurate flood risk assessment in the town. The results will be used to identify areas at risk of surface water flooding and assist with the development of capital schemes in future studies.

A single TUFLOW hydraulic model was developed to address the key limitations of the existing hydraulic model. The available drainage network data was sparse and of low confidence. Therefore, a one-way coupled representation of the gullies within the urban area of Leiston has been developed. More detailed drainage network information could further refine the modelled network and allow for more integrated urban drainage modelling.

The structures at Lover's Lane and Abbey Road have been represented as fully linked 1D hydraulic structures. The Green-Ampt approach has been adopted to modelling soil infiltration losses. The topography has been modified to include kerbs and building upstands.

Rainfall applied to the hydraulic model was extracted with the FEH web-service in line with current guidelines. A storm duration analysis was undertaken to determine the duration which produced the greatest flood extents and depths within the study area. The final model was simulated for five storm events for one critical storm duration. The 1% AEP storm event was simulated for two climate change scenarios in accordance with *'Adaption to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities'* (Environment Agency, 2016).

The model results were processed and used to produce GIS and mapped outputs of 'anytime' maximum depth and hazard. The results are suitable for identifying areas susceptible to surface water flooding within Leiston.

Sensitivity testing of the model was carried out to quantify the impact on the results to variations in key parameters. These included expanding the capacity the original culvert under Lover's Lane as well as adding another culvert to the north and considering all gully pits within the catchment blocked. The results of these tests were compared against the baseline modelling to assess the difference in results and the sensitivity of the model to these parameters.

The model was validated against the storm event on the 8th July 2012. Rainfall for the event collected at the Thorpeness gauge 3km from Leiston was used in the model. The modelled results were then compared to photographic evidence from the real event. The model correlated well with the flooding evidence. A key limitation is the minimal amount of evidence, the photographs are limited spatially and do not have a complete log of times and depths.

Preliminary mitigation options have been proposed based on the baseline results. These mitigation options are targeted to the main flowpaths through Leiston and involve a combination of basins, small bunds and natural flood risk management.

Glossary

	Definition
AEP	Annual Exceedance Probability represented as a % (e.g. 1 in 100-year event = 1% AEP)
Climate Change	Long term variations in global temperature and weather patterns caused by natural and human actions.
Culvert	A channel or pipe that carries water below the level of the ground.
Depth-duration-frequency curves	Depth-duration-frequency (DDF) curves describe rainfall depth as a function of duration for given return periods
Depth Discharge Curve	The relationship between depth over a gully pot to discharge into the sewer network.
DTM	Digital Terrain Model: a topographic model of the bare earth/underlying terrain of the earth’s surface excluding objects such as vegetation and buildings. DTMs are usually derived from DSMs.
Environment Agency	Environment Agency, Government Agency reporting to Defra charged with protecting the Environment and managing flood risk in England.
Flood Estimation Handbook	The Flood Estimation Handbook (FEH) and its related software offer guidance on rainfall and river flood frequency estimation in the UK. Flood frequency estimates are required for the planning and assessment of flood defences, and the design of other structures such as bridges, culverts and reservoir spillways
Hyetograph	A measure of the variation of rainfall depth or intensity with time.
IUD	Integrated Urban Drainage, a concept which aims to integrate different methods and techniques, including sustainable drainage, to effectively manage surface water within the urban environment.
Lead Local Flood Authority	Local Authority responsible for taking the lead on local flood risk management. The duties of LLFAs are set out in the Floods and Water Management Act.
LiDAR	Light Detection and Ranging, a technique to measure ground and building levels remotely from the air, LiDAR data is used to develop DTMs and DEMs (see definitions above).
LLFA	Lead Local Flood Authority, see above.
Main River	Main rivers are a statutory type of watercourse in England and Wales, usually larger streams and rivers, but also include some smaller watercourses. A main river is defined as a watercourse marked as such on a main river map, and can include any structure or appliance for controlling or regulating the flow of water in, into or out of a main river. The Environment Agency’s powers to carry out flood defence works apply to main rivers only.
Surface Water Flooding	Surface water flooding happens when rainwater does not drain away through the normal drainage systems or soak into the ground, but lies on or flows over the ground instead.
Risk	In flood risk management, risk is defined as a product of the probability or likelihood of a flood occurring, combined with the consequence of the flood.
Sewer flooding	Flooding caused by a blockage or overflowing in a sewer or urban drainage system.
Stakeholder	A person or organisation affected by the problem or solution, or interested in the problem or solution. They can be individuals or organisations, includes the public and communities.
Surface water runoff	Rainwater (including snow and other precipitation) which is on the surface of the ground, and has not entered a watercourse, drainage system or public sewer.

Acronyms

Term	Definition
AEP	Annual Exceedance Probability
ARF	Aerial Reduction Factor
AW	Anglian Water
BGS	British Geological Survey
DDF	Depth-duration-frequency curves
DEFRA	Department for Environment, Food and Rural Affairs
DTM	Digital Terrain Model
EA	Environment Agency
FEH	Flood Estimation Handbook
GIS	Geographic Information System
IUD	Integrated Urban Drainage
LiDAR	Light Detection and Ranging
LLFA	Lead Local Flood Authority
mAOD	Metres Above Ordnance Datum (UK)
PLP	Property Level Protection
RoFfSW	Risk of Flooding from Surface Water
SuDS	Sustainable Drainage Systems
SCC	Suffolk County Council
SCF	Seasonal Correction Factor
SWMP	Surface Water Management Plan
TUFLOW HPC	Heavily Parallelised Compute
USDA	United States Department of Agriculture

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1 Introduction

BMT WBM have been commissioned by Suffolk County Council (SCC) as a part of their role as Lead Local Flood Authority to update the Surface Water Management Plan (SWMP) modelling for Leiston. Leiston is in East Suffolk approximately 35km north east of Ipswich (Figure 1-1). The updated modelling for this study includes new and more accurate data to enable a greater understanding of flood risk within the town.

The existing Leiston SWMP model was constructed by AECOM (*Leiston Surface Water Management Plan: Hydraulic Modelling Report*) using ICM software in March 2015.

The purpose of this study is to develop an updated model to include recently available data such as LiDAR, sewer network and gully information as well as providing greater resolution flood risk mapping than previously available. The model results will provide SCC with a more accurate understanding of the current surface water flood risk to Leiston. The results will be used in future studies to identify areas at risk, assist with the development of capital schemes and secure funding for more detailed surface water studies / flood alleviation schemes.

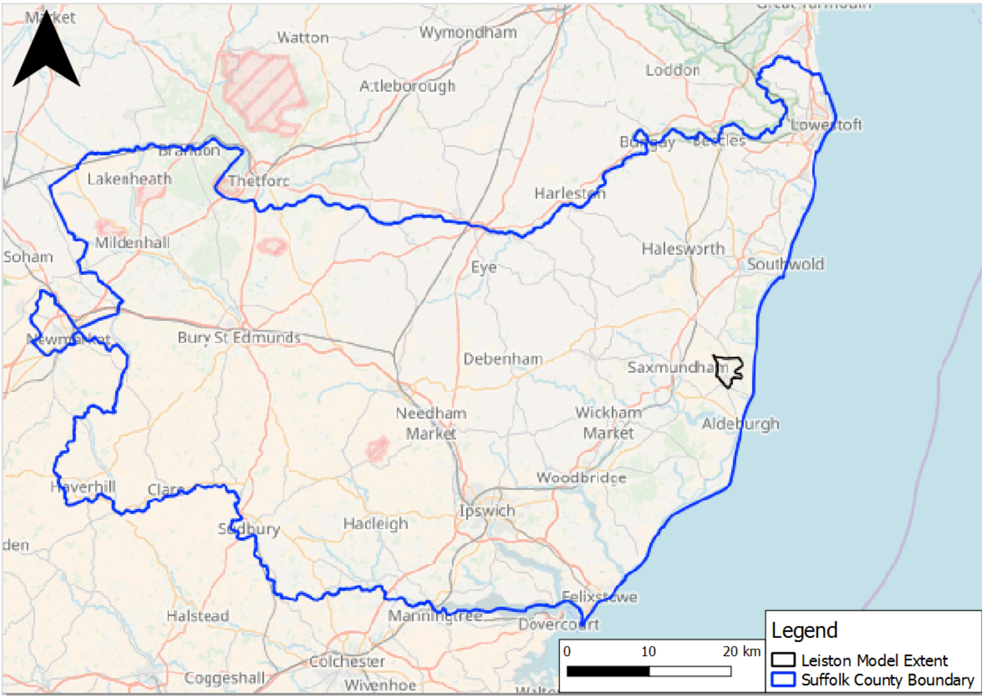


Figure 1-1 Leiston and Suffolk County Council

Leiston is located 3.3km from the sea. It straddles the headwaters of three catchments, with the majority of the town draining north east towards Leiston Ditch. The southern section of the town drains towards Aldeburgh and the Hundred River. A small section in the east of Leiston drains directly east towards the sea (Figure 1-2). The Leiston Ditch is classed as ordinary watercourse upstream of Lover's Lane and Main River downstream. Open ponds on Leiston Ditch are located directly upstream of the Lover's Lane crossing. To the south, the Hundred River is classed as Main River.

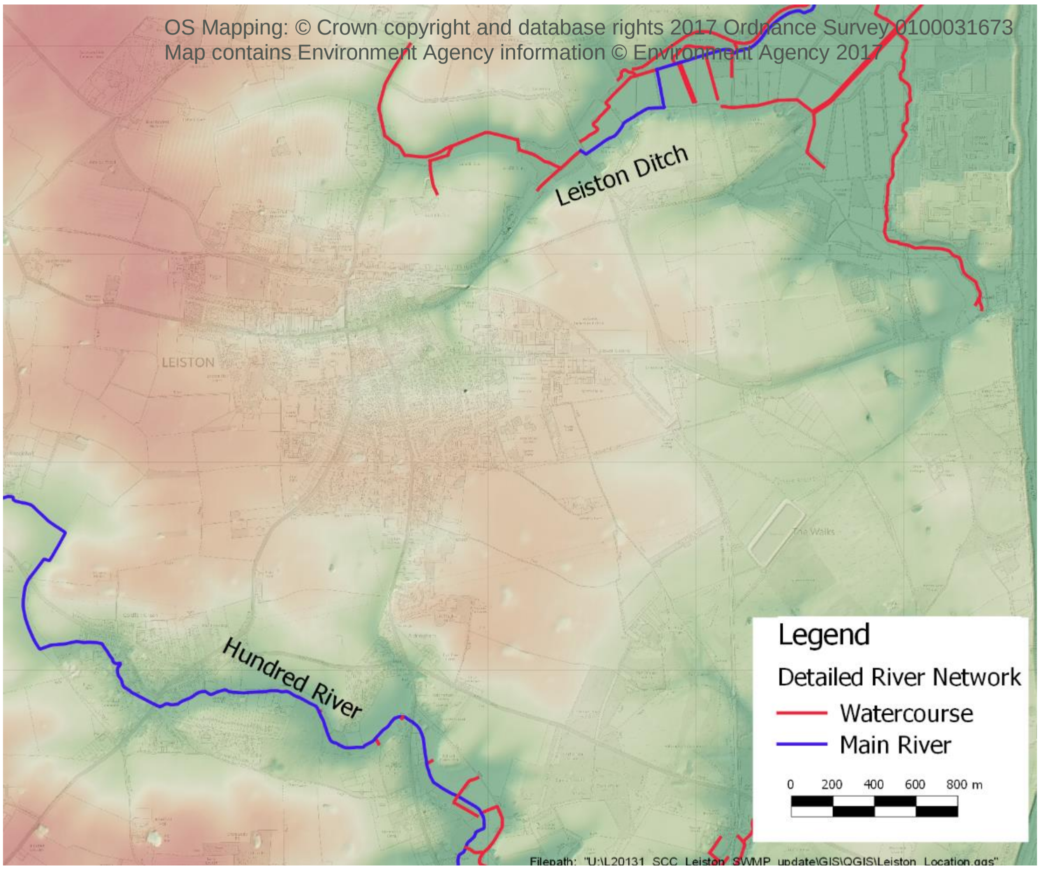


Figure 1-2 Leiston and Surrounding Watercourses

2 Hydrology

2.1 Rainfall

Design rainfall was developed for inclusion in the hydraulic model as inflow boundaries.

The direct rainfall method was selected to derive the rainfall depths. This method is appropriate for assessing flood risk from surface water and it enables the dynamic modelling of rainfall hyetographs which vary in duration and storm frequency.

Total rainfall depths were extracted at a single 1km grid point (NGR 645000, 263000) from the Flood Estimation Handbook (FEH) Web Service Depth Duration Frequency (DDF) model for the following seven storm events:

- 10% AEP (1 in 10 year);
- 3.33% AEP (1 in 30 year);
- 1.33% AEP (1 in 75 year);
- 1% AEP (1 in 100 year); and
- 0.5% AEP (1 in 200 year).

Hyetographs were generated for the four storm durations discussed in section 2.3.

