Surface Water Management Plan for Hoo and Rainham, Kent

Final Report

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This report describes work commissioned by Priscilla Haselhurst, on behalf of Medway Council, by a letter dated 18 August 2018. Ed Hartwell, James Axton and Fiona Hartland of JBA Consulting carried out this work.

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Executive summary

The Hoo and Rainham Surface Water Management Plan (SWMP) was proposed to understand and manage the flood risk arising from local sources of flooding (defined as flooding from surface water, groundwater and ordinary watercourses).

Both the parishes of Hoo St. Werburgh and Rainham have been identified as areas where significant development is likely to take place over the next 15+ years and as such a greater understanding of the flood risk and the impact of future developments on flood risk was required.

Medway Council as Lead Local Flood Authority (LLFA) commissioned JBA Consulting to prepare the Hoo and Rainham SWMP, working in partnership with the Environment Agency, Lower Medway Internal Drainage Board and Southern Water.

Hoo St. Werburgh is predominantly rural, and the wider catchment contains a complex network of sub catchments and land drains which drain surface water to the Hoo Stream which in turn drains out to the tidal Medway. The stream commences at the Ratcliffe Highway to the west of Hoo St. Werburgh and flows in an easterly direction through the village before entering an area of farmland and marshland.

The Rainham study area is predominantly urbanised, situated to the east of Medway on the A2 between Gillingham and Newington. Rainham is less densely urbanised than other nearby settlements in the Medway region, containing more greenfield sites. There are some areas of agricultural land to east of Rainham, and the northern part of the study area is also within the Medway Estuary and Marshes Site of Special Scientific Interest (SSSI) and is designated a Special Protection Area and Ramsar site. There are no Main Rivers or Ordinary Watercourses within Rainham other than the Medway estuary which borders the north part of the study area and which surface water flows eventually end up in.

To better understand flood risk in Hoo St. Werburgh and Rainham, the SWMP has involved the collection of all available flood incident records, which have been supplied by the project partners. Survey data of the Hoo Stream through Hoo St. Werburgh was also collected and LIDAR data supplied by the Environment Agency was used to build integrated hydraulic models using InfoWorks ICM.

Existing and committed development were included with the base model and proposed future developments were added to scenario models to represent the future flood risk situation. A series of options have been considered to manage the flood risks within the study areas. In addition to typical "hard engineering" options a range of Greenfield Runoff Rates (GRR) for the proposed sites were tested to allow an assessment of the impact of these rates on flood risk to be undertaken.

The resulting model scenarios, created as part of this study, are set out in the Model Operation Manual (Appendix B).

All options have been considered on a cost benefit basis. The number of properties at risk of flooding during each option and scenario has been calculated using FRISM (JBA Consulting's in-house flood risk estimation tool). The Multi Coloured Manual (MCM) codes in the National Receptor Database (NRD) were used to identify properties. These were counted where the building footprints (based on the NRD data points) intersected the model flood outlines.

The Environment Agency's Long-Term Costing Tool was been used to estimate the cost (where applicable) of each option and the MCM was used to estimate the damage costs for each simulation.

The results of this assessment can be found in Section 4 and plans of flood risk for different simulations have been included in Appendix D, E and G.

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Abbreviations

1D	One Dimensional (modelling)
2D	Two Dimensional (modelling)
AEP	Annual Exceedance Probability
AOD	Above Ordnance Datum
CFMP	Catchment Flood Management Plan
DTM	Digital Terrain Model
EA	Environment Agency
FEH	Flood Estimation Handbook
FRISM	Flood RISk Metric (JBA in house tool)
FRM	Flood Risk Mapping
FSA	Flood Storage Area
GIS	Geographical Information System
GRR	Greenfield Runoff Rate
IDB	Internal Drainage Board
LFRMS	Local Flood Risk Management Strategy
LPA	Local Planning Authority
MCM	Multi Coloured Manual
NRD	National Receptor Database
OS	Ordnance Survey
PFRA	Preliminary Flood Risk Assessment
PV	Present Value
QBAR	Mean Annual Maximum Flood
QMED	Median Annual Flood (with return period 2 years)
ReFH	Revitalised Flood Hydrograph method
RMA	Risk Management Authority
SFRA	Strategic Flood Risk Assessment
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
SUDS	Sustainable Urban Drainage Systems
SWMP	Surface Water Management Plan

1 Introduction

1.1 Purpose of a Surface Water Management Plan

A Surface Water Management Plan (SWMP) is a study to understand the risk that arises from local sources of flooding, which is defined by the Flood and Water Management Act 2010 as flooding from surface runoff, groundwater, and ordinary watercourses.

SWMPs are led by a partnership of flood risk management authorities who have responsibilities for aspects of local flooding, including Medway Council, the Sewerage Undertaker, Internal Drainage Boards and other relevant authorities.

The purpose of a SWMP is to identify what the local flood risk issues are, the potential options to manage the flood risk or the damage caused and who should take these options forward. This is presented in an action plan which lists the partners who are responsible for taking the various actions forward. The action plan, which will be reviewed periodically, should be agreed by all project partners to manage the flood risk identified.

1.2 Stages of a SWMP

The SWMP has been prepared across a series of four phases as follows:

- Preparation: A partnership approach has been taken to local flood risk management through integrated working between the risk management authorities (RMAs). This also required gathering evidence of and information about flooding.
- Risk Assessment: An initial assessment was undertaken to determine the highest risk locations and the key issues upon which the action plan should focus. Publicly available datasets in combination with local records of flooding have been used to inform the assessment. Additionally, hydraulic modelling of the Hoo Stream has also been prepared in order to gain a comprehensive understanding of the flooding and drainage issues in the area both now and in the future.
- Options: Identification and testing of strategic options for reducing existing flood risk and managing surface water for any future development considerations in high risk areas. These options have been presented to the stakeholders for review and comments to agree on the Action Plan.
- Implementation: An Action Plan has been prepared to outline the actions required and where and how they should be undertaken. The Action Plan sets out which partner(s) or stakeholder(s) is/are responsible for implementing the actions and who will support them. The plan also identifies priorities.

Defra (2010) has produced guidance for those undertaking Surface Water Management Plans in England[1]. These four stages are illustrated in Figure 1-1.

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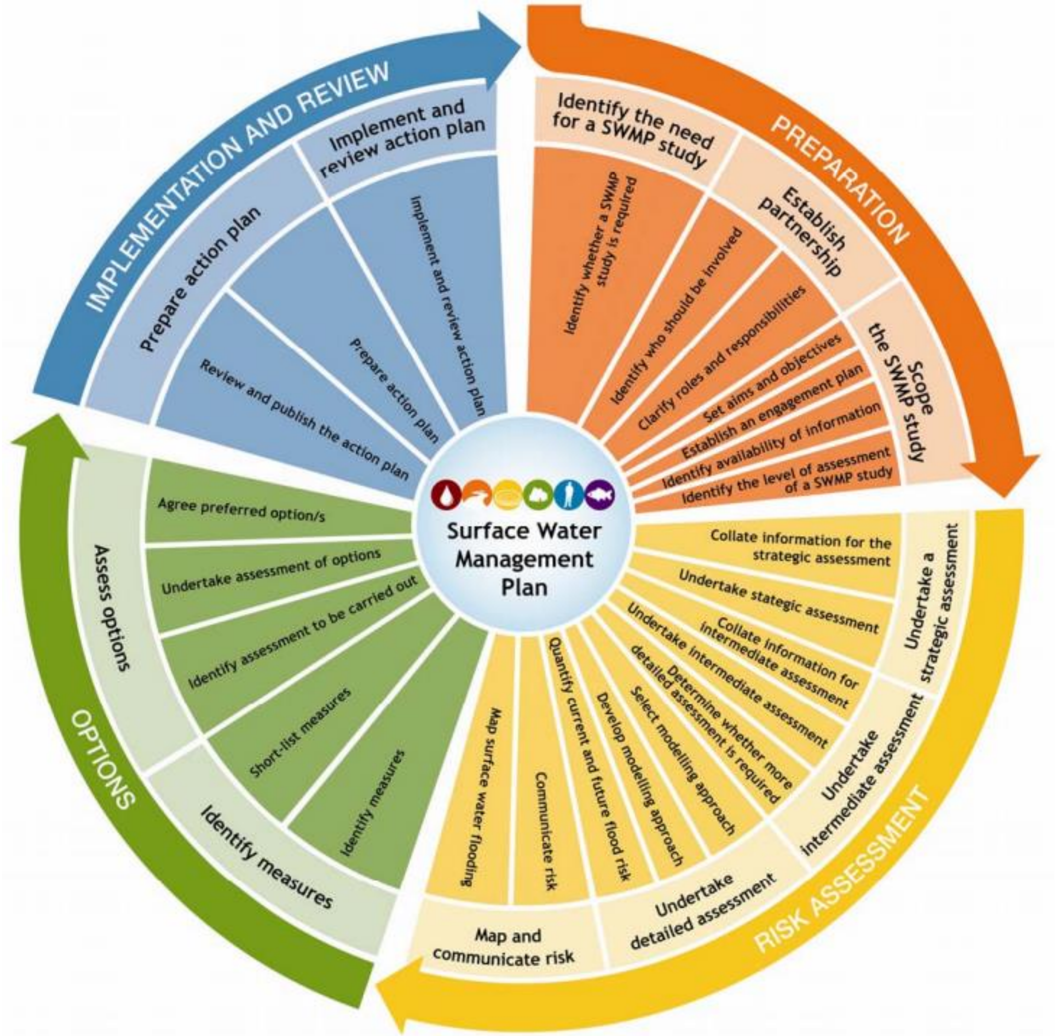
[1] Defra (2010) Surface Water Management Plan Technical Guidance

Figure 1-1: Surface Water Management Plan Wheel



1.3 What is meant by Surface Water Flooding?

In the context of this SWMP, the definition of surface water flooding as set out in the Defra SWMP Guidance has been followed:

Surface water flooding describes flooding from sewers, drains, small water courses and ditches that occurs during heavy rainfall in urban areas. It includes:

- Pluvial flooding; flooding as a result of high intensity rainfall when water is ponding or flowing over the ground surface (surface runoff) before it enters the underground drainage network or watercourse, or cannot enter it because the network is full to capacity.
- Sewer flooding; flooding which occurs when the capacity of underground systems is exceeded, resulting in flooding inside and outside of buildings. Normal discharge of sewers and drains through outfalls may be impeded by high water levels in receiving waters.
- Flooding from small open-channel and culverted urban watercourses which receive most of their flow from inside the urban area.
- Overland flows from the urban/rural fringe entering the built-up area, including overland flows from groundwater springs.

1.4 Background to the Hoo and Rainham SWMP

In 2016, Medway Council undertook a SWMP which focused on the urban areas through Medway which had been identified as part of a national Flood Risk Area by the Preliminary Flood Risk Assessment (PFRA) undertaken in 2011 and included, Gillingham, Chatham, Strood and Rochester.

This 2019 SWMP extends the assessment to Rainham, and Hoo St. Werburgh as part of consideration by Medway Council of potential development sites alongside the Local Plan Development Options consultation. Rainham and Hoo St. Werburgh were both identified as areas with high surface water flood risk in the 2011 PFRA, with Rainham nationally recognised as a Flood Risk Area in a 2017 addendum to the initial PFRA.

This SWMP has been undertaken in consultation with key local partners to understand the causes and effects of surface water flooding and establish a long-term action plan to manage surface water and test potential strategic options.

1.5 SWMP drivers

The preparation of a SWMP was driven in response to the following considerations:

The need to understand the risk of surface water flooding in Rainham and Hoo St. Werburgh, as part of consideration of potential development sites identified in the Local Plan Development Options consultation.

To investigate the flood risk of the Hoo Stream in order to gain a comprehensive understanding of flooding and drainage issues in the area both now and in the future, through the production of a hydraulic model.

To better understand constraints to the development of sustainable urban extension around Rainham to complement the urban regeneration taking place in central Medway.

To better understand the complex drainage network and impacts of discharging surface water to designated SSSI, SPA and RAMSAR areas around Hoo St. Werburgh, that may constrain future development to support the expansion of Medway.

1.6 SWMP objectives

The Hoo and Rainham SWMP has the following objectives:

Create a hydrodynamic flood model of the Hoo Stream, integrating existing available Southern Water sewer modelling, which can model the interaction between surface water sewers, combined sewers, ordinary watercourses, tides and overland flow to predict flooding for a variety of storm durations.

Utilise existing Southern Water hydrodynamic sewer models within Rainham to further understand key areas of risk, to explore potential options for reducing flood risk in existing high-risk areas and areas highlighted within the Development Options consultation.