2.2 Rainfall Depth Adjustment and Hyetograph Generation

An Areal Reduction Factor (ARF) has been applied to the rainfall depths extracted from the DDF model. The ARF is used to reduce the depth of rain in synthetic storms to convert from a typical point rainfall to a rainfall across an area such as a river or sewer catchment. The ARF was calculated for sub-catchments throughout the study area for a range of storm durations. The average ARFs across the sub-catchments ranged from 0.96 for the 15-minute duration to 0.99 for the 9-hour duration. The average ARF for each storm duration was applied to the relevant rainfall depths.

The design rainfall depths are converted into hyetographs (the time distribution of rainfall) for application to the hydraulic model. The storm profile describes the change in rainfall intensity with time. Two storm profiles are typically applied to design rainfall, the 75% winter profile for rural catchments and the 50% summer profile for urban catchments. Most catchments throughout the study area are urbanised. Catchments to the north of and west of Leiston are predominantly rural, however as urban catchments represent the majority of the study area and locations of interest in relation to surface water flooding, the summer storm profile has been applied to the design rainfall hyetographs.

Outputs from the FEH DDF model are based on annual data. Summer and winter seasonal correction factors (SCFs) have been calculated for catchments throughout the study area for a range of durations. The summer SCFs are greater than 0.99 for catchments throughout the study area and for all durations.

2.3 Critical Storm Duration

The critical storm duration is defined as that duration which produces the greatest flood extent and flood depth. Even within a small area, the critical duration can change rapidly due to a number of factors including topography, land use, size of the upstream catchment and nature of the drainage systems. Four storm durations were simulated in the model for the 1% AEP event to determine the critical duration. The four durations tested were the 30 minute, 1 hour, 3 hour and 6 hour.

Following simulation of the hydraulic models, the predicted maximum depth results were processed for each storm duration. This was then processed into a classified grid which highlights the source storm duration which has produced the maximum flood depth at locations across Leiston (Figure 2-1).

The 30-minute duration storm, was found to produce the maximum depths where the depth of water was shallow (less than 0.1m). The longer 3 hour and 6 hour durations generally produced peak depths in rural / larger open space areas where flood waters naturally pond behind embankments.

The 1 hour duration produced the greatest depth along main flow paths. Throughout the majority of the catchment, the difference between the 30 minute and 1 hour is less than 2cm. Due to this dominance along flow paths and small difference in shallow areas, the 1 hour was selected as the critical storm duration.

Typically, urban and rural catchments will have a different critical duration, usually based on the catchment roughness and impervious areas. In Leiston, the catchment is relatively steep and both the urban and rural areas are highly responsive to rainfall (‘flashy’ flood peaks). This means that there is very little distinction between urban and rural catchment critical duration and the 1 hour is suitable for both.

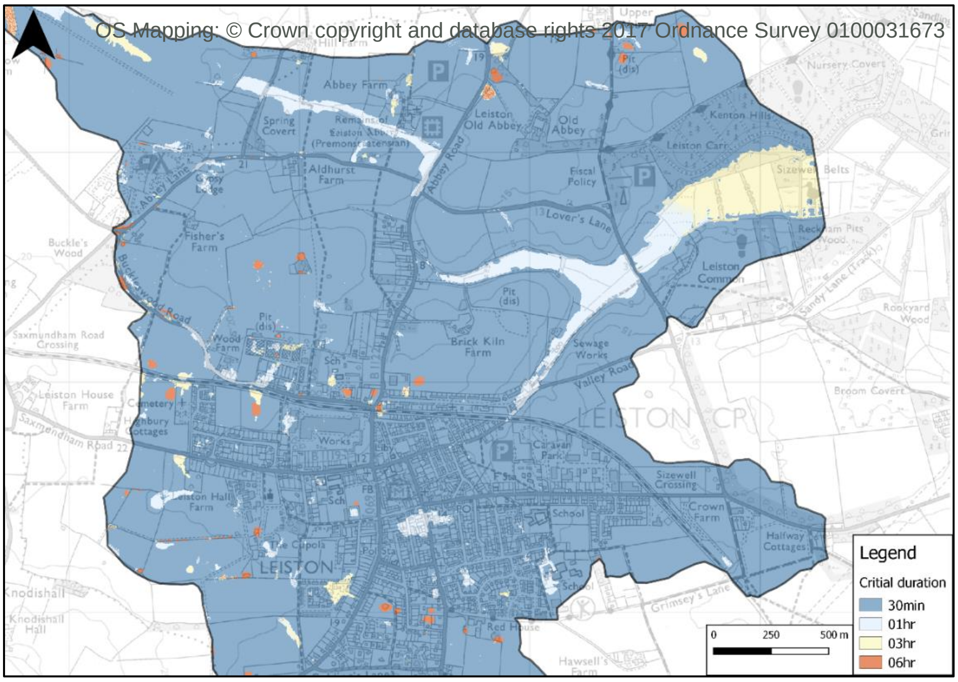


Figure 2-1 Critical Storm Duration Comparison for the 1% AEP Event

2.4 Climate Change

The Environment Agency updated their guidance on climate change allowances to inform flood risk and strategic flood risk assessments in February 2016[1]. Table 4 of the guidance is relevant for this study, and provides peak rainfall intensity allowances in small and urban catchments. This table has been reproduced below within Table 2-1.

Table 2-1 Peak Rainfall Intensity Allowance in Small and Urban Catchments[1]

Allowance Category	Total potential change anticipated for 2010 to 2039	Total potential change anticipated for 2040 to 2059	Total potential change anticipated for 2060 to 2115
Upper End	10%	20%	40%
Central	5%	10%	20%

The Environment Agency guidance recommends assessing both the central and upper end allowances to provide a range of the potential impacts of climate change. The 'central' (20%) and 'upper' (40%) allowances have been applied to the 1% AEP event.

[1] 'Adaption to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities' (Environment Agency, 2016)

3 Model Update Methodology

3.1 Introduction

The primary purpose of undertaking the updated modelling is to ascertain the source and scale of surface water flood risk within Leiston. The updated modelling addresses the key limitations of the existing model. Targeted changes and updates include:

- Definition of the model extent using a rolling ball analysis (Section 3.3.1). This ensures that whole contributing catchment is included.
- A storm duration analysis of four storm durations to select the critical storm duration for the study area (Section 2.3).
- Use of the 0.25m and 2m LiDAR across the whole study area (Section 3.3.2).
- A 0.5m model cell size for high resolution around fine scale urban features (Section 3.3.3)
- Incorporate a one-way coupled urban drainage network (Section 3.3.5).
- Model soils infiltration dynamically, using the Green-Ampt infiltration model incorporating soil texture information and depth to groundwater (Section 3.3.6).

3.2 Software Selection

TUFLOW HPC was selected for the Leiston updated model as it allows a hybrid approach for modelling the impact of drainage networks.

The drainage network data provided by Anglian Water (AW) was sparse and of low confidence. TUFLOW HPC's 'Virtual Pipes' feature allows the creation of a one-way coupled urban drainage network. The virtual pipe approach addresses the key deficiencies of the original SWMP, without the onerous data requirement for developing a fully integrated urban drainage (IUD) model.

TUFLOW HPC has full 1D/2D linking capabilities. Therefore, should further pipe network data become available, the updated model can be extended to include this.

3.3 Model Build

3.3.1 Model Extent

The previous SWMP model boundary was rectangular in shape and did not capture all contributing rainfall that might impact Leiston. The results of the original model may therefore underestimate the surface water flood risk to the town. The extent for the updated model encompassed the entirety of the catchment to capture all surface water flows that may impact the pluvial flood risk to the town.

A rolling ball analysis based on the LiDAR DTM (3.3.2) was undertaken to determine the topographic sub-catchments ('basins') in an area of interest (Figure 3-1). These sub-catchments represent the overland drainage area which contributes to surface water flooding. The model extent incorporates all sub-catchments including rural catchments to the north of Leiston as well as Aldeburgh to the south. These have been included to capture all surface water runoff flowing towards Leiston and any downstream backwater impacts.

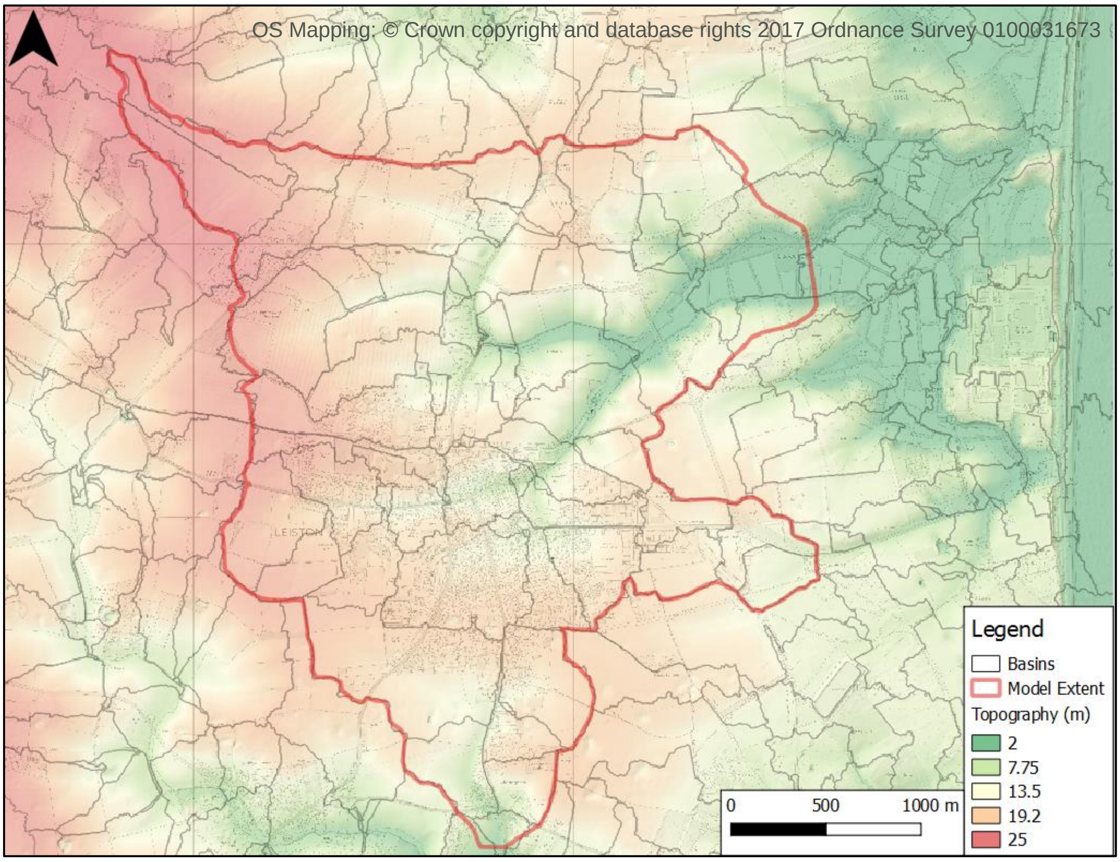


Figure 3-1 Leiston Sub-Catchments and Model Extent

3.3.2 Topography

The ground elevation data has been updated using a combination of 0.25m and 2m resolution LiDAR from the Environment Agency's Data portal. The 0.25m LiDAR covers most of the urban area of Leiston, the 2m is used mostly in the rural parts of the catchment.

The DTM has been modified to include the following topographic amendments representing the urban features of Leiston:

- Incorporation of a building upstand of 0.15m to represent deflection of surface water at shallow depths; and
- Definition of kerbs by lowering of road ground levels by 0.1m.

Both values selected are lower than those used in the Risk of Flooding from Surface Water Maps (RoFfSW). In the RoFfSW national mapping, a building upstand of 0.3m was used. 0.3m was deemed sufficiently high to model the deflection effect of buildings on surface water flows yet allow flow into buildings when damp proofing measures (such as air bricks and raised thresholds) have been overwhelmed. Similarly, in the RoFfSW, kerbs were lowered by 0.125m (the height of a British Standard kerb).

Lower values were selected for Leiston to better reflect the local kerb heights and building thresholds. These values were ascertained using online mapping and verified on site visits. The lower values are consistent throughout the town (Figure 3-2).

Figure 3-2 Low kerb heights and building thresholds on Valley Road

Topographic amendments were included to represent urban features located on the key flow paths through Leiston (Figure 3-3). These included garden fences perpendicular to flow paths, which are assumed to have a height of 2m with 40% permeability. Large walls which will cause a substantial obstruction along key flow routes have been represented as solid.

A site visit was undertaken by BMT WBM to verify the urban features, building thresholds and kerb heights initially identified via online mapping. As a result of the site visit, fences, walls and drainage paths through key flow routes were added to the modelled topography. A main obstruction is the large solid wall in the car park on the corner of High Street and Sizewell Road (Figure 3-4) and a drainage path between Grimsey Road and Sylvester Road (Figure 3-5).

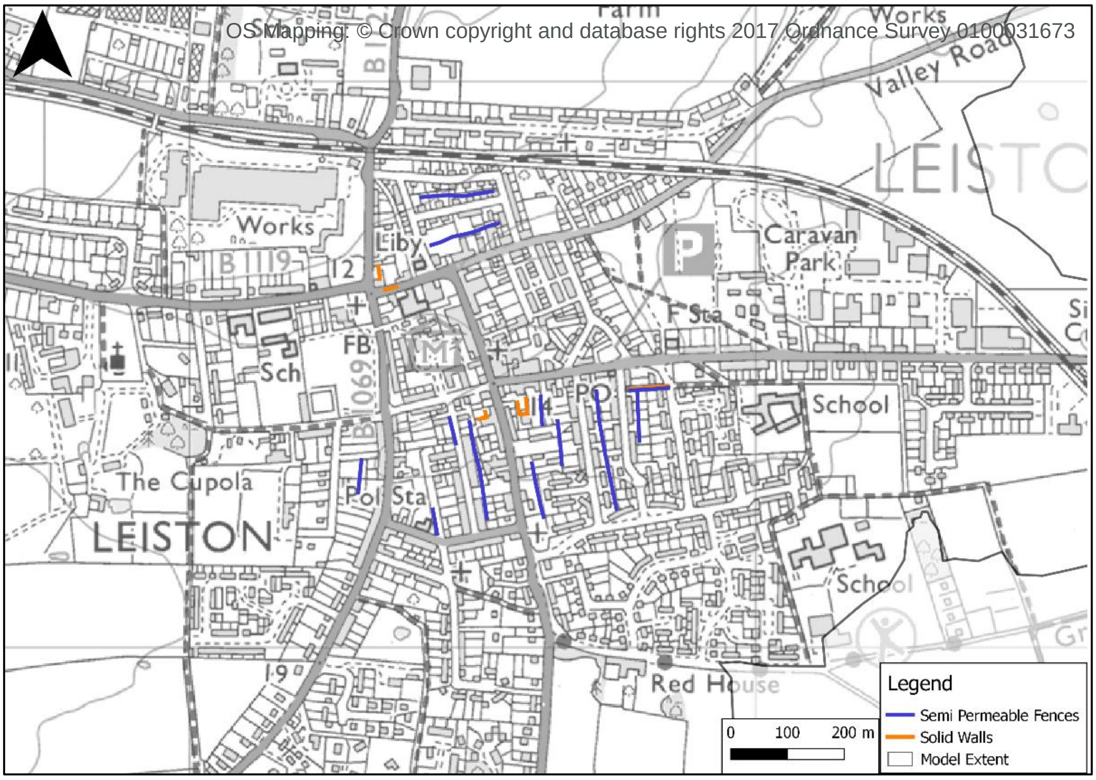


Figure 3-3 Location of modelled fences

Figure 3-4 Large wall in car park east of High Street.

Figure 3-5 Lane between Grimsey Road and Sylvester Road.

Leiston Ditch to the north east of Leiston is the sole formalised watercourse in the study area. The ditch is typically 4m wide and only lightly incised in the surrounding topography. The watercourse invert levels were assumed from LiDAR levels and reinforced in the model. This ensures that there is a continuous flow path along the ditch.

3.3.3 Cell Size

Urban models with complex flow paths through built-up areas are typically sensitive to model resolution. Typically, three to five modelled cells across key flow paths (i.e. a road or channel) are deemed sufficient to capture detail. A balance needs to be met between detailed flood results and sensible model run times. A cell resolution of 0.5m was selected for the entirely of the model extent in Leiston. This resolution was used to best define the finer scale urban features whilst also representing reasonable simulation times.

This resolution is a key difference to previous modelling. The previous modelling used a flexible triangular mesh, with a maximum triangle size of $25m^2$. The current modelling has a fixed rectangular grid of 0.5m cells. The decrease in model cell size allows for greater resolution in the final flood mapping and more accurate comprehension of the flood mechanics around fine scale urban features.

3.3.4 Boundaries

3.3.4.1 Inflow

The rainfall hyetographs (Section 2) were applied as inflow boundaries (direct rainfall) to the whole modelled area. The direct rainfall is assumed to be spatially uniform across the entirety of the model extent. The hyetograph for the 1% AEP storm is event is shown in Figure 3-6 below.

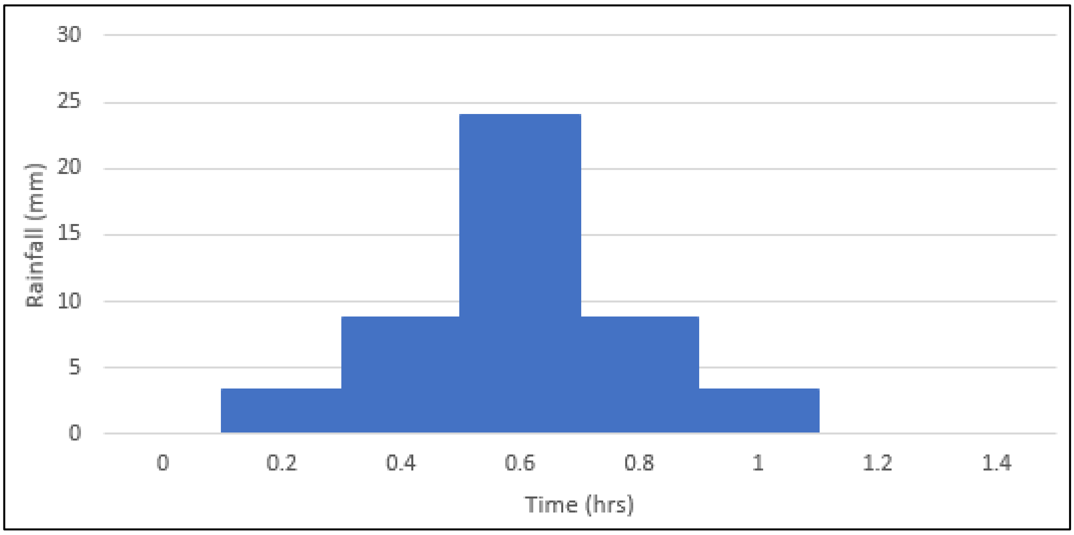


Figure 3-6 Rainfall Hyetograph for 1% AEP

3.3.4.2 Outflow

Downstream boundaries in the model were included where it was observed that water could flow outside of the model extent. These were applied where watercourses outfall away from the area of interest. A normal flow boundary is applied by TUFLOW based on the ground slope of adjacent, upstream cells. The normal flow boundary assumes that there is normal, free surface flow at fixed slope. For example, this means that on the Leiston Ditch, north east of Leiston and downstream of Lover's Lane, is assumed to freely discharge, without constriction.

Three downstream boundaries have been included in the model. The first of these is located to the north east of Leiston on Leiston Ditch, where the main flow path from the urban area drains downstream of Lover's Lane Culvert. This watercourse outfalls to the north of the village of Sizewell, into the North Sea. There is another downstream boundary to the south of this which drains a smaller catchment to the south east of Leiston. The third boundary is in Aldringham where the flow drains into the Hundred River.

These boundaries are sufficiently far away from the area of interest, such that there are no artificial modelled boundary effects.

Effects such as stormwater being unable to discharge due to tidal surges have not been considered.

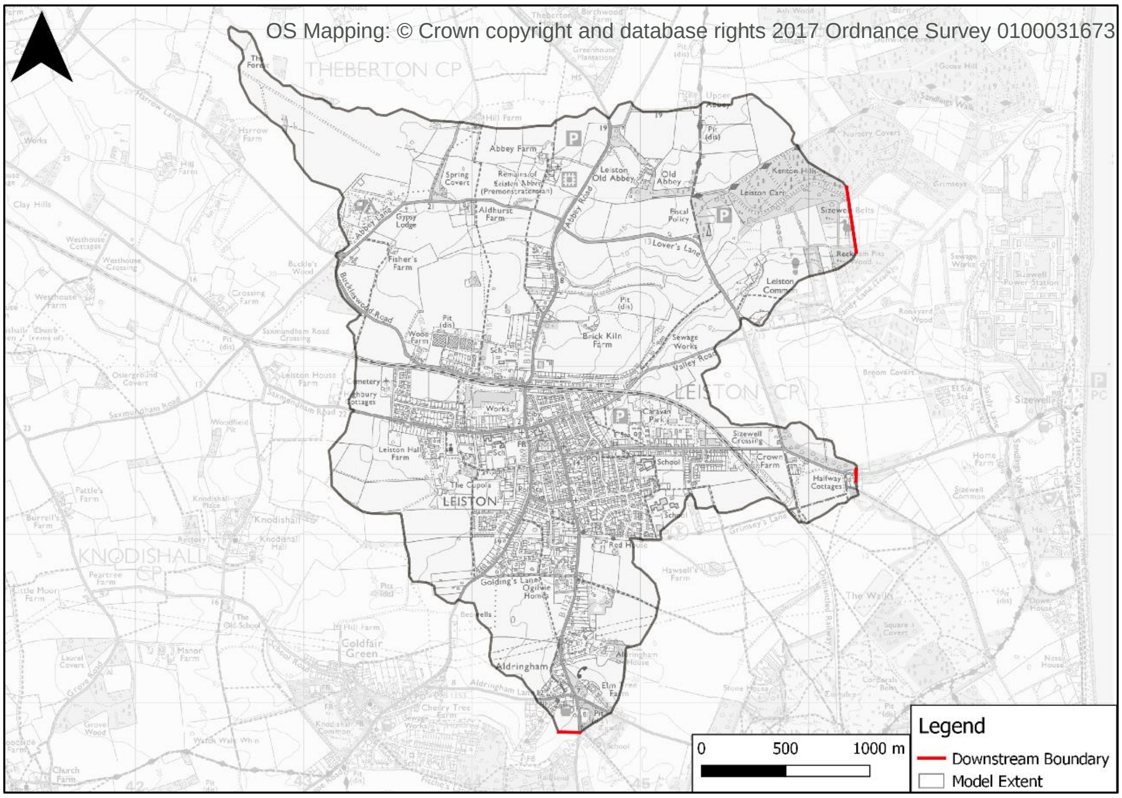


Figure 3-7 Location of Downstream Boundaries

3.3.5 Drainage Network

Drainage asset data and the existing Infoworks CS model was provided by AW for this study. Upon review and consultation with AW, the dataset was found to be spatially sparse and of low confidence throughout the town. AW have stated that the model is over 15 years old and the underlying pipe data pre-dates the model construction by some years[2]. In consultation with SCC, the decision was made to not proceed with the use of this dataset.

The previous SWMP ICM model utilised a fixed loss approach where the estimated total volume of the sewer network was removed from the applied rainfall. In the ICM network the AW surcharge volume from each manhole in each event was applied as an inflow. The limitations of this approach are that it assumes that network drainage is spatially uniform; i.e.: urban areas with gullies lose the same volume of runoff to the drainage network as a field and that the drainage is totally blocked at the outlet.

For the updated model, the 'virtual pipes' feature within TUFLOW HPC was used to represent the drainage network within Leiston. This approach uses information supplied by SCC on the location of gullies across the study area to model a one-way coupled representation. This method was selected to best represent the urban drainage network as the pipe asset information was too poor to model a fully-coupled integrated urban drainage network. Virtual Pipes has the benefit of the drainage varying spatially over the catchment and temporally throughout the event, however does

[2] Personal correspondence, Jonathan Glerum on behalf of Anglian Water, 04/08/2017

not include the limitations of the pipe network. This method assumes that the limiting factor is the flow capacity of the grating/pot and not the associated pipe network.

The supplied gully data was estimated by SCC to have a horizontal accuracy of 5m. This resulted in a substantial proportion of gullies located incorrectly in houses or on high points which did not correlate to locations seen on site or on Google Street View. Gullies observed to be incorrectly located were moved to be located directly onto the nearest road. The updated locations are based on gully survey by SCC highways and supplemented by Google Street View.

The flow through each gully inlet is represented by a depth-discharge curve based on the Design Manual for Roads and Bridges[3] (DMRB). The curves account for the limiting of flow to a maximum of 10L/s around the gully pot trap. Two gully types (carriage way gullies and kerb inlets) were identified in the study area and separate depth-discharge curves derived for each.

The type of carriageway gully was not specified in the original data set provided by SCC. A “Type R” (Figure 3-8) was selected based on photographic imagery and site visits. The kerb gully was assumed to be a standard “Type K” kerb inlet.