Produce an action plan for further work.

1.7 Study Area

The SWMP focuses on the two development areas of Hoo St. Werburgh and Rainham.

1.7.1 Hoo St. Werburgh

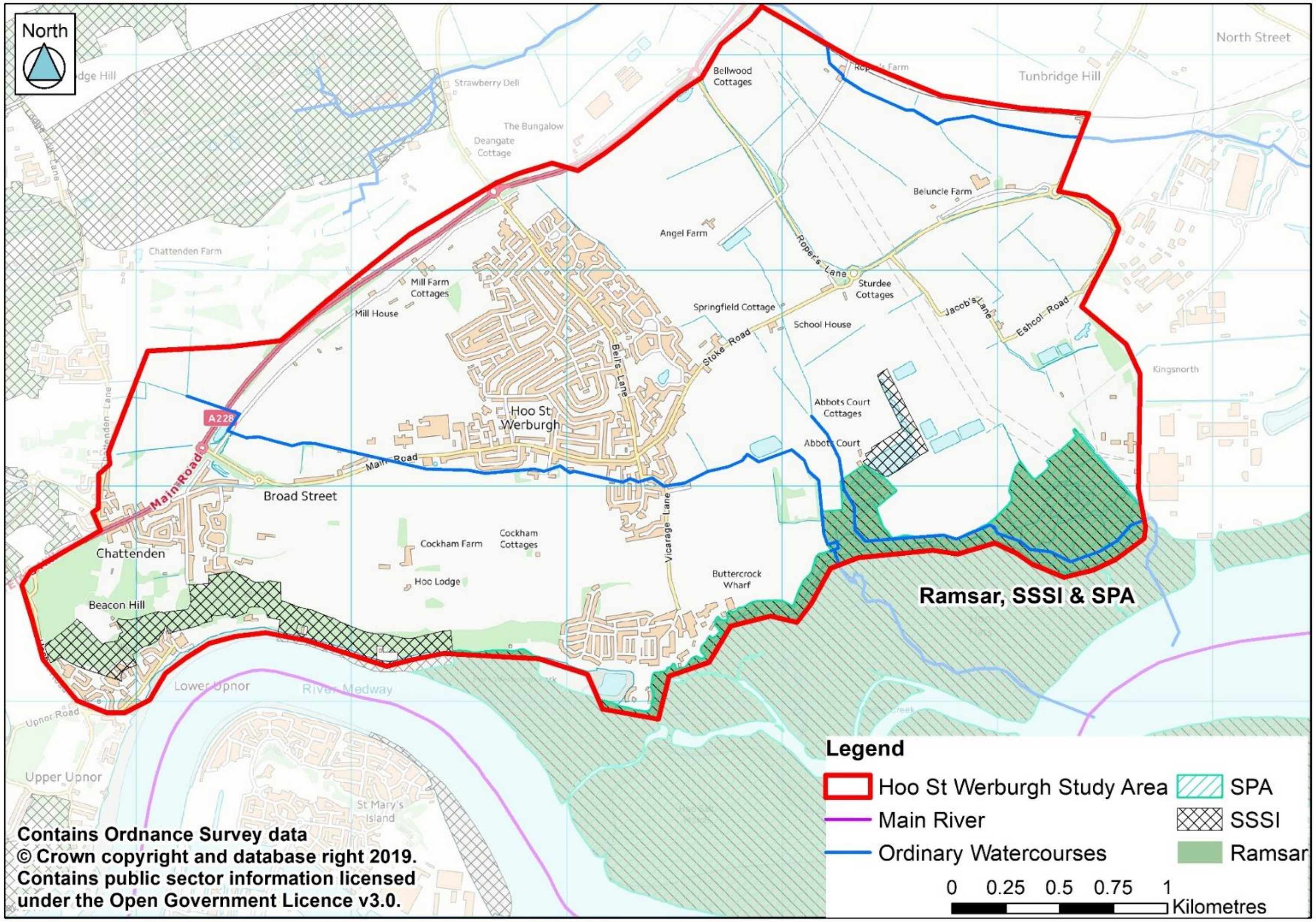
Hoo St. Werburgh is predominantly rural, and the wider catchment contains a complex network of sub catchments and land drains which drain surface water out to the tidal Medway via the farmland and marshland situated within the lower reaches of the catchment. Parts of the Hoo St. Werburgh study area to the south and east are within the Medway Estuary and Marshes Site of Special Scientific Interest (SSSI), Special Protection Area (SPA) and Ramsar designations. The southwest of the study area is part of the Tower Hill to Cookham Wood SSSI. This, alongside the requirements of the Water Framework Directive, increases the importance of the need to ensure the discharge of clean, uncontaminated surface water.

The Hoo Stream is a key ordinary watercourse which passes through the main village. The stream commences at the Ratcliffe Highway and passes through the rear of properties at Main Road, with several culverted sections, before joining the Medway near Abbots Pools. There are two further ordinary watercourses in Hoo St. Werburgh; one flowing southeast from the Abbots Court area to the Medway, and the other flowing east along the northeast edge of the study area. There are currently three attenuation basins within the Hoo St. Werburgh area, with around five further attenuation ponds proposed within current planning consents.

There is a Southern Water public sewer network consisting of foul / combined and surface water sewers throughout the study area. The surface water sewer has several outfalls, discharging into different points along Hoo Stream, the River Medway and a storage pond east of Hoo St. Werburgh. The foul / combined network is pumped out of the study area by two pumping stations, one east of Hoo St. Werburgh and one in the southwest of the study area. There are no Combined Sewer Overflows (CSO) within the study area.

The Hoo St. Werburgh study area is shown in Figure 1-2.

Figure 1-2: Hoo St. Werburgh study area



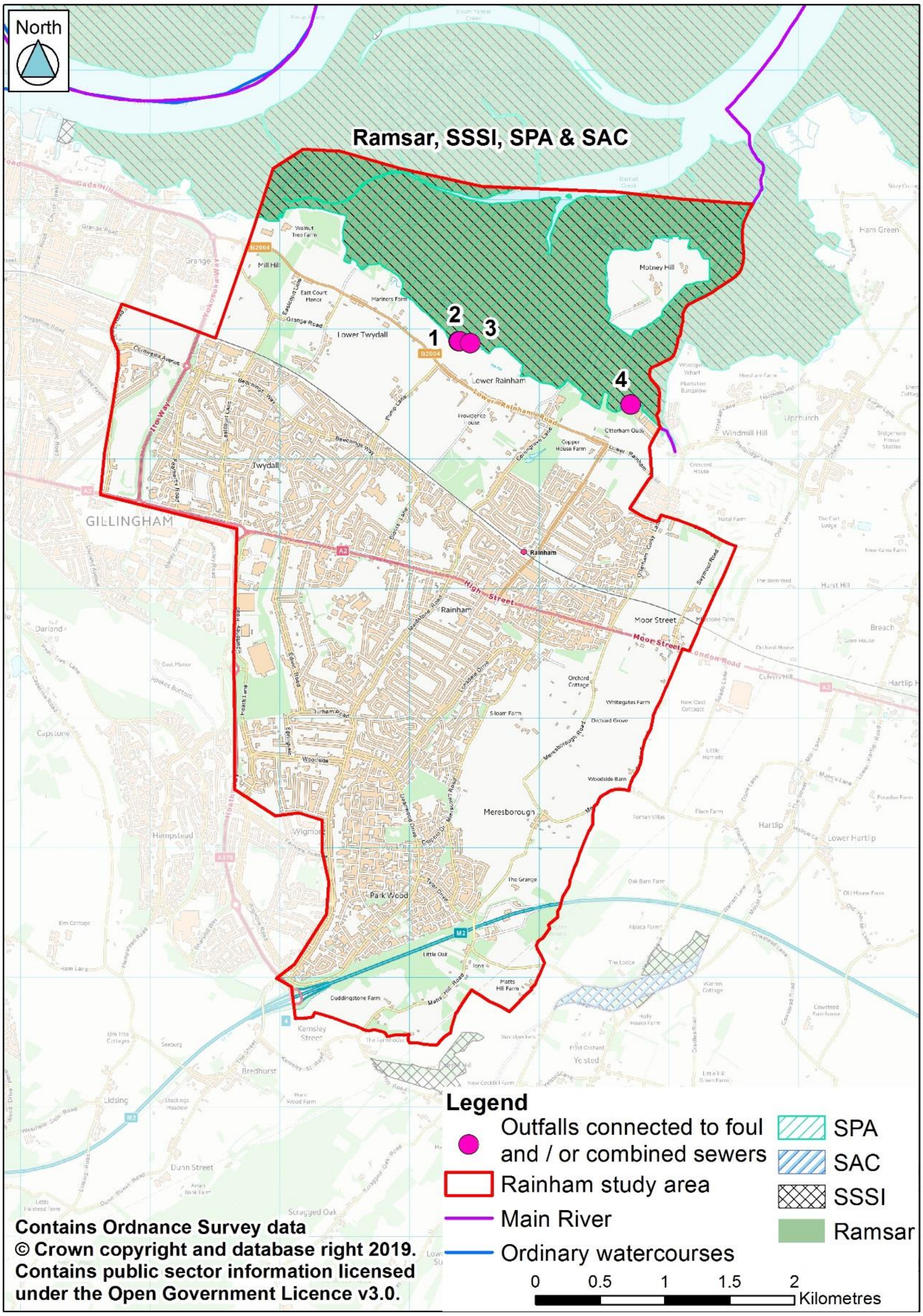
1.7.2 Rainham

The Rainham study area, situated to the east of Medway on the A2 between Gillingham and Newington, is predominantly urbanised. Rainham is less densely urbanised than other nearby settlements in the Medway region, containing more greenfield sites. There are some areas of agricultural land to east of Rainham, and the northern part of the study area is also within the Medway Estuary and Marshes Site of Special Scientific Interest (SSSI), Special Protection Area and Ramsar site designations.

Other than a small section of Main River along the northeast boundary of the study area, there are no Main Rivers or Ordinary Watercourses within Rainham.

The study area is served by the Southern Water public sewer network, which consists of combined, surface water and foul sewers. Rainham is predominantly served by a combined sewer network. However, localised residential areas in north east and north west Rainham, particularly north of A2 London Road, are drained by separate foul and surface water sewer networks. The surface water sewer network drains directly into the River Medway estuary. The foul and combined sewer networks drain to two pumping stations; the eastern portion drains to Lower Halstow Wastewater Pumping Station, whereas the western portion drains to The Strand Pumping Station. There are CSOs at 24 locations within the Rainham study area connecting foul and combined systems to four surface water network outfalls into the Medway Estuary. The locations of these outfalls are shown in Figure 1-3.

Figure 1-3: Rainham study area



1.8 Overview of previous and current activities / projects

The Environment Agency's Flood Zone mapping shows the fluvial and tidal flood risk from the River Medway, and the fluvial risk along the lower part of Hoo Stream. The Flood Zone mapping consists of outlines from detailed modelling (for the River Medway), with national generalised modelling where the detailed modelling does not exist (for watercourses within the Hoo study area).

The Environment Agency's national Risk of Flooding from Surface Water (RoFSW) mapping indicates that there is extensive surface water flood risk in Rainham and Hoo St. Werburgh. The national-scale mapping makes some significant assumptions that could impact its accuracy in the study area, including:

In the modelling used to create the RoFSW mapping culverts are either represented as cuttings through embankments, rather than pipes, or are not represented at all. This could lead to inaccurate estimations of surface water flood risk around culverts in the study area, for example around Church Street and Vicarage Lane in Hoo.

A single assumption of urban drainage capacity is made across the country.

Urban areas were defined based on Ordnance Survey MasterMap information for grid squares 250m by 250m. Where more than 50% of a grid square consists of manmade land uses (including all buildings, roads, paths and other hard-standing) it is determined as "urban" and urban runoff rules are applied. Outside of these "urban" areas the ReFH rainfall-runoff method is applied.

The modelling assumes a free outfall with no account for tidal locking that may limit surface water drainage, with both the Hoo St. Werburgh and Rainham areas potentially affected by this.

The topographic data used for the mapping does not include the newly constructed A228 Peninsula Way. Consequently, these are not accounted for in the surface water flow paths represented within the RoFSW outputs, reducing the accuracy of the mapping in this area.

In 2014 Medway Council commissioned a hydrological assessment and prediction of flood flows for Hoo Stream after a series of flood events caused by the backing up of a culvert at Abbots Court Road in Hoo. The report estimates the flows associated with a flood event in December 2013, concluding that flooding was likely caused by blockages of the culvert.