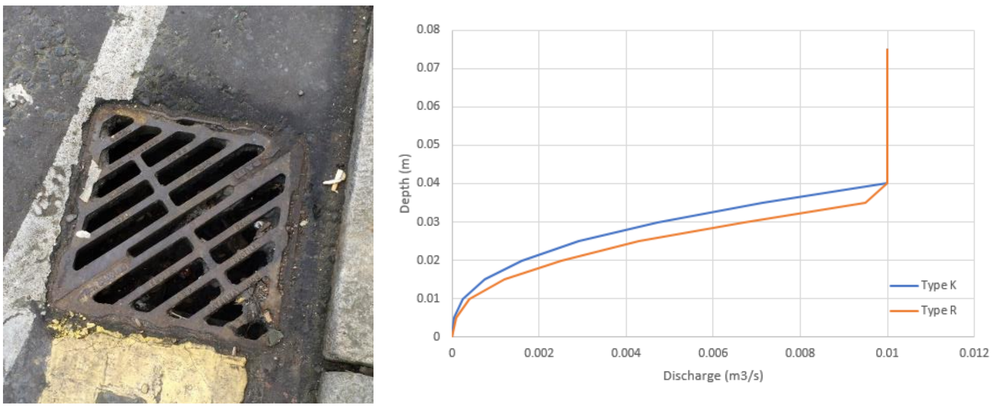


Figure 3-8   Type R and Type K Gully and Depth-Discharge Curves

The gullies are connected to the outfall via a modelled link. These links between the gullies and are not associated with any network storage or lag time. All gullies are assumed to discharge upstream of Lover’s Lane to the north east of the sewage works. This is an assumption based on drainage direction of the catchment and DigDat data. The location was chosen as it is where it looks likely the drainage in Leiston discharges into an open channel. This is not entirely clear and a limitation in the study.

Surcharging of the gullies due to lack of capacity of the pipe network has not been represented. All gullies are assumed to be fully functional and able to drain. Sensitivity testing has been carried out assuming the drainage network is blocked. The results of this testing are discussed in Section 5.2.2.

[3] http://www.standardsforhighways.co.uk/ha/standards/dmrb/

3.3.6 Infiltration

Infiltration losses have been applied to all permeable land uses within the modelled extent. The Green-Ampt approach has been selected as it varies the rate of infiltration over time based on the soil's hydraulic conductivity, suction, porosity and initial moisture content. When a saturated state is reached, the infiltration ceases.

The underlying soil types across the modelled extent were determined from data identified from mySoil from the British Geological Survey (Figure 3-9). This dataset provides a broad scale summary of the soil landscapes for England and Wales.

The catchment is underlain by:

- Moderately alkaline clayey loam and chalky loam soils;
- Permeable sandy loam; and
- Moderately impermeable peat.

These soil types have been determined to correlate to the 'clay loam', 'silty clay', 'sandy loam' and 'silty clay loam' USDA soil types hardwired into TUFLOW.

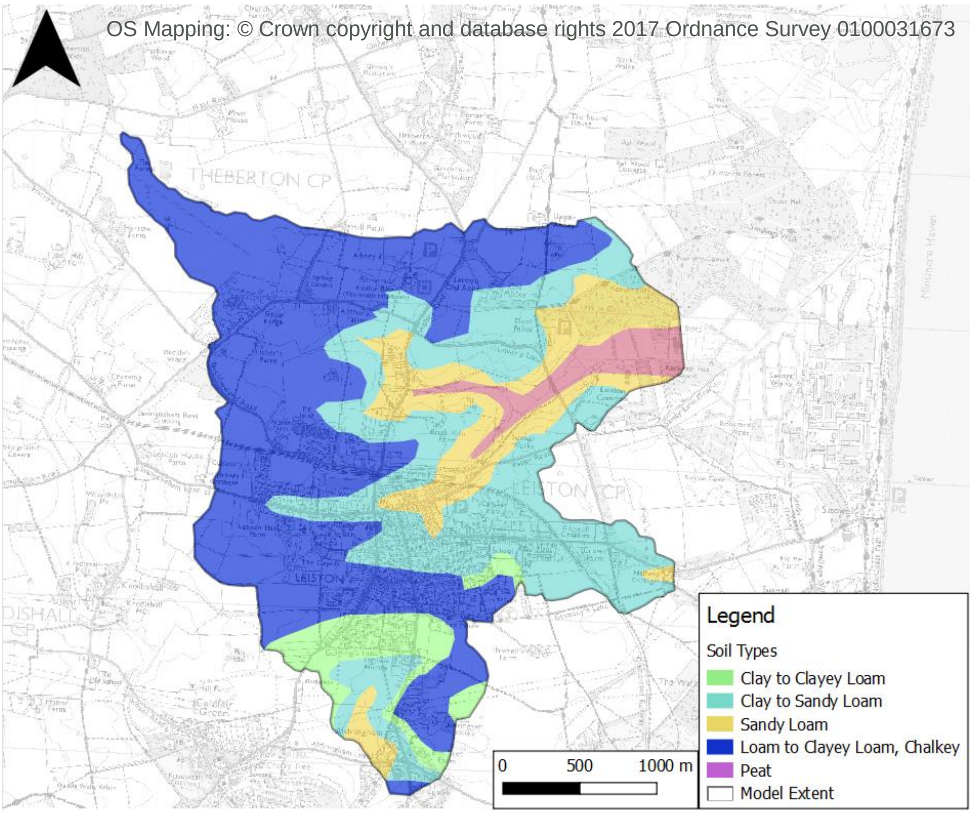


Figure 3-9 Leiston Soils Data

3.3.7 Hydraulic Structures

The Lover’s Lane culvert over Leiston Ditch is a key hydraulic structure. This structure links the ordinary watercourse system upstream (west Lover’s Lane) to the Main River downstream. The road embankment and culvert size hydraulically control the upstream water level and the flow downstream. Baseline modelled results show substantial ponding behind the culverts.

Previous reporting states that the culverts are two 900mm diameter pipes. This measurement has since been confirmed by SCC highways. There are no surveyed levels for the culverts or the road, these have been estimated from LiDAR. The length of the culverts has been estimated to be 15m, based on LiDAR measurements.

Based on site inspection, there has been recent development by EDF energy to formalise the area upstream into wetlands. As a part of these works, changes to the culverts may have taken place. The nature of these works and potential changes is unknown.

4 Model Simulation

4.1 Model Run Parameters

The hydraulic model was simulated using the HPC Solver for TUFLOW build 2017-09-AC-iSP. The only change to default parameters was to reduce the Cell Wet/Dry Depth in line with recommendations within the TUFLOW Manual[4] for Surface Water models. The model naming convention is outlined in Table 4-1.

Table 4-1 Model Naming Convention

SCC_LEI_~e1~_~e2~_~s1~_021.tcf			
~e1~	Rainfall return period	0010R 0030R 0075R 0100R 0200R 0100RCCU 0100RCCL	10% AEP event 3.33% AEP event 1.33% AEP event 1% AEP event 0.5% AEP event 1% AEP event with 'upper end' climate change allowance 1% AEP event with 'central' climate change allowance
~e2~	Storm Duration	30mn 01hr 03hr 06hr	30-minute storm duration 1 hour storm duration 3-hour storm duration 6-hour storm duration
~s1~	Scenario	EXG SS1 SS2 VAL	EXG Baseline Model SS1 Increased Lover's Lane Culvert Capacity SS2 Assumed urban drainage blocked. VAL Validation scenario

The baseline model was simulated for the storm events listed within Section 2.1 for the 1 hour storm duration. In addition, two climate change events were simulated for the 1% AEP event, corresponding to the 'central' (20%) and 'upper' (40%) allowances (Section 2.4).

[4] Page A-5 TUFLOW User Manual Build 2016-03-AA (BMT WBM)

4.2 Model Results

4.2.1 Baseline Flood Mechanisms

There are two primary flow routes through Leiston – east along Valley Road and parallel to Sizewell Road, moving through the allotments (Figure 4-1). For clarity, both flowpaths have been presented in terms of source of flooding, pathway, and risk receptors.

Figure 4-1 Leiston Baseline Results Animation, 1.33% AEP Flood Depth

OS Mapping: © Crown copyright and database rights 2017 Ordnance Survey 0100031673

Valley Road Flowpath
Source The Valley Road flow route originates in the upper catchment to the west of Leiston. The upper catchment is primarily fields south of Waterloo Avenue, however runoff is also collected from west Leiston, including the Masterlord Industrial estate and Leiston Middle School.
Pathway Runoff is channelled down Waterloo Avenue, east through junctions with Station Road and High Street and continues down Valley Road. Modelling shows this section of the flowpath is largely confined to the roadway for lower order events (less than the 1.33% AEP storm event) but spills into adjacent properties for larger events. The flowpath is constrained downstream of Valley Road at the railway bridge before moving through Carr Avenue and Valley Road to the Sewage Treatment Works and ponding upstream of Lover's Lane in Leiston Ditch. Flow is eventually discharged through the Lover's Lane culverts
Receptors Modelled results highlight that the key areas of risk associated with this flow path are at the

Valley Road Flowpath
intersections of Waterloo Avenue and Station Road and Main and High Streets and further downstream at Carr Avenue and Valley Road. In the upstream locations, modelling shows that runoff leaves the roadway and enters properties such as the pubs on the corner of Station Road and Waterloo Avenue and the bank on the corner of Main and High Streets. Downstream at Carr Avenue and Valley Road, modelling shows that low-lying properties are inundated by the main flowpath moving toward the Sewage treatment works. In addition to direct property risk, this flow path presents 'Danger to Most' hazard in the 3.33% AEP Storm Event and 'Danger to All' hazard in all modelled larger events. This presents potential evacuation and access risks.

Sizewell Road Flowpath
Source The Sizewell Road flowpath has a smaller catchment than the Valley Road flowpath, it is constrained to the urbanised area between the Leiston Football ground west of Huntingfield Road and Seaward Avenue towards Leiston Primary School. The source of flooding is urban surface water runoff generated from the catchment.
Pathway Flow moves parallel to Cross Street and Sizewell Road through High Street, Eastward Ho, Grimsey Road and Sylvester Road. Substantial ponding is shown between Central Road and High Street as flow is constrained to low points by buildings and fences. It is channelled through drainage easements and residential gardens. Unlike the Valley Road flowpath, this flowpath is not constrained to the roadway and ponds and moves around obstructions such as house thresholds and road kerbs. The flowpath crosses Sizewell Road at the intersection with Sylvester Road and move through the fire station before proceeding through the allotments. This flowpath meets the Valley Road flowpath at Valley Road near the alloment buildings. With the Valley Road flowpath, it is constrained at the railway overpass before moving downstream to Carr Avenue, the sewage treatment plant and Leiston Ditch.
Receptors Despite having a smaller catchment area and typically lower flood hazards, there are more potential receptors along the Sizewell flowpath as it moves through gardens and properties, not along the roadway. Modelling shows that key locations of risk on this flowpath are the ponding between Central Road and High Street, isolated properties through Eastward Ho, Grimsey Road and Sylvester Road and the fire station on Sizewell Road. Similar to the Valley Road flowpath, low lying properties downstream on Valley Road and Carr Avenue are shown as inundated in events larger than the 10% AEP storm event.

4.2.2 Flood Maps

Flood maps for maximum depth and hazard have been produced for the 1 hour storm event and are found within Appendix A and Appendix B. The intervals used to map the depth results are consistent with that used for the Risk of Flooding from Surface Water (RoFfSW) map by the EA and has been reproduced below:

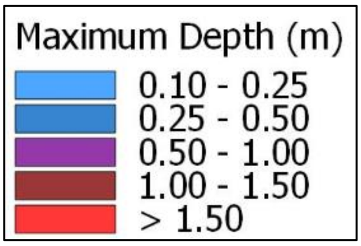


Figure 4-2 Mapped Depth Intervals

Values below 0.1m deep have been excluded from the mapped results as it is assumed they are shallow sheet flow and not classed as flooding. As Leiston is modelled as direct rainfall, all cells have a rainfall depth applied, thus this minimum depth for mapping also clarifies the flooded extent by excluding these very shallow depths.

The flood hazard result is based on the Flood Hazard Rating as defined by the DEFRA/Environment Agency guidance document[5]. Flood hazard is classified based upon the following formulae:

$$Flood\ Hazard\ Rating\ (HR) = d \times (v + 0.5) + DF$$

Where:

d = depth of flooding (m)

v = velocity of flood waters (m/s)

DF = Debris Factor, according to depth

A Debris Factor of 0.5 was used for depths less than and equal to 0.25m, and a debris factor of 1.0 was used for depths greater than 0.25m. Following calculation of the flood hazard rating, a flood hazard category is assigned based on the criteria as outlined within Table 4-2 and Figure 4-3 below

Table 4-2 Hazard Rating Category

Flood Hazard		Description
Low	<0.75	**Caution** – Flood zone with shallow flowing or deep standing water
Moderate	0.75 – 1.25	**Dangerous for some (i.e. children)** – Flood zone with deep or fast flowing water
Significant	1.25 – 2.5	**Dangerous for most people** – Flood zone with fast flowing water
Extreme	>2.5	**Dangerous for all** – Flood zone with deep fast flowing water

[5] Flood Risk Assessment Guidance for New Development - FD2321/TR1 (DEFRA/Environment Agency, March 2006).

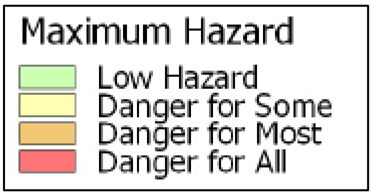


Figure 4-3 Mapped Hazard Intervals

4.2.3 Post-Processing

Processed model results have been delivered as part of this study supplied in either FLT grid format or ESRI SHP file format.

The maximum predicted flood extent for each simulated storm event has been generated by adopting a depth threshold of 0.1m. Cleaning of the model results (removal of dry islands, etc) was not undertaken.

All processed results can be found within Appendix C of this report.

5 Model Validation

5.1 Validation Event

A record of historical flooding incidents has been held by Suffolk County Council since 2012.

Leiston was subject to surface water flooding in July 2012 and October 2013. According to local reports and in discussion with SCC, the event on the 8th July 2012 event was the more severe of the two recent events. Reports indicate that the surface water drainage system was overwhelmed in the town leading to roads, houses and critical infrastructure being flooded. The primary evidence source for flood impacts in this event are community photos. This event was chosen for the validation event.

Rainfall records closer to Leiston were sought, in an effort to capture the most accurate record of the event. Available sources are listed below in Table 5-1 and shown in Figure 5-1.

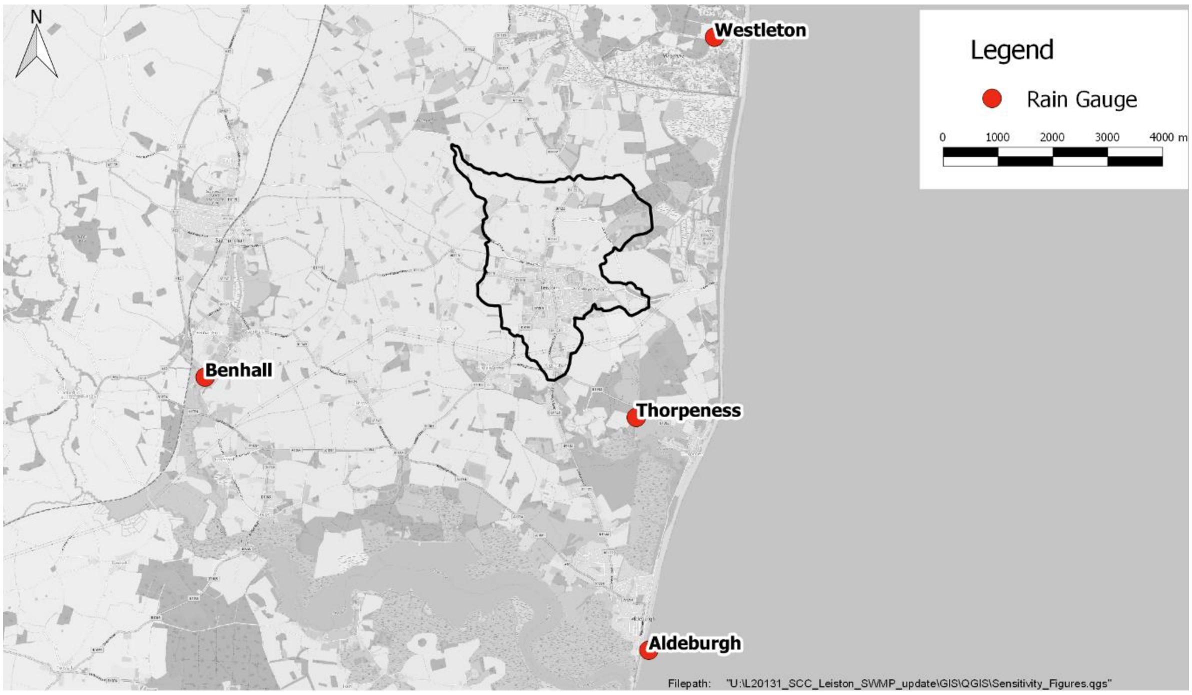


Figure 5-1 Rainfall Gauge Location

Table 5-1 Available Rainfall Data Sources

Data Source	Data Owner	Data type	Distance to Leiston	Data Frequency
Benhall Gauge	EA	Point rainfall data	6.3km	Daily
Thorpeness Gauge	EA	Point rainfall data	3km	15 minute
Westleton	Met Office	Point rainfall data	5.5km	Daily
Aldeburg	Met Office	Point rainfall data	6.8km	Daily

BMT WBM

There is a rain gauge located at the nearby Sizewell C facility, however this rainfall record was unavailable for this study. Due to the short duration 'flashy' storms typical to towns at the headwaters of the catchment, daily rainfall gauges were deemed insufficient. Daily rainfall increments would not capture the temporal variation in rainfall in sufficient resolution.

Rainfall data from the 8th of July 2012 from a rain gauge 3km away in Thorpeness was used for the validation event input data. This is a tipping bucket rainfall gauge with 15 minute intervals. The limitation of using gauge data 3km from Leiston is that the gauge record may not reflect the true rainfall received in Leiston. This could result in over or under prediction of the rainfall in the validation event.

Rainfall was used from 11am to 4pm on the day which captures the entire duration of the event (Table 5-2). In the 48 hours preceding this event there was 0.4mm rainfall. Due to the low volume and time gap between this rainfall and the event on the 8th July, no antecedent conditions were added to validation event; i.e. the soil is assumed to be able to infiltrate, watercourses are beneath their capacity and downstream boundaries can drain normally.

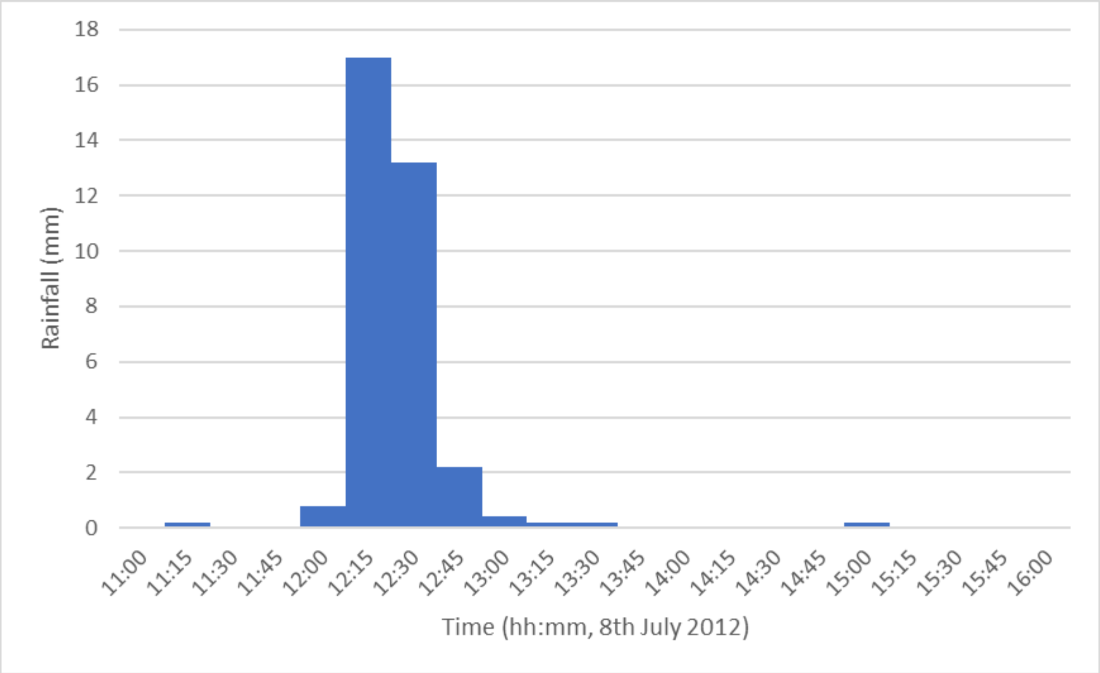


Figure 5-2 Thorpeness Gauge Rainfall Record

The modelled peak depths were compared to anecdotal evidence of the event in the form of photos and videos (Table 5-2). The online videos[6] are likely from the event on the 8th July 2012, but this cannot be ascertained. As a result, these have not been used as a part of the validation dataset. Should additional data from this event be found, it can be added to validation data and compared to the modelled results.

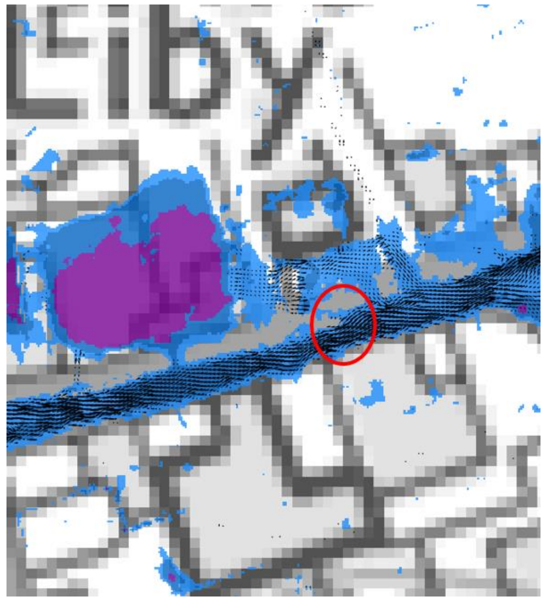
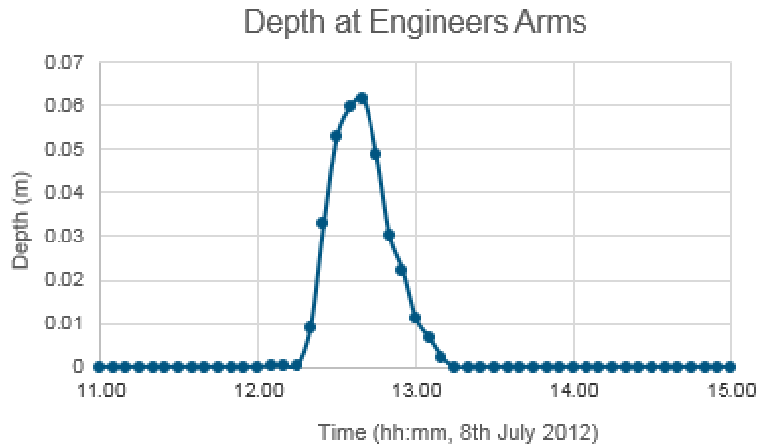
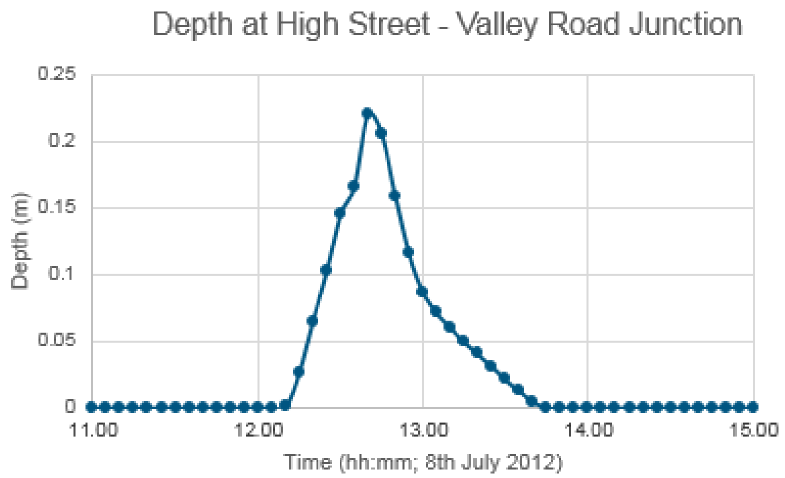
[6] https://www.youtube.com/watch?v=tPKSIUIBEJA and https://www.youtube.com/watch?v=wKCu47XMaIU