At the time of writing, there are no major projects or new activities being undertaken by any of the partners within the study areas.

1.9 Policy context and links with other plans

This SWMP will integrate and align with the existing network of plans and processes for the Medway area that may influence or be influenced by the SWMP.

1.9.1 Local Flood Risk Management Strategies

The Flood and Water Management Act 2010 (FWMA) requires each Lead Local Flood Authority (LLFA) to produce a Local Flood Risk Management Strategy (LFRMS), with Medway Council's published in 2014. The LFRMS outlines Medway Council's approach as LLFA to manage local flood risk from surface water, groundwater and ordinary watercourses. The LFRMS is linked to and supported by a Catchment Flood Management Plan (CFMP), Preliminary Flood Risk Assessment (PFRA), Strategic Flood Risk Assessment (SFRA) and SWMP.

1.9.2 North Kent Rivers Catchment Flood Management Plan

CFMPs have been developed by the Environment Agency for 77 catchments in England and Wales, setting out the flood risk management policies for inland water, addressing current and future risk and seeking to direct investment where risk is greatest.

Rainham and Hoo St. Werburgh are covered by the North Kent Rivers CFMP, published in 2009, which considers all types of inland flooding (rivers, groundwater, surface water, tidal), though there is limited information for surface water available. Rainham is predominantly within the Policy 3 North Kent Marshes area, with a small region in the Policy 1 North Kent Downs and Plains area, while Hoo St. Werburgh is mostly covered by Policy 1, with a small area within Policy 3. Policy 1 covers areas of little or no flood risk where the proposed actions are to continue to monitor and advise flood risk. Policy 3 covers areas of low to moderate flood risk and key actions include encouraging the uptake of flood resilience measures and seeking opportunities for wetland creation and restoration.

1.9.3 Medway Council Preliminary Flood Risk Assessment

The PFRA is required as part of the Flood Risk Regulations, with Medway Council's PFRA published in 2011 covering the Medway Unitary Authority area. The PFRA contains information on historic flooding from local sources, primarily surface water, groundwater and ordinary watercourses, as well as an assessment of future flood risk and the potential effects of climate change.

Within the PFRA, Rainham is identified as being within an Indicative Flood Risk Area (IFRA), where there is potential risk of surface water flooding which has the potential to cause 'significant harmful consequence'. As the PFRA is a county-scale assessment of flood risk, Hoo St. Werburgh is not identified as an IFRA given its more rural location, though the settlement of Hoo is identified as having a high flood risk.

In 2018 the Environment Agency published an updated PFRA for England, which identifies further Flood Risk Areas where flooding is likely to be significant for people, the economy or the environment. In the updated PFRA, Rainham is located within the Medway Flood Risk Area for surface water flooding, as well as the IFRA identified in the 2011 PFRA. Additionally, the area east of Hoo St Werburgh around the Kingsnorth Power Station is located within the London and Thames Estuary Flood Risk Area at risk of from rivers and sea.

1.9.4 Medway Council Strategic Flood Risk Assessment

Each Local Planning Authority (LPA) is required to produce a SFRA under the National Planning Policy Framework (NPPF), providing an important tool for guiding planning policies and land use decisions. The latest Medway Council SFRA is due to be published in Summer 2020 and should be referred to by developers. The SFRA will include mapping showing the potential risk of flooding across Medway and identify Sensitive Drainage Areas, as well as detailing requirements for surface water management.

1.9.5 Medway Surface Water Management Plan

The initial SWMP within the Medway Council area was published in 2016, assessing the risk of surface water flooding using modelling results from the LFRMS and Environment Agency mapping. Four areas were prioritised for detailed assessment based on historic incidents, potential for future development, surface water drainage infrastructure and predicted numbers of buildings flooded. These prioritised areas were Strood, Rochester, Chatham and Gillingham. Though the Hoo St. Werburgh area was identified as having a high risk of surface water flooding, it was only assessed at an intermediate level.

2 Preparation

2.1 Identify the need for a Surface Water Management Plan

In accordance with the Defra (2010) guidance Hoo St. Werburgh and Rainham have been prioritised within the Medway Unitary Authority area as areas considered to be at significant risk of surface water flooding and are areas where partnership working is considered essential to both understand and address surface water concerns.

Surface water flooding can cause damage to properties and disrupt road, rail and pedestrian movements in affected areas. In addition, the sudden onset of surface water flooding can create road safety hazards and risk to pedestrians. Consequently, surface water flooding is an issue that must be understood and addressed with all future development plans.

Medway Council undertook a SWMP in 2016 which outlined the level of probable risk, prioritised higher risk areas for further investigation, and assessed options to identify potential flood mitigation actions, focusing on Gillingham, Chatham, Strood and Rochester. This SWMP extends this assessment to Rainham, and Hoo St. Werburgh to support the consideration of potential development sites in the study areas.

This Surface Water Management Plan for Rainham and Hoo St. Werburgh helps to understand the causes and effects of surface water flooding and establishes a long-term action plan for managing surface water, with potential strategic options tested.

2.2 Establish Partnership

Surface water cannot be managed by a single authority, organisation or partner; all the key organisations and decision-makers must work together to plan and act to manage surface water in Rainham and Hoo St. Werburgh. Many organisations have rights and responsibilities for management of surface water. Although Medway Council commissioned this project, key partners have been consulted during the SWMP process. Working in partnership encourages co-operation between different agencies and enables all parties to make informed decisions and agree the most cost-effective way of managing surface water flood risk for the long term. The partnership process is also designed to encourage the development of innovative solutions and practices; and improve public engagement and understanding of surface water flooding.

2.2.1 Who is involved

Partners are defined as organisations with responsibility for the decision or actions that need to be taken to manage surface water flooding. The key partners involved in this project are:

Medway Council

Environment Agency

Lower Medway Internal Drainage Board (LMIDB)

Southern Water

2.2.2 Roles and responsibilities

Table 2-1 highlights the roles and responsibilities of key partners. Other groups also have notable roles and responsibilities in Hoo St. Werburgh and Rainham:

Riparian owners / Large landowners – have a responsibility for channel maintenance along their reaches

Public – have responsibilities with respect to drainage of their properties, and, since 2008, to adhere to legislation with regards to permeable paving of driveways[2]

Table 2-1: Formal roles, duties and powers for partner organisations

Organisation	Role	Duties and powers
Medway Council	Local Planning Authority Lead Local Flood Authority (LLFA) Riparian owner Highways Authority	Input to National and Local Statutory Strategies. Ordinary watercourse management. Management of surface water, groundwater and other sources of flooding. Input to national strategy. Formulate and implement local flood risk management strategy. Monitor flooding within their area and investigate the causes and map the hazard associated with the source of flooding. Under the Flood and Water Management Act (FWMA), LLFAs are designated the SUDS Approval Body (SAB) for any new drainage system, and therefore must approve, adopt and maintain any new sustainable drainage systems (SUDS) within their area. This aspect of the FWMA is yet to be formally enacted in England.
Environment Agency	National supervisory role for flood risk management	Management of main rivers, sea, and reservoirs. National Statutory Strategy Reporting and general supervision. Permissive powers.
LMIDB	Drainage Board	Operational and regulatory powers along drainage network.
Southern Water	Sewerage Undertaker	Operational and regulatory powers along Sewer network. Cooperate with LLFA regarding surface water.

[2] https://www.gov.uk/government/publications/permeable-surfacing-of-front-gardens-guidance

2.3 Available information

The following is a summary of the information available for this study:

OS MasterMap Topography mapping was used in the modelling process to distinguish between land uses across the settlements. It was also used to better define the model grid so key flow paths around buildings and along roads and watercourses are more appropriately represented.

Ground height data in the form of 1m LIDAR collected in 2018 was obtained from the Environment Agency. The LIDAR covered the SWMP study's areas and the wider catchment area. LIDAR data was used to model the shape of the terrain.

The Flood Estimation Handbook (FEH) CD-ROM was used to obtain the rainfall parameters needed to define the hydrological inputs for the InfoWorks ICM models and to derive fluvial inflows for watercourses in Hoo St. Werburgh.

The National Receptor Database (NRD) 2014 was used when quantifying risk to properties and prioritisation of potential measures and actions

Boundaries of committed development sites within the study areas to include within the model scenario representing the present day, with information on the proposed drainage strategies available from the Medway Council planning portal

Boundaries of potential future development sites within the study areas, including information on the proposed completion dates of the developments and number of properties on each site.

Various records of historic flooding were used to verify model results.

- Environment Agency's Historic Flood Map
- Environment Agency's Recorded Flood Outlines
- Medway Council's record of local flood history
- Medway Council's combined flood records
- Southern Water's sewer flood history
- Anecdotal information relating to local flood history and flood risk areas

Environment Agency Flood Zones were used to identify the fluvial and tidal flood risk within the study area.

Environment Agency Risk of Flooding from Surface Water (RoFSW) mapping was used to assist with the verification of the surface water modelling.

Southern Water's InfoWorks ICM sewer model and sewer network GIS database for the study areas were used for the model build, model verification and options assessment.

A topographic survey was commissioned as part of this study for Hoo Stream, an ordinary watercourse, between Ratcliffe Highway and Abbots Court Road. The survey data was used to define the geometry of the watercourse through Hoo St. Werburgh in the InfoWorks ICM model.

Information on existing and proposed Flood Alleviation Schemes, notably attenuation basins.

Asset information from a variety of sources were used to define pipes and structures in the InfoWorks ICM model, enabling 1D elements to be modelled with greater accuracy

- Southern Water's InfoWorks ICM sewer model

- Topographic survey for Hoo Stream
- Lower Medway IDB asset register and maintenance log
- Environment Agency's Asset Information Management System (AIMS)
- Medway Council's asset register

Existing reporting was used to provide a background to flood risk in the study area

- Medway Council Strategic Flood Risk Assessment (SFRA) 2006
- Medway Council Preliminary Flood Risk Assessment 2011
- Medway Council Local Flood Risk Management Strategy (LFRMS) 2014
- Medway Council Hydrological Assessment and Prediction of Flood Flows for the Drainage Ditch at Abbots Court Road, Hoo, Medway 2014
- Medway Surface Water Management Plan 2016

A full listing of all data supplied by each of the partner organisations is provided in the project data register displayed in Appendix A.

2.4 Overview of flood history

There is a history of flooding from a range of sources in the study area, with several recorded incidents of surface water flooding in Hoo St. Werburgh and in Rainham. While the southeast of the Hoo St. Werburgh area was impacted by the February 1953 tidal flooding, the majority of recorded flood incidents are caused by surface water and sewer flooding. There is regular flooding from the Hoo Stream around Vicarage Lane, Abbots Court Road and Church Street, with flooding recorded twice in 2013 and twice in 2000. There are fewer recorded flood events in the Rainham area, with the incidents generally caused by surface water or sewer flooding. Cherry Tree Road has been identified as a particular flood hot spot with flooding occurring from surface water runoff from the land to the south of the road.

Table 2-2 and Table 2-3 outline the information relating to historic flood events that been collected during this process in Hoo St. Werburgh and Rainham respectively.

Table 2-2: Historic flooding in the Hoo St. Werburgh study area

Source of flooding	Location / consequence	Date	Data source
Tidal storm surge	Widespread flooding in coastal area southeast of Hoo around Kingsnorth and Abbots Pools	February 1953	EA Recorded Flood Outlines
Ordinary watercourse	Backing up of Culvert under Vicarage Lane in Hoo flooded surrounding area. Highway flooding also recorded at Roper's Green Lane.	December 2013	Medway Council's combined flood records and record of local flood history
Ordinary watercourse	Backing up of Culvert under Vicarage Lane in Hoo.	June 2013	Medway Council's Hydrological Assessment of Abbots Court Drainage Ditch
Ordinary watercourse	Backing up of Culvert under Vicarage Lane in Hoo.	October 2000	Anecdotal evidence from Medway Council
	Flooding around Church Street and Vicarage Lane.	June 2000	Medway Council's record of local flood history and Hydrological Assessment of Abbots Court Drainage Ditch
Surface water	Highway flooding of Stoke Road where Highway Lagoon is heavily silted		Medway Council's combined flood records
Surface water	Pottery Road, Hoo	September 2015	Medway Council's combined flood records
Surface water	Knights Road, Hoo	February 2014	Medway Council's combined flood records
Surface water	Wylie Road, Hoo	December 2013	Medway Council's combined flood records
Surface water	Knights Road, Hoo	August 2013	Medway Council's combined flood records
Surface water	Gardens and allotments adjacent to Hoo Stream	Regular flooding in periods of heavy rainfall	Anecdotal evidence from Medway Council

Sewer	Foul sewer flooding at Main Road, Hoo	May 2018	Southern Water's records
Sewer	Foul sewer flooding at Wylie Road, Hoo	September 2017	Medway Council's combined flood records & Southern Water's records
Sewer	Foul sewer flooding at Wylie Road, Hoo	August 2017	Medway Council's combined flood records & Southern Water's records
Sewer	Foul sewer flooding at Killick Road, Hoo	July 2017	Medway Council's combined flood records & Southern Water's records
Sewer	Stoke Road, Hoo	July 2016	Medway Council's combined flood records & Southern Water's records
Sewer	Foul sewer flooding at Grandsire Gardens, Hoo	June 2016	Medway Council's combined flood records & Southern Water's records
Sewer	Foul sewer flooding at Bells Lane, Hoo	June 2016	Medway Council's combined flood records & Southern Water's records
Sewer	Foul sewer flooding at Main Road, Hoo	June 2016	Medway Council's combined flood records & Southern Water's records
Sewer	Foul sewer flooding at Main Road, Hoo	March 2016	Medway Council's combined flood records & Southern Water's records
Sewer	Surface water sewer flooding at Pottery Road, Hoo	September 2015	Southern Water's records
Sewer	Foul sewer flooding at Grandsire Gardens, Hoo	August 2015	Medway Council's combined flood records & Southern Water's records
Sewer	Foul sewer flooding at Main Road in Chattenden and surface water sewer flooding at Knights Road, Hoo	February 2014	Medway Council's combined flood records & Southern Water's records
Sewer	Foul sewer flooding at Newitt Road, Hoo	October 2013	Medway Council's combined flood records & Southern Water's records

Sewer	Trubridge Road, Hoo	October 2013	Medway Council's combined flood records
Sewer	Surface water sewer flooding at Wylie Road	December 2012	Southern Water's records
	Fields near Main Road, Hoo	Winter 2013-14	Medway Council's combined flood records
	Flooding recorded around St. Werburgh Crescent	August 2010	Medway Council's combined flood records
	Flooding recorded around Peal Close, Hoo	June 2007	Medway Council's combined flood records
	Area around Church Street, Hoo	February 2007	Medway Council's combined flood records
	Highway flooding of Main Road, Hoo	May 2005	Medway Council's combined flood records

Table 2-3: Historic flooding in the Rainham study area

Source of flooding	Location / consequence	Date	Data source
Surface water	Cherry Tree Road, Rainham		Discussions with Medway Council and Southern Water
Surface water	Hoath Way, Rainham		Medway Council's combined flood records
Surface water	South Bush Lane, Rainham. Run-off from surrounding farmland regularly inundate road	Winter months	Medway Council's combined flood records
Sewer	Foul sewer flooding at Maidstone Road and surface water sewer flooding at Thompson Close on separate occasions	May 2018	Southern Water's records
Sewer	Flooding from private sewer at Lambourne Place	April 2018	Southern Water's records
Sewer	Combined sewer flooding at Chalky Bank Road, Rainham	July 2017	Medway Council's combined flood records & Southern Water's records
Sewer	Combined sewer flooding at Beechings Way, Rainham	May 2016	Medway Council's combined flood records

			& Southern Water's records
Sewer	Foul sewer flooding at separate locations on Maidstone Road, Rainham and Thompson Close, Rainham on the same day	August 2014	Medway Council's combined flood records & Southern Water's records
Sewer	Caused by Rising Main at Beechings Way, Rainham	July 2014	Medway Council's combined flood records & Southern Water's records
	Flooding recorded around Lower Rainham Road, Rainham	August 2007	Medway Council's combined flood records
	Flooding recorded around Beechings Way, Rainham	July 2007	Medway Council's combined flood records
	Flooding recorded around Maidstone Road, Rainham	September 2005	Medway Council's combined flood records

2.5 Level of assessment

Hoo St. Werburgh and Rainham have been identified as areas of higher risk of surface water flooding in the previous Medway Council SWMP (2016), as well as the Medway Council 2011 PFRA and subsequent Environment Agency 2018 updated PFRA for England. Therefore, in line with the DEFRA guidance (2010), a 'detailed assessment' has been undertaken as part of the Hoo St. Werburgh and Rainham SWMP.

2.6 Conclusions

The outputs of the preparation stage included a SWMP partnership being formed, data being shared under a protocol agreed by all partners, and a better overview of historic flooding from all sources across the study area. The needs for and scope of the SWMP were confirmed, enabling the project to move on to the risk assessment stage.

3 Risk Assessment

A detailed assessment has been undertaken as part of the Hoo St. Werburgh and Rainham SWMP. This level of assessment aims to provide a detailed understanding of the causes and consequences of surface water flooding, and to test the benefits and costs of mitigation measures. This will be achieved through the modelling of surface and sub-surface drainage systems, with the results of detailed analyses then used to prepare an action plan.

The risk assessment was carried out using the Source > Pathway > Receptor approach:

Sources refers to the sources of flooding – in this case flooding from pluvial (intense rainfall), sewers and watercourses has been quantified using a hydraulic model

Pathways of flooding are how the flood waters get from the source to the receptor. In this study, overland pathways from all modelled sources have been considered using the 2D model described in Section 3.1.

Receptors refer to anything which can be impacted by flooding, including people, households, community facilities, infrastructure and land. This is discussed further in Section 3.1.

Having applied the Source-Pathway-Receptor model it is possible to mitigate the flood risk by addressing the source (often very difficult), block or alter the pathway or remove the receptor e.g. steer development away.

3.1 Modelling approach

An integrated modelling approach was employed for the Hoo St. Werburgh and Rainham SWMP, including all drainage systems excluding private sewerage (for which no information was available). This detailed approach is justified by the requirement to use the model to test a variety of flood risk management options to reduce flood risk in the two study areas. The detailed approach also sought to address the key limitations of the Risk of Flooding from Surface Water mapping discussed in Section 1.8, aiming to better represent the local drainage, the influence of culverts along the Hoo Stream and locally specific runoff from the rural and urban areas. Additionally, scenarios were modelled including potential future development sites to gain an understanding of where new development could contribute to reducing surface water flooding.

Separate surface water flood risk models were built and run using the hydraulic modelling software InfoWorks ICM for the Rainham and Hoo St. Werburgh study areas. Full technical details are provided in the Model Operation Manual in Appendix B. The following points briefly describe the modelling approach:

InfoWorks ICM was selected for its ability to model river networks, sewer networks and surface water flow routes in one software package

The Hoo Stream watercourse has been included in the Hoo St. Werburgh model using the survey data commissioned as part of this study. This includes structures (bridges and culverts) that were deemed hydraulically significant. The watercourse in the northeast of the Hoo model was represented using a uniform channel dimension assumed from LIDAR data in the absence of survey data. All watercourses in the Rainham model and the remaining watercourses in the Hoo St. Werburgh model are represented in the 2D zone, defined by the topography and mapping data

The foul / combined and surface water sewer network systems were included using the models provided by Southern Water

The surface water network in Hoo St. Werburgh has been connected to the river reaches, a storage pond and the River Medway where applicable to represent discharges from the outfalls of the surface water sewer into the water bodies. In the Rainham model the surface water network is connected to the River Medway

The model of the catchment surface includes representation of features that direct, divert and store surface water, including buildings, roads and small ditches

Both models had rainfall inputs estimated for the 50%, 3.33%, 1.33% and 1% annual exceedance probabilities (AEP) using the Revitalised Flood Hydrograph (ReFH) Rain Event Generator in InfoWorks ICM with parameters derived using the FEH CD-ROM

Fluvial inflows for the Hoo Stream and the stream in the northeast of the Hoo St. Werburgh study area were derived for the 50%, 3.3%, 1.3%, 1%, and 1% AEP fluvial events using the ReFH approach with the FEH CD-ROM. The inflows were applied to the 1D watercourses

To account for the potential impacts of climate change on flood risk in the study areas, the rainfall inputs for the 1% AEP event were uplifted by 40%, in line with Environment Agency's climate change allowances for the upper end category[3]. Additionally, fluvial inputs in the Hoo St. Werburgh model were uplifted by 70% in line with the upper end allowances for the Thames River Basin District

A 315-minute duration winter storm was used as the critical storm event for the Hoo St. Werburgh model, with a 255 minute duration summer storm used for the Rainham model. These were identified as the critical durations by the hydrological analysis. Model testing of different durations found there to be negligible differences in flood extents from these critical durations

Committed development sites were included in the model scenario representing the present day with outflows modelled at agreed rates provided by Medway Council.

Potential future development sites were included in eight scenarios covering two-year time horizons between 2019 and 2035 (i.e. 2019-2021, 2021-2023). Flows from each site were limited to a percentage of the QMED greenfield runoff rate for each study area reflecting the percentage of the proposed completion of the developments at each time horizons. As the development runoff rate is increased, the percentage of rainfall applied to the 2D domain within the development site is decreased proportionally to ensure all runoff is continuously accounted for, and to avoid double counting of runoff. A final Post-2035 scenario included all potential development sites, including those without details of proposed completion dates. Further details on the representation of committed and potential development sites, including their location and connection to the drainage network, are provided within Appendix B and the model extents can be seen in Figure 3-1 and Figure 3-2.

[3] Environment Agency Climate Change Allowances, February 2019. Available: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