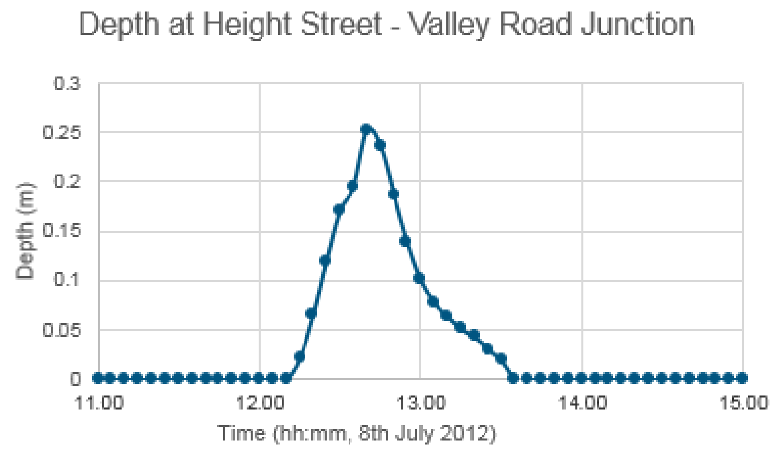
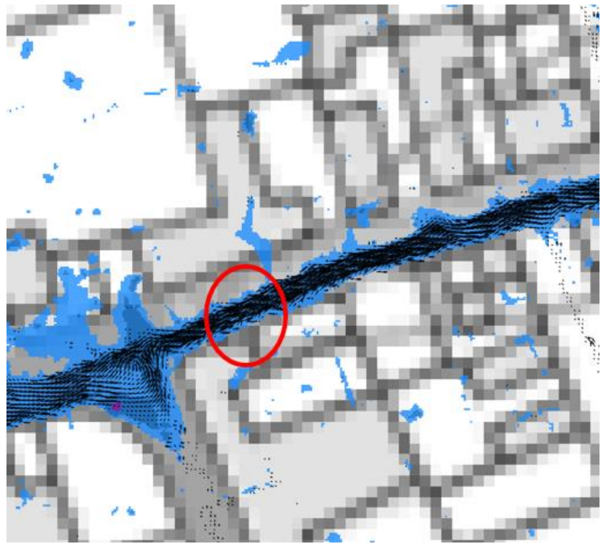
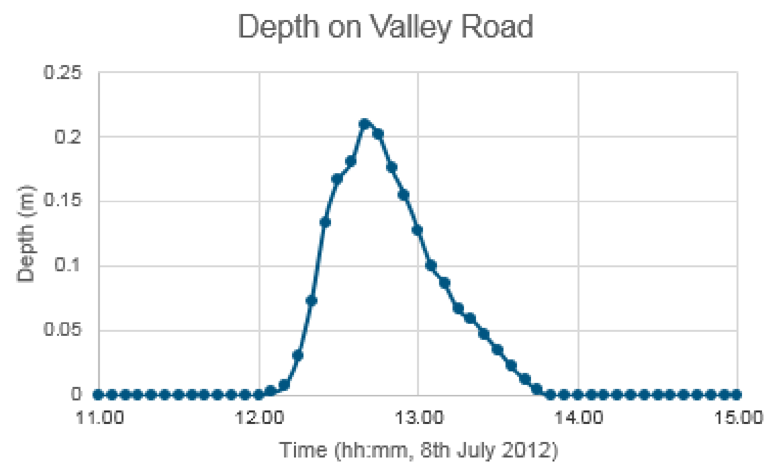
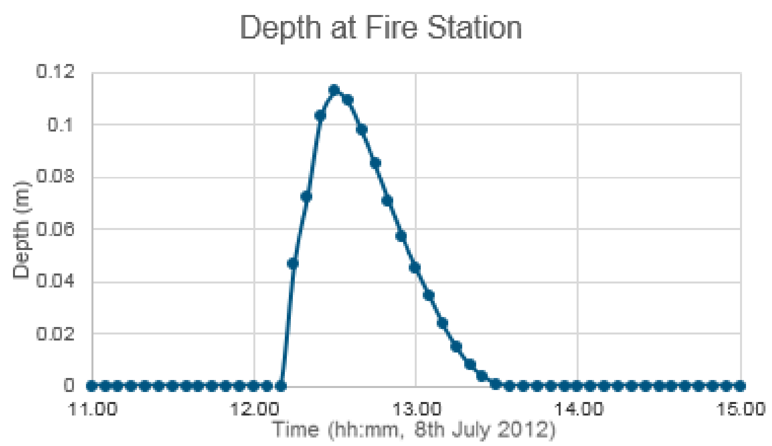
The time at which the photos were taken is not captured and the depths of ponding water not measured. Therefore, this validation is limited to confirming locations of predicted inundation and a comparison of estimated depth of ponding. In addition, the photo locations are limited to two primary risk areas in Leiston and do not have spatial coverage across other aspects of the flow path (Figure 5-3). Locations such as the ponding behind High Street near Central Road, Carr Avenue and Grimsey Road cannot be validated using the currently provided dataset.

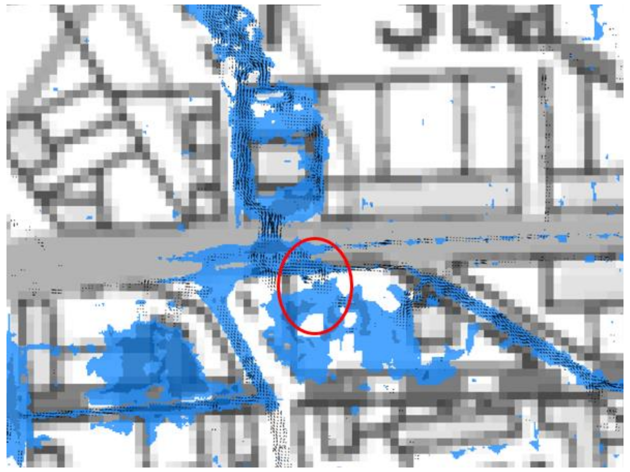
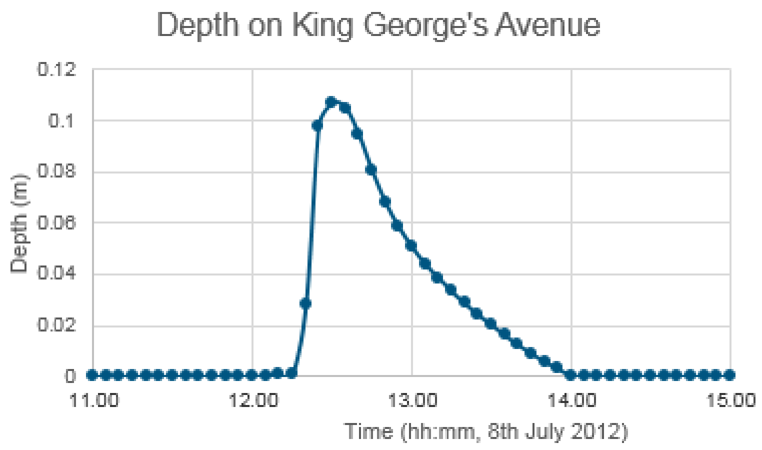
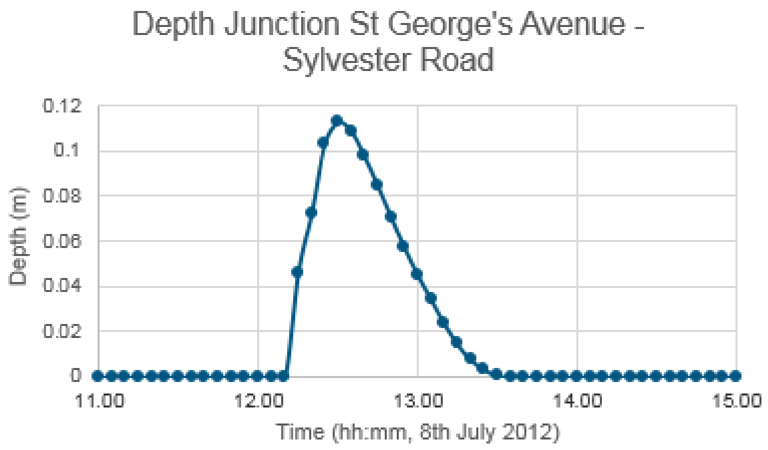
Figure 5-3 Leiston Validation Photo Location

The locations of predicted surface water flooding correlate with those shown in the photos. Where there are differences in depth, these discrepancies may be due to the photos not capturing the peak depth, the Thorpeness gauge not fully representing the rainfall in Leiston or modelled effects such as drainage networks or fine scale urban features.

Table 5-2 Comparison of Modelled Flood Depth and Event Flood Depth

<table>
<tr><th>Location</th><th>Modelled Flooding at Location</th><th>Photograph of Event</th><th>Depth</th><th>Comments</th></tr>
<tr><td>1</td><td></td><td></td><td>
</td><td>The location of predicted inundation in the model correlates with the photographic evidence.
The photo shows flooding below building thresholds and almost at the level of the air bricks of the Engineers Arms. Water is flowing east along Valley Road at an approximated depth of less than 0.1m.
The model results show water flowing east along Valley Road with a peak depth of 0.06m</td></tr>
<tr><td>2</td><td></td><td></td><td>
</td><td>The location of predicted inundation in the model correlates with the photographic evidence.
The photo indicates flooding along Valley Road at a depth of approximately 0.15m. It is unclear from the photo whether the Barclays Bank experienced any internal flooding. Flood waters appear to be ponding at the junction with High Street.
The model results show surface water flowing along Valley Road and ponding at the junction with High Street. The modelled peak depth is approximately 0.22m. The discrepancy in depth could be due to the photo not capturing the flood peak.</td></tr>
</table>

Location	Modelled Flooding at Location	Photograph of Event	Depth	Comments
3				The location of predicted inundation in the model correlates with the photographic evidence. The photograph shows ponding at the junction of Valley Road and High Street. Water can be seen flowing along Valley Road. The depth of water is estimated at between 0.05 and 0.1m from this photo. It does not appear any adjacent buildings experience internal flooding. The modelled results show water flowing down Valley Road and ponding at the junction. Buildings are not shown as inundated above the thresholds.
4				The photograph shows shallow flow east along Valley Road. The depth of water is estimated to be below 0.1m. The footpath is visible beneath the flood water and building thresholds do not appear to be overtopped. The modelled results predict surface water flowing east along Valley Road. The predicted peak depths of 0.2m are greater than that shown in the photograph.
5				The photograph shows ponding on the road in front of the fire station. Water is shown to pond on the road and overtops the kerb into the front yard. Flood waters are shown to surround the fire station. It is not known if the fire station building was inundated internally. Results from the model show ponding water on King George's Avenue in front of the fire station. Flood waters are predicted to overtop the kerb and flow into the fire station grounds and surround the building. The flooding mechanisms and depths predicted by the model are a reasonable correlation with the photograph.

Location	Modelled Flooding at Location	Photograph of Event	Depth	Comments
6				The photograph shows ponding water in the front garden of a house on the south of King George's Avenue. The depth is estimated to be approximately 0.1m; water is level with the building threshold and potentially deeper in the garden. The model results predict an area of ponding in the same location where water flows over the top of the kerb and into the front garden. The building is not predicted to be inundated.
7				The photograph shows the area of ponding in location 5 from a different angle. The photo shows ponding flood waters at the junction of St George's Avenue and Sylvester Road. Road marking are visible through the flooding and a vehicle is seen passing through the water. The depth is estimated to be less than 0.1m Results from the model predict ponding water at the same location. The model shows a peak flood depth of 0.1m.

5.2 Sensitivity Testing

Sensitivity testing is the study of how the variation in the output of a model can be apportioned, qualitatively or quantitatively, to different changes in the model inputs (model variables, boundary conditions and parameters).

Sensitivity analysis is used to identify:

- The factors that have the most influence on model outputs;
- The factors that need further investigation to improve confidence in the model; and
- Regions in space of inputs where the variation in the model output is maximum.

Two key assumptions made within the hydraulic assessment were selected for sensitivity testing. The first of these was increasing the flow capacity of Lover's Lane culvert. The second was the gullies within the baseline model were assumed blocked and therefore unable to store or transport any water. Further discussion on the choice of these two parameters is discussed below.

The sensitivity testing was carried out on the 3.33% and 1% AEP storm events. There were chosen to provide an understanding of the differing impacts these variations may have on the results of both more frequent and less frequent storm events.

5.2.1 Lover's Lane Culvert

The Lover's Lane culvert was selected for sensitivity testing as, at the time of model construction, little information was provided on the dimensions, length and elevations of the structure. It has been represented as twin 900mm circular pipes in the baseline model, which is in line with SCC's understanding of the culvert's size and shape.

A site visit undertaken by BMT, uncovered evidence of wetland development on land owned by EDF energy. The evidence included recent fencing and new signage about the wetland system. The site is located upstream of Lover's Lane, and it is unknown if the wetland construction included changes to the culvert layout or alignment. Some evidence was found on site that the culvert capacity may be larger than was modelled, however, no measurements or levels could be taken due to access issues. Site measurements were taken of the culvert headwall and depth from headwall level to invert.

As described previously in Section 3.3.7, the culvert is a key hydraulic constriction in the study area. It has the potential to impact the prediction of surface water flooding and remains a key area of uncertainty within the model. It was therefore selected for sensitivity testing. The results of the testing may also be used to assess the potential impact of future upgrades.

The culvert representation was modified from twin 900mm circular culverts to twin rectangular 1.4m x 1.1m culverts with an additional 900mm circular culvert to the North West. (Figure 5-4). These increased measurements are based on the approximate dimensions assessed on site. The additional culvert in the north west is based on observed headwalls and a minor drainage ditch visible on site. Due to lack of data, the length, invert level and culvert material have not been changed.