Figure 3-1: Hoo St. Werburgh model schematic

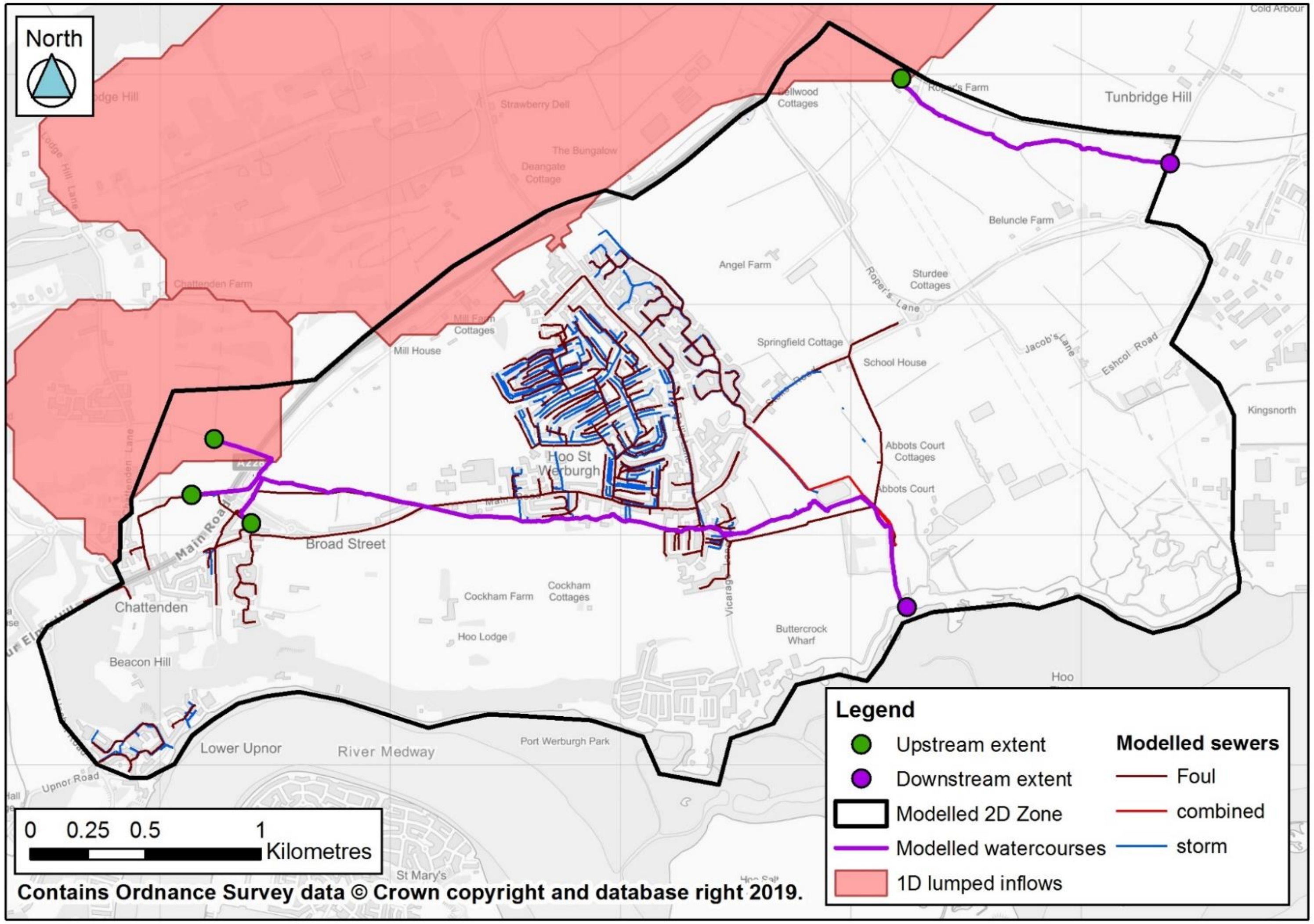
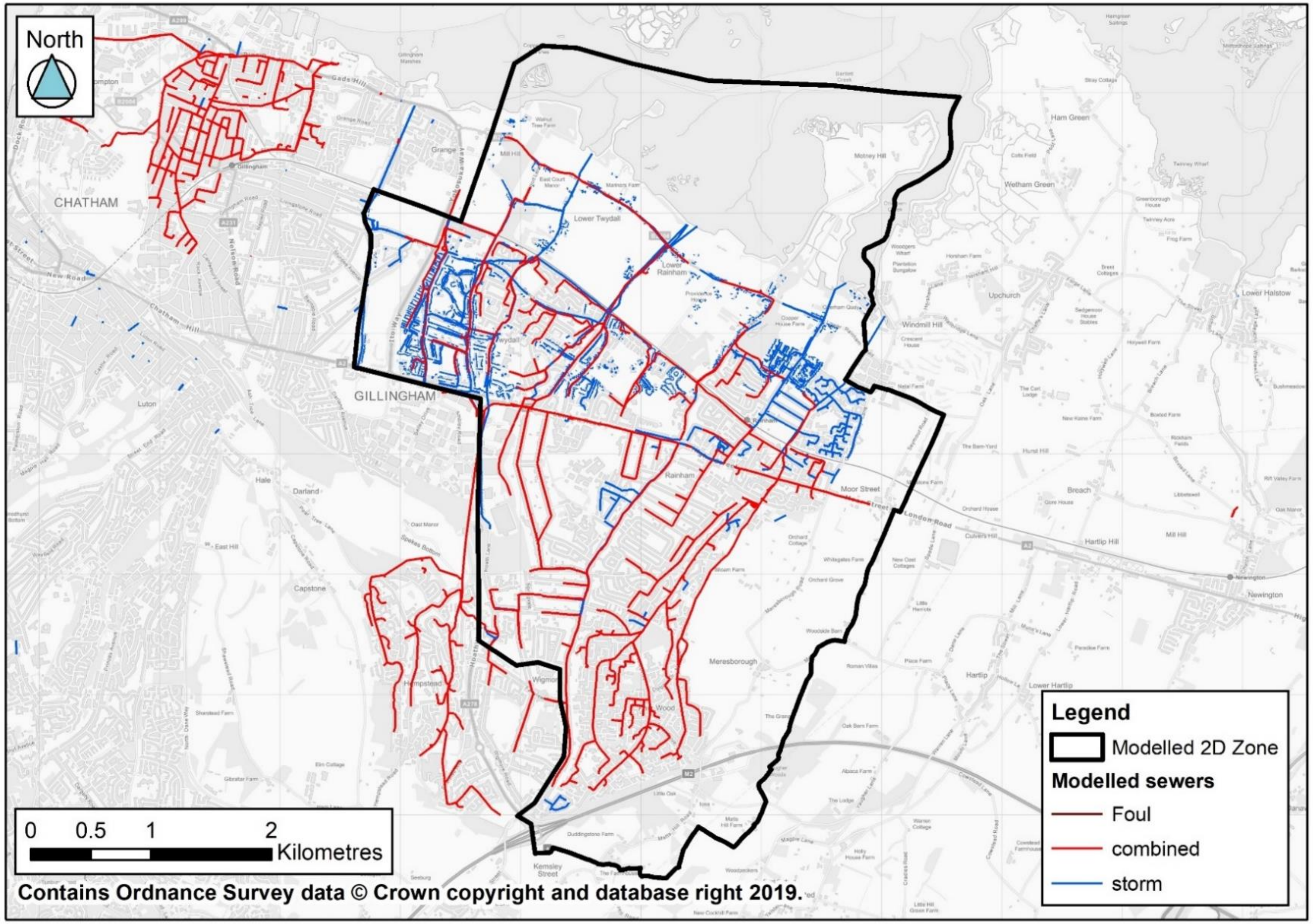


Figure 3-2: Rainham model schematic



3.2 Validating the model outputs

There is limited data against which to validate the integrated models, with no gauge data on Hoo Stream. Comparisons with the RoFSW has been used to demonstrate that flow paths identified in the modelling occur in the same areas in the existing generalised scale modelling. However, detailed comparisons with the RoFSW datasets has not been conducted due to potential inaccuracies in the EA's RoFSW mapping, as detailed in Section 1.8, and differences in the filtering approaches applied to the results.

An assessment of the model representation was made during the internal audit process and the draft results have been reviewed by representatives from Medway Council. Many of the areas recorded to have experience flooding detailed in Section 2.4 are modelled to experience potential flooding, such as the Vicarage Lane and Abbots Court Road are of Hoo and the Cherry Tree Road area of Rainham.

3.3 Options

3.3.1 Objectives

The objective of the options assessment process was to identify, shortlist and assess measures for mitigating surface water flooding within the two study areas and agree the preferred options. The preferred options were then carried forward to the Action Plan.

3.3.2 Options meeting

At the options meeting with Medway Council the flood risk in Hoo St. Werburgh and Rainham was reviewed to identify where the implementation of options would be required and what type of solutions should be considered.

Each option was tested for the 3.33% AEP and 1% AEP rainfall events. It was agreed that options testing would be carried out on the Development Scenario for the Post-2035 time horizon. Options 1, 2 and 3 for Hoo St. Werburgh were also tested on the scenario representing the present day.

The options tested for Hoo St. Werburgh and Rainham are summarised in Sections 3.4 and 3.5 respectively, with the modelling approach for each option detailed in the Model Operation Manual (Appendix B). Mapping detailing the locations of the options for Hoo St. Werburgh and Rainham is shown in Figure 3-3 and Figure 3-4 respectively.

3.4 Hoo St. Werburgh options

3.4.1 Option 1 – Increase capacity of the Hoo Stream

There may be scope to increase the capacity of the Hoo Stream between the culvert downstream of Main Road and the allotments west of Everest Drive to reduce out of bank flooding and convey flows through the town quicker. The south bank of the watercourse along this stretch is largely undeveloped, potentially enabling the channel to be widened to increase the capacity.

3.4.2 Option 2 – Increase capacity of existing Southern Water storage area

The Southern Water storage area to the east of Hoo is currently only filled by a pipe inflow from the surface water sewer network draining part of eastern Hoo and by direct rainfall. If the storage capacity of the area was increased there may be scope to store fluvial flood flows from Hoo Stream until the flood peak has passed to reduce the extent of flooding downstream.

3.4.3 Option 3 – Create a new storage area at Hoo Sports Field

Under the present day and Post-2035 future development scenarios there is already flooding predicted at Hoo Sports Field, west of the allotments by Everest Drive. There is the potential to formalise the field as an online Flood Storage Area (FSA) with embankments used to confine flood waters to the open spaces and a flow control structure on Hoo Stream at the downstream end of the fields to divert flows into the FSA. The storage area would be drained by gravity. A flood wall may be required along the northern bank of Hoo Stream to prevent flooding of properties and gardens along Main Road. If land at Hoo Sports Field below 12.6m AOD was allowed to flood the storage area would have a potential capacity of around 11,000m^3, covering roughly 17,000m^2 with embankments of up to 1.6m required. By storing flood waters at Hoo Sports Field and reducing the peak flood flows downstream there is the potential to reduce flooding at the hotspots in the centre of Hoo around Vicarage Lane, Church Street and Abbots Court Road.

3.4.4 Options 4a, 4b, 4c – Increase greenfield runoff rates to the 3.33% AEP rate for potential future development groups

In the Post-2035 development scenario flows from all the potential future development sites were limited to the greenfield runoff rates for QMED (approximately a 50% AEP event). Option 4 investigated the potential to increase the greenfield runoff rates from the sites to determine if more leniency could be given to potential developments in certain locations. The potential future development sites were split into three groups based on where they drained to; Upstream of Hoo (Option 4a), Downstream of Hoo (Option 4b) and the Eastern watercourse (Option 4c). The flows were increased to the 3.33% greenfield runoff rate for all sites within each group in separate scenarios to assess the impact of increasing the rate in the different parts of Hoo. The greenfield runoff rates for Hoo are detailed in Table 3-1.

3.4.5 Option 5a, 5b, 5c – Increase greenfield runoff rates to the 1% AEP rate for potential future development groups

Option 5 was carried out for the same reason as Option 4, though with the 1% AEP greenfield runoff rate used to set the flows from the potential future development sites to assess the impact of further increasing the flows. The future sites were again grouped into Upstream of Hoo (Option 5a), Downstream of Hoo (5b), and the Eastern Watercourse (Option 5c). The greenfield runoff rates for Hoo are detailed in Table 3-1.

3.5 Rainham options

3.5.1 Option 1 – Change connection location for development site 0847 (Siloam Farm)

During the SWMP process, it was identified that Cherry Tree Road, south of the High Street in north east Rainham, had experienced surface water flooding issues. A number of development sites may arise in the area upstream of Cherry Tree Road (the 'Southeast' group explained in 3.5.3). Therefore, an option was developed to test the impact which sites with the potential to discharge into the sewer network on neighbouring Mierscourt Road could have on flood risk to Cherry Tree Road.

This involved changing the point of discharge for development site 0847 from Moor Street to Mierscourt Road.

3.5.2 Option 2 – All potential future developments connected to soakaway

The development horizon scenarios assume that future development sites will discharge into the nearest surface water or combined sewer network.

However, many of the committed development sites in Rainham are proposed to discharge to soakaway, as the underlying chalk geology in the upper study area is conducive to infiltration.

In Option 2 all surface runoff generated from all new development sites is discharged to soakaway, rather than directly into the sewer network. This allows an assessment into how surface water flood risk within the Rainham study might change, should the developments utilise infiltration techniques to manage surface water runoff.

3.5.3 Options 3a, 3b, 3c – Increase greenfield runoff rates to the 3.33% AEP rate for potential future development groups

Option 3 was implemented using the same method as Option 4 in the Hoo St. Werburgh study area, as detailed in Section 3.4.4. The proposed future development sites were divided into three development groups based on where they drained to. The three groups were named 'Northwest' (Option 3a), 'Northeast' (Option 3b) and 'Southeast' (Option 3c), with the committed development sites in the study areas not included in these grouping. The 3.33% greenfield runoff rate for Rainham was used to calculate the baseflow from the subcatchments representing each site in the three groups, instead of the QMED rate. The greenfield runoff rates for Rainham are detailed in Table 3-1.

3.5.4 Option 4a, 4b, 4c – Increase greenfield runoff rates to the 1% AEP rate for potential future development groups

Option 4 within the Rainham model used the same approach as Option 3, with the 1% AEP greenfield runoff rate used to assess the impact of further increasing flows from the potential future development sites. The future sites were again grouped into Northwest' (Option 3a), 'Northeast' (Option 3b) and 'Southeast' (Option 3c). The greenfield runoff rates for Rainham are detailed in Table 3-1.