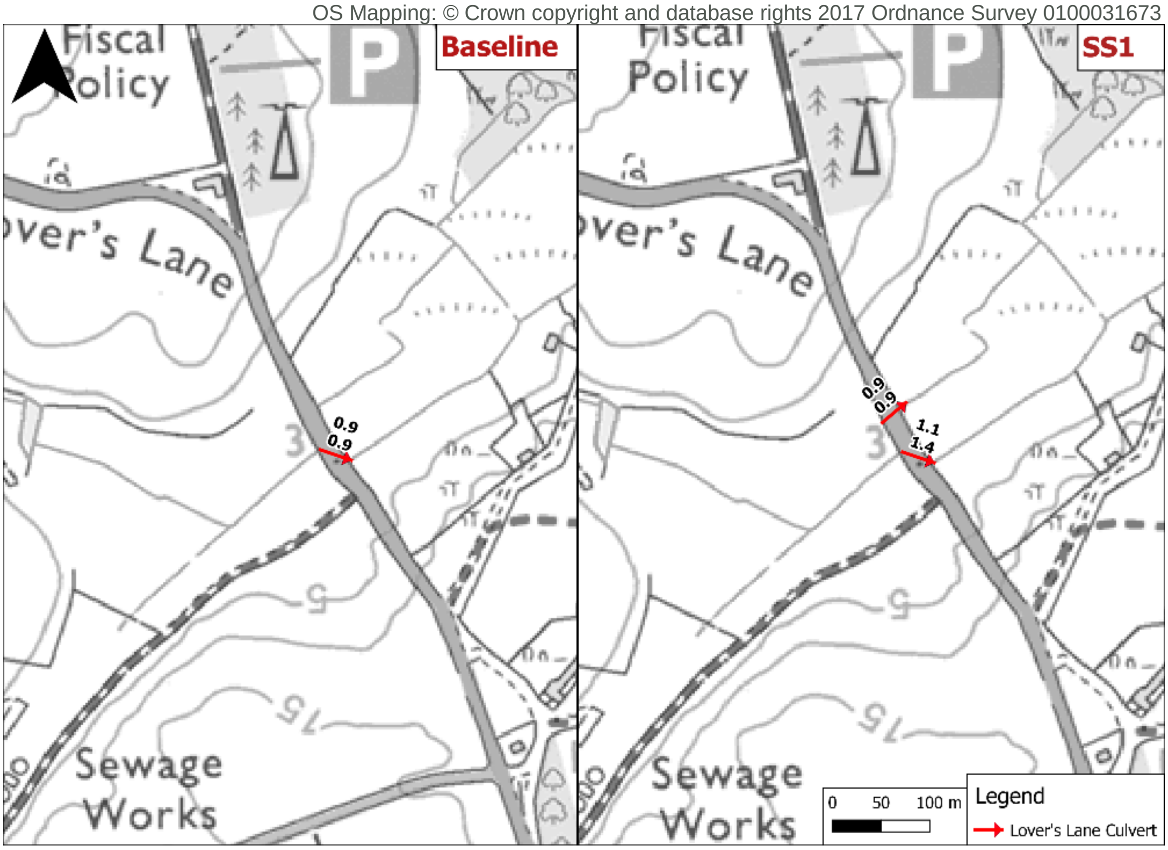


Figure 5-4 Lover's Lane Culvert Layout and Sensitivity Testing

The results show the increased culvert capacity conveys a greater volume of surface water runoff downstream. There is a predicted decrease in peak flood depths upstream of Lover's Lane and a corresponding increase downstream. The upstream decrease is approximately 0.1m in the 3.33% AEP event (Figure 5-5) and 0.2m in the 1% AEP event (Figure 5-6) extending for a distance up to 300m towards the sewage treatment works. The corresponding increase downstream is 0.1m in the 3.33% AEP event and 0.2m in the 1% AEP event. The increase downstream extends for 150m in the 3.33% AEP event and up to 800m in the 1% AEP event. The increase downstream is predicated to not impact any receptors, impact is restricted to fields and drains.

There are no predicted impacts on surface water flood risk to the urban area of Leiston. The town sits at a higher elevation than the area in the immediate vicinity of the culvert and is not shown to be impacted by an increase in size of the Lover's Lane culvert.

Figure 5-5 3.33% AEP Lover's Lane Culvert Sensitivity Testing

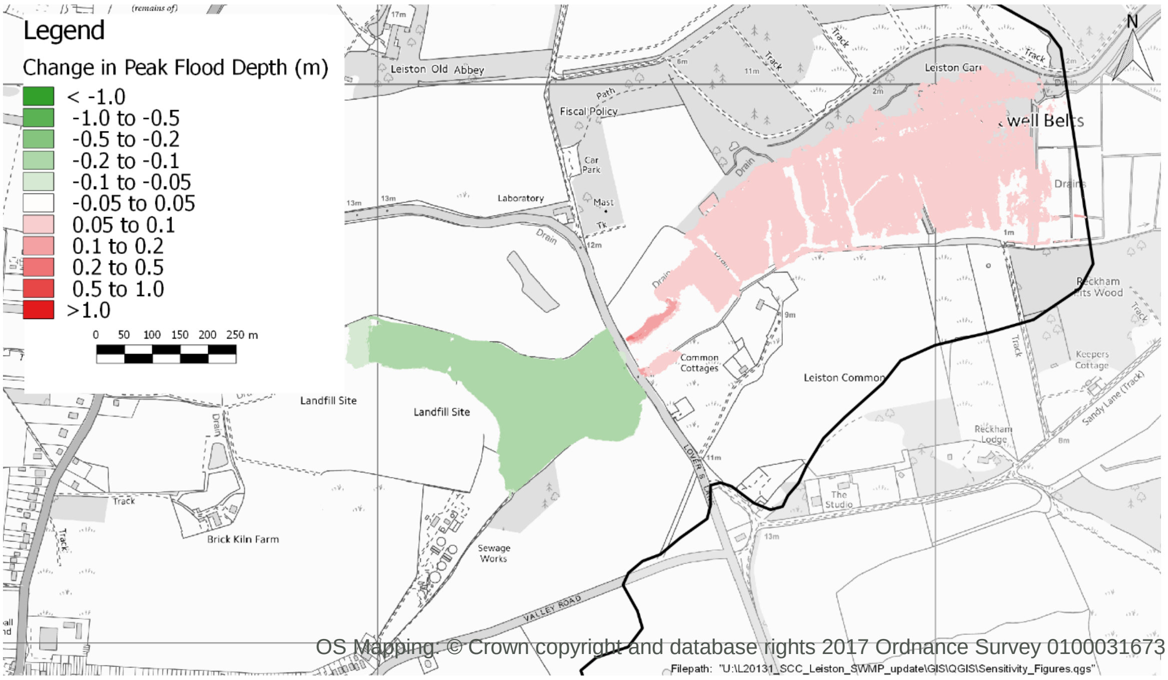


Figure 5-6 1% AEP Lover's Lane Culvert Sensitivity Testing

5.2.2 Gully Blockage

There are reports from SCC that the surface water drainage system though Leiston has been observed to be heavily impeded during historic flood events. This is understood to be a result of either through blocked outfalls or clogged gully inlets. To ascertain the impact this may have on surface water flood prediction through the town, the efficacy of the gully pits has been sensitivity tested.

Testing of a 100% blocked state of all gullies in Leiston was agreed with SCC. The results from this test can also be used to quantify the impact of poor gully maintenance on flood levels.

Considering the drainage network blocked has caused an increase in flooding within the urban areas and decrease at the pipe outfall. The magnitude of this increase is up to 0.35m in the 3.33% AEP event (Figure 5-7) and up to 0.5m in the 1% AEP (Figure 5-8). Areas of greatest impact are primarily located along the main flow route through the urban area of Leiston, concentrated directly upstream of the railway bridge. Receptors along Valley Road, centred around the intersections with Station Road and High Street and on the second flow path between Central Road and Grimsey Road are shown as impacted by the increased depth.

The sensitivity test show gully blockage results in an increased surface water flood risk to Leiston as runoff is unable to be conveyed through the gullies to the below ground drainage network.

Figure 5-7 3.33% AEP Gully Blockage Sensitivity Testing

Figure 5-8 1% AEP Gully Blockage Sensitivity Testing

6 Mitigation Options

As part of this project, BMT have undertaken a high-level assessment do determine if any potential locations could be utilised to reduce the risk of flooding in the town. These have been separated into two types of mitigation approaches; natural flood management (e.g. additional woodland areas) and engineered flood management (constructed storage measure).

6.1 Natural Flood Management

The EA's recently released evidence base on Working with Natural Processes to Reduce Flood and Coastal Erosion Risk[7] presents options for the Leiston area. This approach involves implementing measures that help to protect, restore and emulate the natural functions of catchments, floodplains, rivers and the coast.

These maps present options and signpost areas for more detailed, local field or modelling investigations. The maps can also be used in discussions with catchment stakeholders in combination with local knowledge.

One key option is identified for the Leiston area; additional catchment woodland (Figure 6-1). There are minor options presented for runoff attenuation features, however these are best addressed through a more targeted detailed approach as shown above.

The locations shown in green in Figure 6-1 below highlight areas with potential to effectively attenuate flooding through tree planting and catchment management.

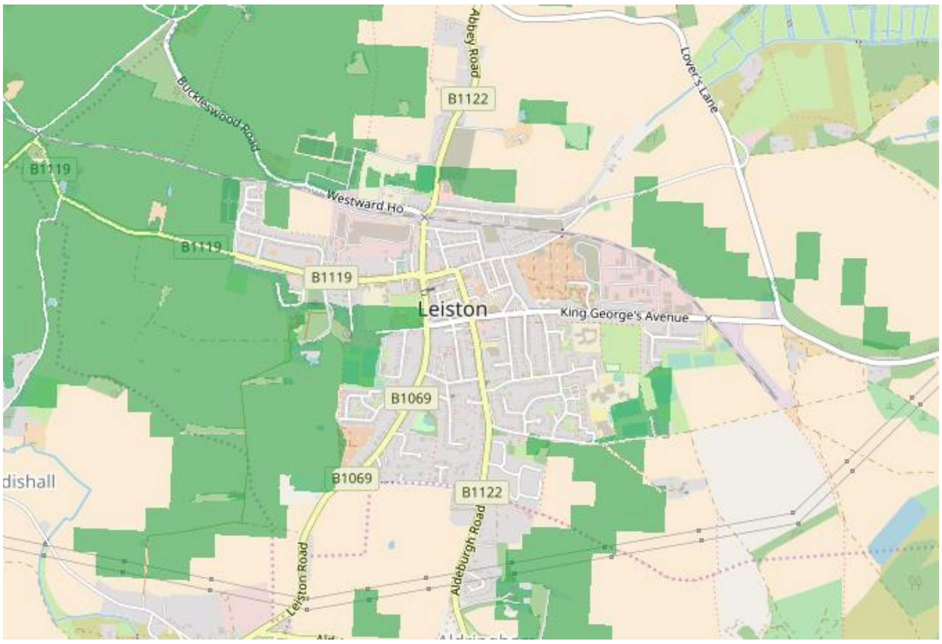


Figure 6-1 Natural Flood Risk Management – Additional Catchment Woodland

The natural flood management options around Leiston are expected to assist in the mitigation of lower order, more frequent events. Whilst having substantial benefits associated with bio-diversity,

[7] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/654429/Working_with_natural_processes_summary.pdf

water quality and erosion management, the area required to mitigate surface water events is expected to be substantial. This measure could be used to complement other options.

6.2 Engineered Flood Management

Preliminary non-natural mitigation measures have been identified, categorised and scored according to the overall objectives of the study and their technical, economic, social and environmental merits. The selection matrix and details of the proposed options within Leiston are provided in Table 6-2.

Asset information relating to power supply, communications locations etc., were not provided for this study, but should be considered during conceptual and detailed design phases. Management and maintenance obligations have not been considered in this high-level assessment, but should be assessed in more detail at any future conceptual and detailed design stages.

Further investigation of the mitigation measures should consider existing/future uses, land ownership, potential benefit (i.e. size and upstream inflows), perceived costs, and any existing measures (and locations). The options assessment matrix provides a transparent and auditable record for selecting the best combination of measures to achieve the greatest benefit.

Individual measures being considered have been scored against criteria (Table 6-1) recommended in the DEFRA SWMP guidance (DEFRA 2010)[8] and scores summed.

Table 6-1 Mitigation Measures Criteria

Criteria	Description	Score
Technical	Is it technically possible and buildable? Will it be robust and reliable?	U (unacceptable) – measure eliminated from further consideration - 2 severe negative outcome -1 moderate negative outcome +1 moderate positive outcome +2 high positive outcome
Economic	Will benefits exceed costs?	
Social	Will the community benefit or suffer from implementation of the measure?	
Environmental	Will the environment benefit or suffer from implementation of the measure?	
Objectives	Will it help achieve the objectives of the SWMP partnership?	