Table 3-1: Greenfield runoff rates for the study areas

Study area	QMED	3.33% AEP	1% AEP
Hoo St. Werburgh	2.66l/s/ha	6.98l/s/ha	9.67l/s/ha
Rainham	0.78l/s/ha	2.05l/s/ha	2.84l/s/ha

Figure 3-3: Location of the options tested in Hoo St. Werburgh

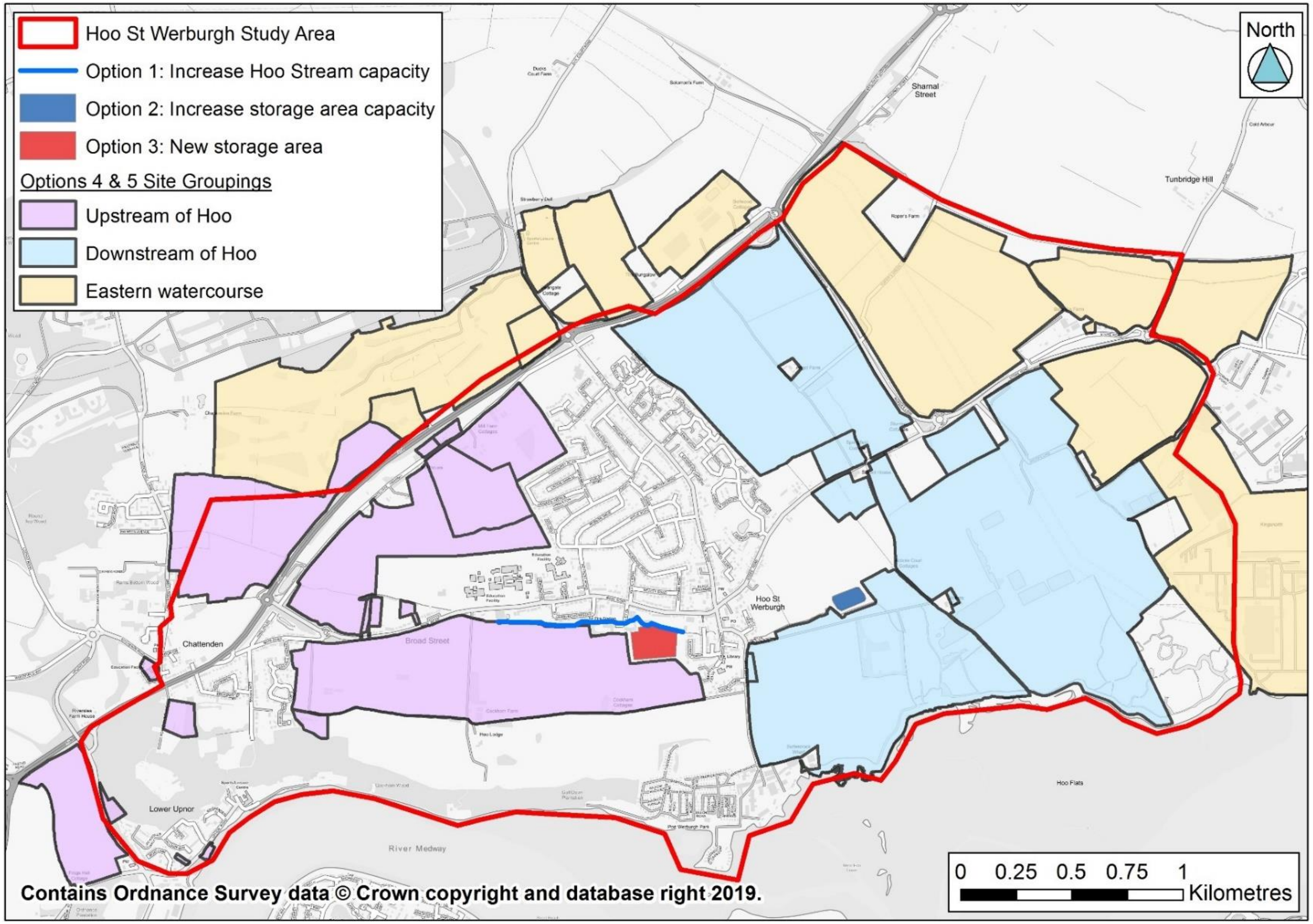
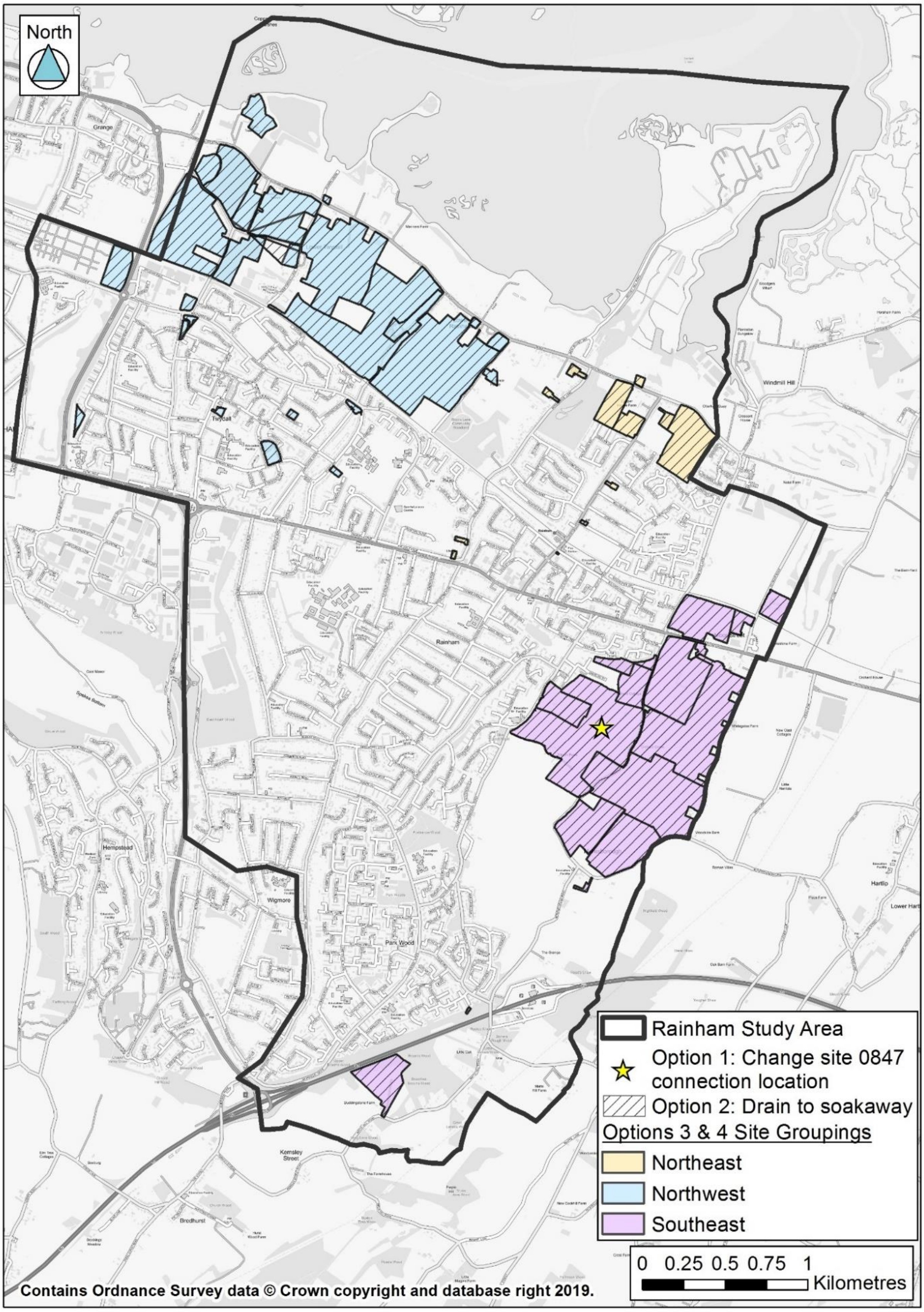


Figure 3-4: Location of options tested in Rainham



4 Results

The results of the modelling have been used alongside receptor information (NRD 2014 data and building footprints from OS MasterMap) to provide estimates of the potential economic damages and counts of impacted properties associated with each flood event in the Hoo and Rainham study areas. These estimates have been calculated using JBA's in-house flood risk metrics tool FRISM, with damages estimated using the data in the 2013 update to the Multi-Coloured Manual for economic appraisal.

It should be noted that the property counts and estimated damages are provided to give an understanding of the differing flood risk between modelled events and scenarios. Properties intersecting small surface depressions in the 2D mesh may be counted as flooding although road gullies and other local surface drainage features that were not modelled may reduce the risk of flooding in these areas. As a result, the estimated property counts and damages may be higher than those experienced in an actual flood event, particularly during the 50% AEP event. If more accurate counts and estimates are required it is recommended that further modelling of high risk areas is carried out to better represent local drainage features (see Section 5).

Further details of the property count and damage cost appraisal is included in Appendix C.

4.1 Present Day scenario results

Flood risk mapping has been produced for the Present Day scenario which includes committed development sites within the study areas. The mapping shows the modelled flood depths for the 50%, 3.33%, 1.33% and 1% AEP storm events, as well as the 1% AEP event plus 40% rainfall (and plus 70% fluvial inflows in the Hoo model) which accounts for climate change. Property counts and estimated damages are also detailed for each event.

Locations and key flow paths mentioned in the reporting of the results in Hoo St. Werburgh and Rainham are shown in Figure 4-1 and Figure 4-2 respectively.

4.1.1 Hoo St. Werburgh

Mapping showing modelled flood depths in Hoo St. Werburgh during the Present Day scenario is provided in Appendix D.1, with property counts and estimated potential damage costs for each event detailed in Table 4-1.

Figure 4-1 shows the primary flow pathways within the catchment along with the location of roads and places noted in the following section.

During the 50% AEP event there are 36 properties in Hoo predicted to experience flood depths of at least 0.15m, though it is worth noting these are largely the result of isolated surface water ponding in depressions in the DTM. Many of these areas of flooding would not be represented in the RoFSW mapping as they would be filtered out due to having a low hazard rating.

During the 3.33% AEP event there is a large increase in the number of properties predicted to be at risk of flooding, with 49 additional properties compared to the 50% AEP event, as surface water flow paths become more established and connect to the Hoo Stream, resulting in areas of out of bank flows. The modelled flood extents in Hoo increase at the larger return periods, with a total of 116 properties predicted to flood to a depth of at least 0.15m resulting in estimated damage costs of over £1,700,000 during the 1% AEP event.

When the impact of climate change is considered in the 1% AEP + climate change event there is an increase in the modelled flood depths and extents in the centre of Hoo. As a result, there is an increase of 49 properties that are predicted to flood to a depth of 0.15m compared to the 1% AEP event, with the estimated damages predicted to increase by over £650,000.

The area around Church Street, Vicarage Lane and Abbots Court Road is predicted to be one of the highest risk locations within the study area, which is supported by the flood history detailed in Table 2-2, with depths of up to 0.5m predicted during the 1% AEP event. Flows within the Hoo Stream are modelled to be contained within banks during the 50% AEP event, but from the 3.33% AEP event the culvert under Vicarage Lane restricts flows and flooding occurs. Additionally, from the 1.33% AEP event the culvert under Church Street also begins to restrict flows, contributing to further out of bank flows. Overland flows running south down Bells Lane (flow path 1 in Figure 4-1) and north down Church Street (flow path 2 in Figure 4-1) are also predicted to contribute to flooding in this area. Flooding of properties from the Hoo Stream is also predicted to occur where the culvert under Brookside road restricts flows in all but the 50% AEP event.

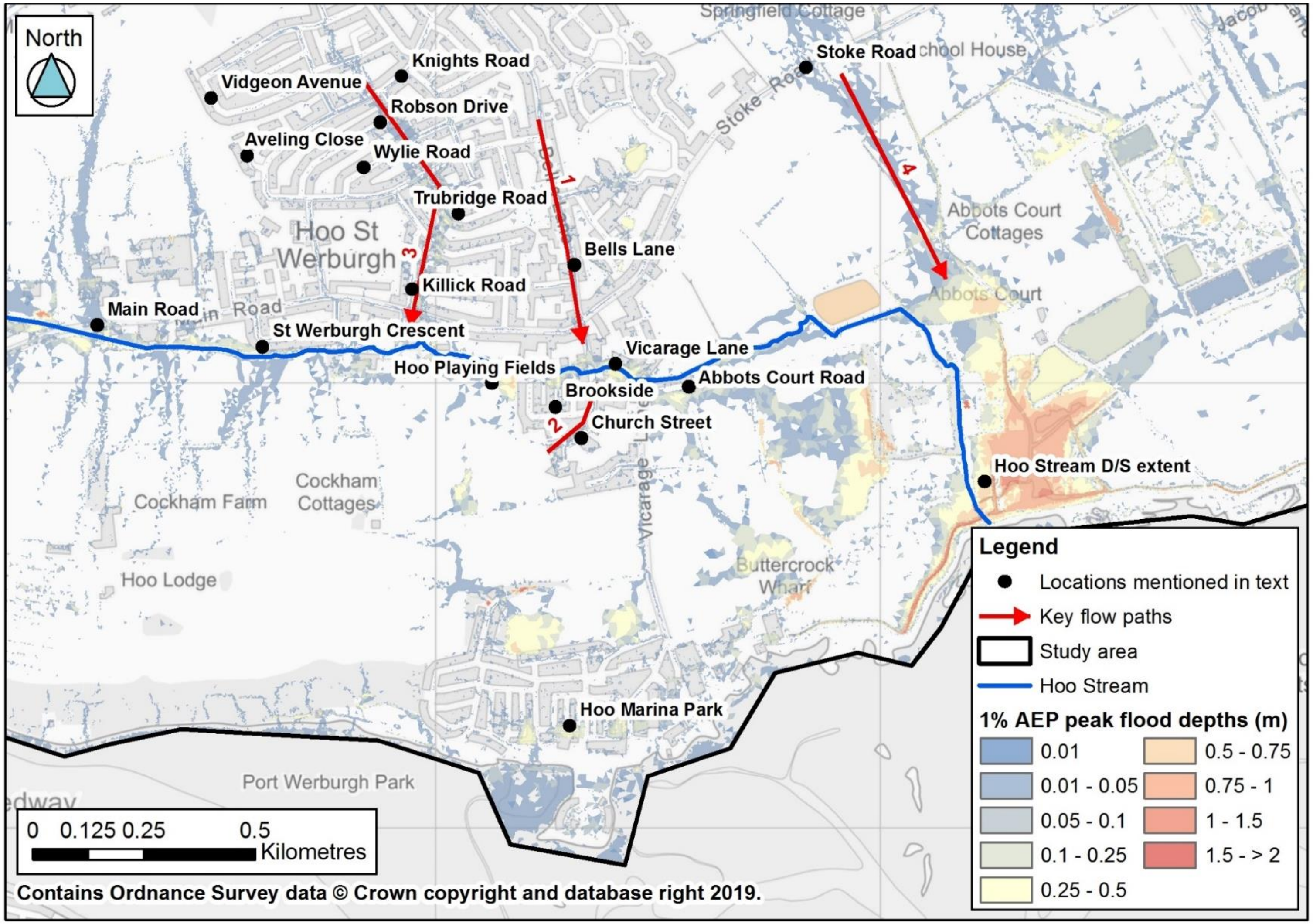
A large number of the properties predicted to be at risk of flooding are in the centre of Hoo, where an overland flow path is predicted to form around Robson Drive and Knights Road (flow path 3 in Figure 4-1), flowing south through Trubridge Road, Wylie Road and Killick Road. This is again supported by the flood history detailed in Table 2-2. This flow path is present in the 50% AEP event though flood depths are predicted to be relatively low, with larger areas of flood depths above 0.1m from the 3.33% AEP and above.

There also a number of residential properties predicted to be at risk of flooding at the Hoo Marina Park, where areas of surface water ponding is likely to impact static homes in the area. These are included in the damage calculations.

Table 4-1: Summary of flood damages for Present Day scenario events in Hoo St. Werburgh

Return Period (AEP)	Number of properties flooded to a depth of 0.15m	Total damages
50%	36	£650,000
3.33%	85	£1,157,000
1.33%	110	£1,590,000
1%	116	£1,740,000
1% + Climate change	164	£2,397,000

Figure 4-1: Locations and key flow paths in Hoo St. Werburgh



4.1.2 Rainham

Mapping showing modelled flood depths in Rainham during the Present Day scenario is provided in Appendix D.2, with property counts and estimated damages for each event detailed in Table 4-2.

Figure 4-2 shows the primary flow pathways within the catchment along with the location of roads and places noted in the following section.

A number of significant surface water flow paths form and pass through Rainham during the 50% AEP and larger rainfall events. The flow paths form on high ground north of the M2 motorway in the upper study area from where they are routed along several dry channels in the landscape, through the densely populated central and northern areas of Rainham.

In total, 74 properties are at risk of flooding during the 50% AEP event, resulting in estimated damage costs of £1,802,000. These properties are situated within the surface water flow paths across Rainham and are therefore dispersed, with a slightly larger proportion located towards the north of the study area.

The number of properties at risk of flooding in Rainham significantly rises as AEPs increase. During the 3.33% AEP event, 248 properties are identified as at risk, with an estimated damage cost of £6,701,000. The additional properties are located in north Rainham, close to the railway embankment, at Berengrave Lane, Lower Twydall Lane, and also between Cherry Tree Road and Winchester Way.

A 1% AEP event sees 524 properties affected, with an increase in properties at risk within the flow paths identified in the 3.3% AEP event, in the south of the study area at Queendown Avenue and Lonsdale Drive, as well as in the north west at Lower Rainham Road. In total, there is an estimated £10,470,000 of damages accrued in a 1% AEP event. As expected, the largest number of properties at risk (808) and the greatest total estimate damage costs (£15,953,000) is seen in the 1% AEP + 40% climate change event.

The greatest surface water flood risk in Rainham occurs at four locations, where the flow paths encounter significant topographic barriers: A2 London Road/High Street/Moor Street; the Chatham Main Line railway embankment; B2004 Lower Rainham Road and against the River Medway tidal defences.

At A2 High Street/Moor Street, flood risk is concentrated at the junction between the road and Maidstone Road, Mierscourt Road, Lonsdale Drive, as well as on Moor Street, east of the junction with Meresborough Road. This flooding forms during a 50% AEP, and continues to increase in extent with greater magnitude rainfall events. Flood depths remain moderately shallow, reaching a peak of 0.35m at the junction between A2 High Street and Mierscourt Road during a 1% AEP event.

To the south of the Chatham Main Line railway embankment, ponding is predicted to form at the rear of Pembury Way and Ely Close; at Rainham railway station on Tufton Road; and between A2 High Street and Winchester Way. This occurs during a 3.33% AEP event and greater rainfall events, with a maximum flood depth of 1.7m reached at Winchester Way and Scott Avenue during the 1% AEP event.

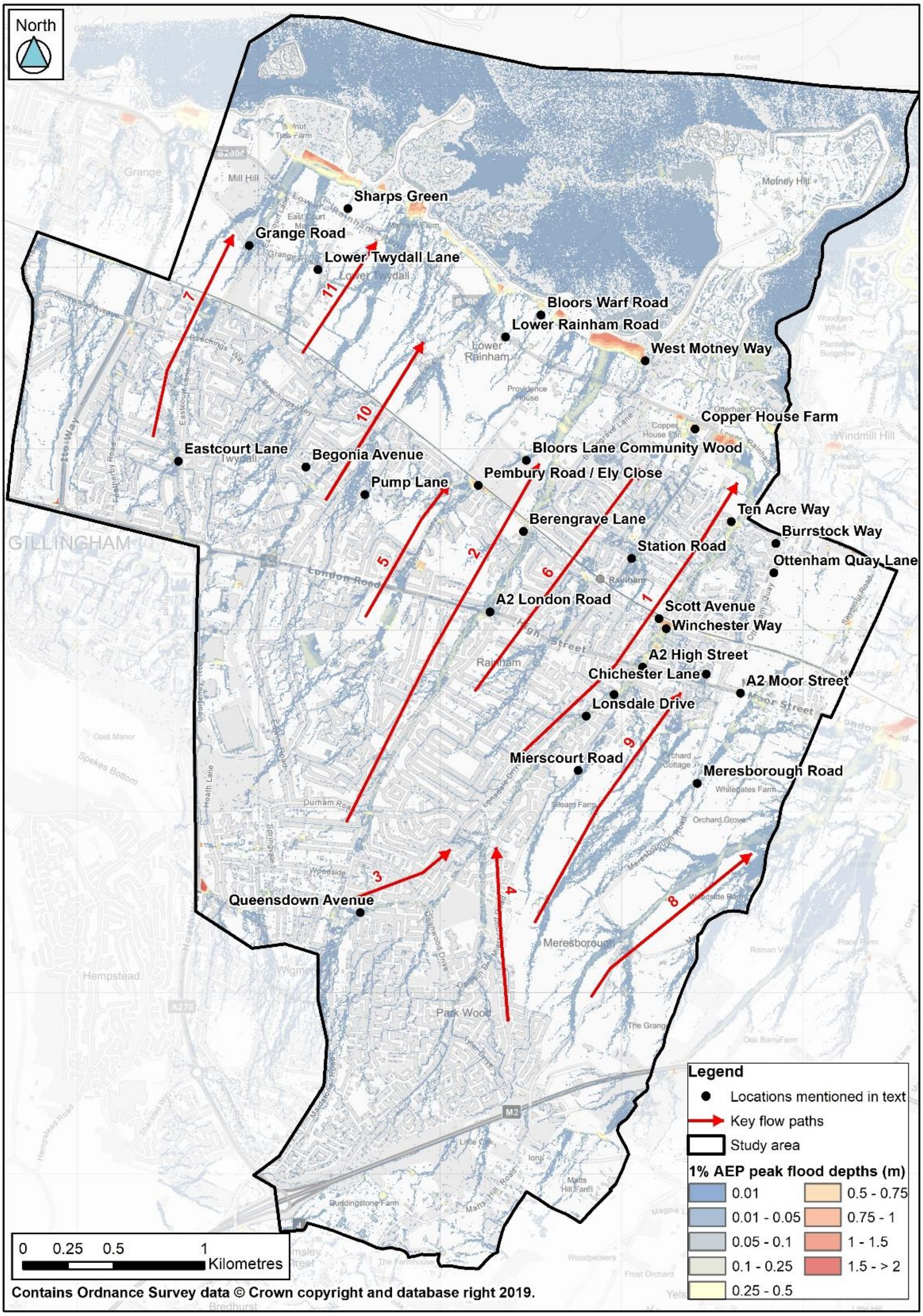
Areas of surface water ponding are also predicted to form against B2004 Lower Rainham Road, affecting the junctions with Eastcourt Lane and Pump Lane, and land at the junction with A2004 Station Road. Flooding at these locations forms during the 3.33% AEP event and reaches a maximum depth of 1.38m near Copper House Farm during the 1% AEP event.

In addition, flooding occurs on flatter marshland in the lower catchment, against the River Medway tidal defences. Flooding forms here in the 50% AEP event and is particularly extensive between West Motney Way and Bloors Warf Road, where peak flood depths of 1.5m are reached during a 1% AEP event.

Table 4-2: Summary of flood damages for Present Day scenario events in Rainham

Return Period (AEP)	Number of properties flooded to a depth of 0.15m	Total damages
50%	74	£1,802,000
3.33%	248	£6,701,000
1.33%	448	£9,523,000
1%	524	£10,470,000
1% +40% Climate change	808	£15,953,000

Figure 4-2: Locations and key flow paths in Rainham



4.2 Development horizon results

4.2.1 Hoo St. Werburgh

Mapping comparing depths in the Post-2035 development scenario and the Present Day scenario is provided in Appendix E.1, with property counts and estimated damages for each event detailed in Table 4-3. Additionally, depths for key locations in the study area for each development horizon are tabulated in Appendix F.1, which also includes mapping showing where these key points are located.

By the Post-2035 development scenario, assuming that runoff from all development sites is restricted to QMED (approximately a 50% AEP event), the mapping shows that the inclusion of the development sites results in decreases in flood depth across the majority of the study area, with larger decreases at the larger return periods as runoff rates are restricted to QMED. There are areas with residential properties in Hoo where depths are predicted to decrease by over 0.10m in the 3.33% AEP event and above, largely due to the reduction in out of bank flows from Hoo Stream, with negligible changes seen along the overland flow path through the centre of Hoo. At all return periods there is a small decrease in the number of properties predicted to be at risk of flooding, but the reduction in flood depths results in relatively large decreases in the estimated damages, with 9 fewer properties but £300,000 less in damages predicted in the 1% AEP event compared to the present-day scenario.

At all return periods there is a small increase in depths at Stoke Road because the large development north of the road (Hoo1084) is set to discharge entirely to the sewer network at one location. The connection was modelled in this way due to the high-level nature of the SWMP. On-site measures would need to be developed as part of a drainage strategy to ensure the development would not increase flood risk in the surrounding area.

The tabulated results for the five key locations in Hoo show that generally there is a gradual decrease in flood depths over time, with few large decreases between development horizons. Notably, the largest decrease between the 2033-35 development horizon scenario and the Post-2035 scenario is only 0.2m, with there being no change at all at many of the sites.

The changes at Main Road are predicted to be relatively small, with only a 0.05m decrease by the Post-2035 scenario in the 1% AEP event. The changes are more notable at Brookside and Abbots Court Road, with decreases of 0.13m and 0.16m respectively by the Post-2035 scenario.

Table 4-3: Summary of flood damages for the Post-2035 Development Horizon scenario in Hoo St. Werburgh

Return Period (AEP)	Number of properties flooded to a depth of 0.15m	Total damages
50%	33	£539,000
3.33%	80	£1,058,000
1.33%	97	£1,300,000
1%	105	£1,432,000
1% + Climate change	143	£2,031,000
* Note, the number of properties predicted to flood and the estimated damage costs do not include properties which were not contained within the NRD dataset or MasterMap layer. Consequently, properties on sites which are under development or have not been developed are not included.		