[8] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69342/pb13546-swmp-guidance-100319.pdf

Table 6-2 Options Assessment Matrix

Option	Option Description	Option Assessment							Summary of Scheme
		Technical	Economic	Social	Environmental	Strategic Objective	Overall	Take Forward?	
Do Nothing	Do nothing	2	2	-2	0	-2	0	×	Make no intervention or maintenance – no benefit to area.
Do Minimum	Do minimum	2	0	-1	0	-1	0	×	Continue existing maintenance regimes – minimal benefit and (currently) does not include increased maintenance for the predicted increase in rainfall as a result of climate change.
Improved Maintenance	Improved maintenance of drainage network	2	1	1	0	1	5	✓	This option will be relatively easy to implement by increasing the regularity of the existing maintenance regime. It is however only likely to see localised flooding benefits.
Planning Policy	Adapt spatial planning policies	2	2	0	1	1	6	✓	Limit locations for redevelopment within the key flow routes (allotments are possible locations), however this risk should be reviewed as part of the LLFAs responsibilities in managing surface water flooding and being a consultee in the planning process.
Source Control, Attenuation and SUDS	Manage flows as close to the source of runoff (e.g. raingardens, permeable paving etc.)	1	1	1	1	1	5	✓	Implementation of property level SuDS measures such as rainwater harvesting systems may offer a minor benefit a combination of these on a larger scale could assist with managing some of the predicted flooding in the catchment. Consider rainwater harvesting at school sites.
Flood Storage / Permeability	Attenuate/manage stormwater volumes within strategic areas of the catchment (e.g. detention basins, storage tanks etc.)	2	1	0	1	1	5	✓	Providing additional storage within the catchment may assist with reducing the overall risk to properties and residents'/site users. It is recommended that the feasibility of an attenuation basin is investigated within the upper catchment of Leiston, with additional storage in the fields behind Waterloo Avenue and the Gables.
Upgrade surface water drainage network	Improve drainage network capacity within key risk areas	1	0	1	0	1	2	✓	Upgrade the surface water drainage system to remove bottlenecks and improve sub-surface drainage. This is an expensive and technically complex option, however could provide substantial reductions to surface water flood risk in frequent events. This has knock on benefits of enabling future housing development.
Preferential / Designated Overland Flow Routes	Increase kerb heights and/or lower road levels along key flow paths	2	0	1	0	0	3	✓	Increasing the kerb heights along Valley Road could allow more flood flow down the road while keeping footpaths and building thresholds dry. This could have an impact in minor flood events. The impacts from larger events would need to be tested to quantify the benefit. Lowering Valley Road has the drawback of causing disruption through construction and may potentially result in accessibility issues through the town.
Community Resilience	Improve community resilience to reduce damages from flooding	2	1	2	0	1	6	✓	This option could protect properties from flooding through the installation of flood barriers/gates on the doors of properties. There may be local resistance to the uptake of the barriers and the success of the barriers relies on human intervention and the dissemination of appropriate flood warnings. It is also a costly exercise to fit multiple properties with demountable barriers and/or property level resilience measures. Property level measures, such as ensuring building and gate thresholds and installation of water butts, for example, may provide some benefits.
Natural Flood Management	Additional catchment woodland and natural runoff attenuation features	2	1	1	2	2	8	✓	The EA's Working with Natural Processes Evidence Base Map shows Leiston is suitable for additional Catchment woodland and runoff attenuation features. These measures can improve water quality, community amenity and reduce runoff. Key constraints are land ownership issues. – See section 6.1
Infrastructure Resilience	Community Awareness	2	0	1	0	1	4	✓	This option could be considered for schools and infrastructure predicted to flood in the wider catchment, but is likely to be achieved through improved education / awareness and small-scale SuDS measures such as rainwater harvesting, raingardens etc.
Other or Combination of Above	Combination of above	2	0	1	2	2	7	✓	It is recommended that a combination of potential natural flood management and retention options are explored. Any preferred approach has the potential to be coupled with complementary measure such as rainwater harvesting, bioretention / rain garden devices. In developing a combined solution, a well-rounded and robust mitigation scheme can achieve multiple benefits, such as community engagement, environmental quality and strategic goals.

6.3 Potential Mitigation Options

Based on the results of the updated model (Section 4.2.1), several potential mitigation option locations have been identified in the high-level assessment. These options have been selected with a focus on mitigating surface water runoff from the key predicted flow routes, as opposed to localised minor impacts (Figure 6-2).

Leiston is located near to the top of the catchment. As a result, mitigation options upstream may not capture or divert runoff effectively. However, a distributed approach with a number of smaller measures working in parallel may provide a more comprehensive and robust approach to reducing surface water flood risk within the town.

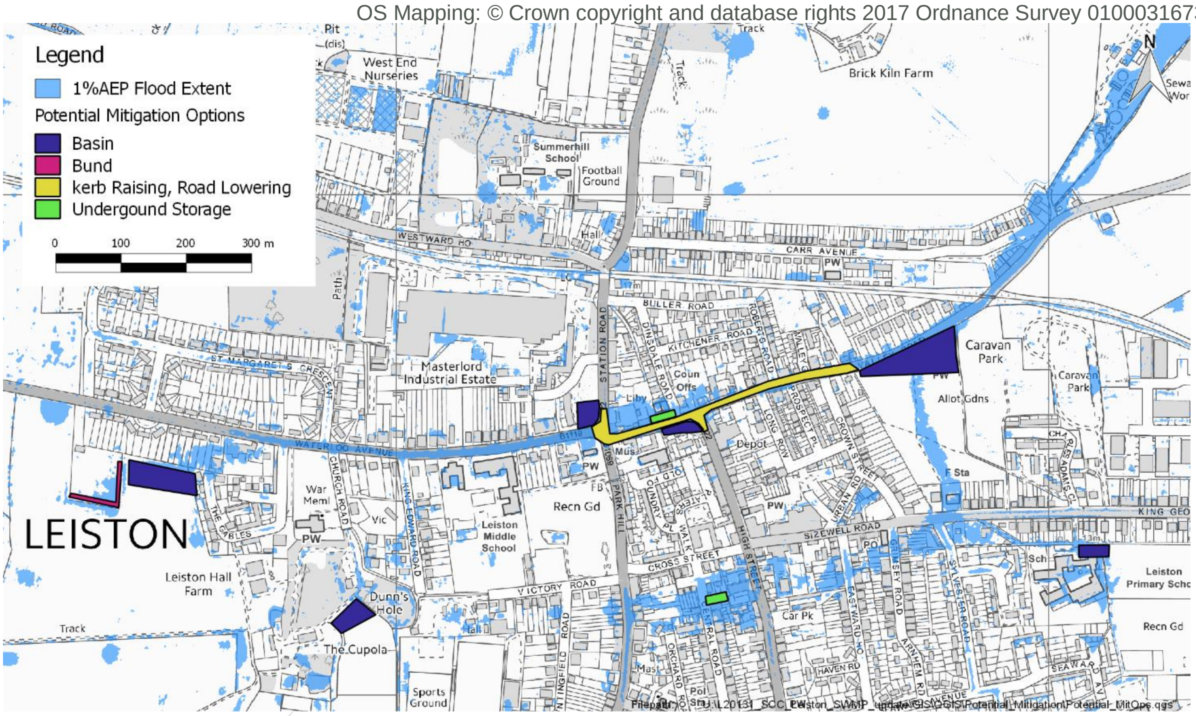


Figure 6-2 Potential Mitigation Option Locations

7 Limitations and Recommendations

The level of confidence that may be placed in the results of a hydraulic model are heavily dependent on the data used to inform them. Where gaps have been identified in these datasets, this necessitates the need to make assumptions in order to provide an appropriate representation of the flooding mechanisms in the study area. This section of the report discusses the key limitations of the model and recommendations for future improvements.

- More comprehensive drainage network data is needed to provide a more accurate understanding of surface water flood risk in Leiston. This will allow fully integrated urban drainage modelling, accounting for the nature and limitations of the drainage network and how it interacts with the surface flow. Currently, a one-way coupled representation of the drainage network has been incorporated into the model. This approach assumes the limiting factor is the flow capacity of the grating/pot and not the associated pipework and downstream outfall constraints. The ability of the gullies to surcharge has not been represented.
- Adjustments to rainfall depths and selection of the design hyetograph storm profile have been made based on review of the whole Leiston catchment. Two storm profiles are typically applied to design rainfall, the 75% winter profile for rural catchments and the 50% summer profile for urban catchments. As urban catchments represent the majority of the study area and locations of interest in relation to surface water flooding, the summer storm profile has been applied to the design rainfall hyetographs.
- The urban drainage network is assumed to freely discharge to Leiston Ditch. This decision has been based on the provided DigDat data and catchment characteristics. This assumption does not account for potential alternate pipe outfall locations, pipe blockage or backwater surcharging.
- Culvert dimensions of the structures beneath Lover's Lane and Abbey Road have been approximated based on previous modelling in the area (AECOM, 2015) and information by the SCC Highways Department. The structure lengths, invert levels and construction material are unknown and have been estimated based on LiDAR and areal imagery. There is therefore some uncertainty associated with their conveyance and impact on surface water flood risk in Leiston. Due to this uncertainty, the dimensions of this structure were included in the model sensitivity testing. It is recommended that survey is undertaken to provide a more accurate representation to inform future studies.
- The hydraulic model results are suitable for identifying the key areas in and around Leiston susceptible to surface water flood risk. Detailed modelling may be required for options assessment of flooding hotspot areas.
- The hydraulic model has been built to assess surface water flood risk. Modification to the model may be necessary should they be used to assess other sources of flooding.
- The soil infiltration rates included within this model has been determined based on broad scale datasets. Future studies may consider obtaining site specific information such as through borehole logs, to provide more accurate infiltration rates for each study area.

- Mitigation measures have been assessed on a high level and are based on potential opportunities to attenuate flooding. Detailed analysis, including damages assessment, benefit cost analysis and detailed design is recommended before implementation.
- Normal flow boundaries are applied in the model and are based on the ground slope of adjacent, upstream cells. The normal flow boundary assumes that there is normal, free surface flow at fixed slope. For example, this means that on the Leiston Ditch, north east of Leiston and downstream of Lover's Lane, is assumed to freely discharge, without constriction. Effects such as stormwater being unable to discharge due to tidal surges have not been considered.
- The inverts and dimensions of Leiston ditch have been estimated from LiDAR and aerial imagery. The ditch is assumed to be empty at the onset of a storm event. The impact of existing high water levels on the ditch has not been assessed. This is assumed to have little impact on the surface water flood risk in the urban area of Leiston due to the difference in elevation between the ditch and the town.
- The validation event was modelled using rainfall data from Thorpeness gauge, 3km from Leiston. This distance may mean that the recorded rainfall in Thorpeness does not match the true rainfall in Leiston and under or over predict flooding. High confidence could be placed in the rainfall record if there was a rainfall gauge located in Leiston.
- The validation evidence is limited spatially and does not have a full record of the flooding depths and times at which they occurred. Validation can only be carried out in areas with evidence, the veracity of other areas, such as the ponding near Central road cannot be verified. In addition, the timing and mechanisms of flooding cannot be verified with the static images without timestamps.

8 Conclusions

A single hydraulic model was constructed using the TUFLOW HPC software for Suffolk County Council. This model presents a more accurate and complete estimation of the surface water flood risk in Leiston. Updates to the model include:

- One-way drainage network based on updated gully information from SCC to account for the urban drainage network varying spatially through the catchment and temporally throughout the event;
- Model extent covering the whole surface water catchment ensuring that all contributing runoff is captured;
- Dynamic infiltration losses to more accurately show the soil losses and variation over the catchment;
- Inclusion of the latest 2m and 0.25m EA LiDAR datasets on a 0.5m model cell size. In addition, fine scale urban features such as kerbs, walls, building thresholds and fences and augmented this base dataset. This enables greater accuracy flood results though urban areas.

The baseline model results show two key flowpaths through Leiston, along Valley Road and parallel to Sizewell Road. The Valley Road flowpath is largely constrained to the roadway in low events but nevertheless presents high hazard, due to high velocity runoff. The Sizewell Road flowpath is shown to impact properties as it moves through back gardens, drainage easements and roadways.

Preliminary recommendations have been made for mitigation options, including natural flood management measures. These mitigation options are targeted to the two key flowpaths through the urban area and are distributed throughout the catchment. A range of measures are proposed, including basins, kerb lowering and small bunds. Detailed analysis, including cost-benefit assessment and detailed design is recommended before options are implemented.

Appendix A Flood Maps - Depth

Leiston	
Map Reference Number	**Description**
A-1	10% AEP Storm Event, Maximum Depth
A-2	3.33% AEP Storm Event, Maximum Depth
A-3	1.33% AEP Storm Event, Maximum Depth
A-4	1% AEP Storm Event, Maximum Depth
A-5	0.5% AEP Storm Event, Maximum Depth
A-6	1% AEP Storm Event with Climate Change Allowance (Central - 20%), Maximum Depth
A-7	1% AEP Storm Event with Climate Change Allowance (Upper End - 40%), Maximum Depth

Appendix B Flood Maps - Hazard

Leiston	
Map Reference Number	**Description**
B-1	10% AEP Storm Event, Maximum Hazard
B-2	3.33% AEP Storm Event, Maximum Hazard
B-3	1.33% AEP Storm Event, Maximum Hazard
B-4	1% AEP Storm Event, Maximum Hazard
B-5	0.5% AEP Storm Event, Maximum Hazard
B-6	1% AEP Storm Event with Climate Change Allowance (Central - 20%), Maximum Hazard
B-7	1% AEP Storm Event with Climate Change Allowance (Upper End - 40%), Maximum Hazard

Appendix C Digital Deliverables

Digital Deliverable
TUFLOW model
GIS Depth outputs, all events
GIS Hazard output, all events
GIS Flood extents, all events
Report PDF