4.2.2 Rainham

Mapping comparing depths in the Post-2035 development scenario and the Present Day scenario is provided in Appendix E.2, with property counts and estimated damages for each event detailed in Table 4-4. Additionally, depths for key locations in the study area for each development horizon are tabulated in Appendix F.2, which also includes mapping showing where these key points are located.

In Rainham, the 2019-2021 development horizon sees a decrease in the 1% AEP flood extent in the north east corner of the study area, on Otterham Quay Lane and Burrstock Way, when compared against the Present Day scenario. There is also a decrease in flood extent between Station Road and Lower Rainham Road, as well as at Bloors Lane Community Woodland. Elsewhere flood extents remain the same as the Present Day scenario, highlighting the impact of the development of sites in eastern Rainham.

No change in flood extent is seen across Rainham during the 1% AEP event for any of the scenarios between 2021 and 2033.

The greatest change is seen within the Post-2035 scenario. When compared against the 1% AEP event in the Present Day scenario, a decrease in flood depth of up to 0.76m is expected along the larger surface water flow paths in the east and north west of the study area. This leads to a reduction of 29 properties at risk of flooding in a 1% AEP event, particularly in east and north east Rainham, which results in a reduction in damages of £523,795. The most significant decrease in flood depths is seen at the tidal defences in the north of the study area.

When compared against the 2019 – 2021 scenario, a significant decrease in flood extent is seen downstream of the development sites. This includes the south of the study area, at Brooms Wood; in the east around Meresborough Road, Moor Street, Otterham Quay Lane and Mierscourt Road; as well as in north Rainham behind the tidal defences and south of Lower Rainham Road.

Overall, development of potential sites in Rainham, when limited to the QMED greenfield runoff rate of 0.78l/s/ha, leads to a reduction in the Present Day flood extents and depths.

Table 4-4: Summary of flood damages for the Post-2035 Development Horizon scenario in Rainham

Return Period (AEP)	Number of properties flooded to a depth of 0.15m	Total damages
50%	75	£1,952,000
3.33%	232	£6,579,000
1.33%	430	£9,044,000
1%	495	£9,946,000
1% +40% Climate change	780	£15,636,000
* Note, the number of properties predicted to flood and the estimated damage costs do not include properties which were not contained within the NRD dataset or MasterMap layer. Consequently, properties on sites which are under development or have not been developed are not included.		

4.3 Options testing results

4.3.1 Hoo St. Werburgh

The changes in modelled flood damages and property counts for Options 1, 2 and 3 in Hoo St. Werburgh are detailed in Table 4-5. Additionally, the estimated costs of implementing the structural measures associated with Options 1, 2 and 3 is detailed in Table 4-6.

4.3.2 Option 1 – Increase capacity of Hoo Stream

When the capacity of the Hoo Stream is increased in the Present Day scenario there is a relatively large decrease in flood depths adjacent to Hoo Stream at Hoo Playing Fields and behind St. Werburgh Crescent, with depths typically decreasing by up to 0.05m in the 3.33% AEP and 1% AEP events. There are very small and isolated areas of increased flood depths below 0.05m around Vicarage Lane predicted in both events.

With Option 1 applied to the Present Day scenario there are limited benefits for flood risk in Hoo St. Werburgh during the 3.33% AEP event. However, due to the reduced flood depths behind St. Werburgh Crescent there is a reduction in the estimated damages of £57,100, despite an additional two properties predicted to be at risk.

When Option 1 is applied to the Post-2035 development scenario there is again a reduction in flood depths, typically up to 0.05m, in the same areas as in the Present Day scenario for both return periods tested. However, there is a slightly larger area adjacent to the Hoo Stream at Vicarage Lane where depths are predicted to increase by up to 0.05m in the 3.33% AEP event.

Due to the flood extents and depths already being reduced in the Post-2035 scenario compared to the Present Day scenario the reductions in flood depth behind St. Werburgh Crescent provide little benefit to properties in the area. As a result, there are no changes in the number of properties at risk and an £800 increase in the estimated damages for the 3.33% and 1% AEP events.

The estimated total cost of Option 1 is £928,000 (including an optimism bias).

4.3.3 Option 2 – Increase capacity of existing storage area

When Option 2 is applied to the Present Day scenario there is a large area at the downstream extent of the Hoo Stream where flood depths are predicted to decrease, typically by up to 0.05m in both the 3.33% and 1% AEP events.

However, as there are very few residential properties in the downstream area of the Hoo Stream the reduction in flood depths have little benefit to the estimated damages and number of properties predicted to flood. In both return periods tested there is a very slight increase in the estimated damages due to isolated areas of slight increases in flood depth (<0.02m) around Vicarage Lane.

When Option 2 is applied to the Post-2035 scenario there is again a reduction in flood depths around the downstream extent of Hoo Stream, typically of up to 0.05m in both the 3.33% and 1% AEP events.

In both events tested for the Post-2035 scenario there are no changes to the number of properties predicted to be at risk of flooding, with a negligible change in estimated damages for the 1% AEP event.

The estimate total cost of Option 2 is £1,972,000 (including an optimism bias).

4.3.4 Option 3 – New storage area

When Option 3 is implemented on the Present Day scenario, flood depths are predicted to decrease downstream of the proposed storage area through the centre of Hoo, with depths around Abbots Court Road predicted to decrease by up to 0.2m in the 3.33% AEP event and up to 0.35m in the 1% AEP event. However, it should be noted that the discharge rate from the storage area was set based on flood levels in the Post-2035 scenario. As a result, flood depths in the storage area reach up to around 1.85m during the 1% AEP event in the Present Day scenario.

With Option 3 implemented in the Present Day scenario, with the outfall set based on flood levels in the Post-2035 scenario, there are relatively small decreases in the number of properties predicted to flood to a depth of 0.15m. However, in the 3.33% AEP the reduction in flood depths results in a decrease in estimated damages of over £80,000, with this almost doubling to £156,800 in the 1% AEP event.

When Option 3 is implemented in the Post-2035 scenario there are again decreased flood depths predicted around the Hoo Stream downstream of the proposed storage area in the 1% AEP event, though the changes are more modest in the 3.33% AEP event. Flood depths at Abbots Court Road are predicted to decrease by up to 0.2m in the 1% AEP event, but are largely unchanged in the 3.33% AEP event. Depths in the storage area reach up to around 1.6m during the 1% AEP event.

The reductions in flood depths in the Post-2035 scenario are more modest than in the Present Day scenario. Although, in the 3.33% AEP event seven fewer properties are still predicted to be at risk of flooding. In the 1% AEP event this increases to 17 fewer properties, as well as a reduction in estimated damages of £58,200.

The estimate total cost of Option 3 is £1,345,000 (including an optimism bias).

Table 4-5: Changes in modelled flood damages for Options 1, 2 and 3 in Hoo St. Werburgh

Option	Scenario	Return period (AEP)	Number of properties flooded to a depth of 0.15m	Change in number of properties flooded to a depth of 0.15m	Change in total damages
Option 1 – Increase Hoo Stream capacity	Present Day	3.33%	85	0	-£900
		1%	118	+2*	-£57,100
	Post-2035 Development Horizon	3.33%	80	0	+£800
		1%	105	0	+£800
Option 2 – Increase Southern Water storage area capacity	Present Day	3.33%	85	0	+£100
		1%	117	+1*	+£400
	Post-2035 Development Horizon	3.33%	80	0	£0
		1%	105	0	-£100
Option 3 – New storage area at Hoo Sports Field	Present Day	3.33%	79	-6	-£80,400
		1%	109	-7	-£156,800
	Post-2035 Development Horizon	3.33%	78	-7	-£18,700
		1%	99	-17	-£58,200
* Note: An additional property (located in the centre of Hoo) is predicted to flood in these scenarios. Flood levels in this property are very close to the 0.15m threshold and the fact it is counted in this scenario is likely due to slight variation between scenarios when direct rainfall is modelled, as opposed to being caused by the implementation of Option 1 or Option 2. The further additional property in the Option 1 Present Day scenario is located near Vicarage Lane, where the mapping shows a slight increase in flood depths as a result of the proposed option, raising flood depths just above the 0.15m threshold.					

Table 4-6: Estimated costings of Options 1, 2 and 3 in Hoo St. Werburgh

Option	Estimated total cost (Present value)	Estimate total cost (Present value +60% optimism bias)
Option 1 – Increase Hoo Stream capacity	£580,000	£928,000
Option 2 – Increase Southern Water storage area capacity	£1,232,000	£1,972,000
Option 3 – New storage area at Hoo Sports Field	£841,000	£1,345,000

The changes in modelled flood damages and property counts for Options 4 and 5 in Hoo St. Werburgh compared to the Present Day scenario are detailed in Table 4-7.

4.3.5 Option 4a – Upstream Group 30-year greenfield runoff rate

When a 30-year GRR is applied to the upstream group of development sites there are decreases in flood depths across large parts of the study area compared to the Present Day scenario, though in the 3.33% and 1% AEP events the reductions along Hoo Stream south of Main Road are smaller than in the Post-2035 scenario where all sites have the GRR restricted to QMED.

However, there are increases in the predicted flood depths adjacent to Hoo Stream upstream of Main Road during the 3.33% and 1% AEP events, as well as at Vidgeon Avenue where depths are predicted to increase by up to 0.03m in both events due to a number of sites in the upstream group connecting to this area. In the 3.33% AEP event this also leads to increases in flood depths of up to 0.02m through the centre of Hoo, though these changes are not seen in the 1% AEP event.

The increased flooding results in an additional five properties predicted to be at risk of flooding during the 3.33% AEP event, though the wider reductions in flood depths mean the damages are predicted to decrease by £20,100. In the 1% AEP there are four fewer properties predicted to be at risk of flooding, with the wider benefits in flood risk resulting in a reduction in the total estimated damages of £232,300 compared to the baseline scenario.

4.3.6 Option 4b – Downstream Group 30-year greenfield runoff rate

When a 30-year GRR is applied to the downstream group of development sites the reductions in flood depths in the town of Hoo are generally the same as those seen in the Post-2035 scenario for the 3.33% and 1% AEP events.

However, as within the Post-2035 scenario there is a large area along and south of Stoke Road where flood depths are predicted to increase, with increases greater than 0.05m at Stoke Road in the 3.33% and 1% AEP events. As detailed in Section 4.2.1, this due to the large development north of Stoke Road (Hoo1084) modelled as connecting to a single location on the sewer network, which does not have the capacity for the entire area. Additionally, there is a large area at the downstream extent of Hoo Stream where depths are predicted to increase by up to around 0.05m in the 3.33% AEP event and around 0.02m in the 1% AEP event.

The increases in flood depths generally occur where there are few properties, so the estimated damages decrease by £97,300 and £305,900 in the 3.33% and 1% AEP events respectively. There are 80 properties (five fewer than the Present Day scenario) predicted to experience flood depths greater than 0.15m in the 3.33% AEP event, and 105 (11 fewer than the Present Day scenario) in the 1% AEP event, with these values the same as in the Post-2035 scenario.

4.3.7 Option 4c – Northeast Group 30-year greenfield runoff rate

When a 30-year GRR is applied to the northeast group the reductions in flood depths across the study area are effectively the same as those predicted during the Post-2035 development scenario, with widespread decreases in flood depths in the 3.33% and 1% AEP events.

As a result, the changes in the property counts and estimated damages are similar to the Post-2035 scenario, with reductions in total costs of £98,800 and £308,400 predicted during the 3.33% and 1% AEP events compared to the Present Day scenario.

4.3.8 Option 5a – Upstream Group 100-year greenfield runoff rate

As within Option 4a, when a 100-year GRR is applied to the upstream group of development sites the reduction in flood depths along Hoo Stream is less during the 3.33% AEP and 1% AEP events than in the Post-2035 development scenario.

During the 3.33% and 1% AEP events there are larger areas of increased flood depths around Vidgeon Lane and the flow path through the centre of Hoo and around Aveling Close than in Option 4a, though depths are generally below 0.05m. Additionally, during the 3.33% AEP event with the 100-year GRR applied to the upstream group flood depths at the downstream extent of Hoo Stream are predicted to increase by around 0.06m

The areas of increased flood extents compared to the baseline scenario in the 3.33% AEP event result in an additional seven properties being predicted to experience flood depths greater than 0.15m, with an increase in estimated damages of £7,200. However, during the 1% AEP event the wider benefits to the study area associated with limiting GRR to runoff rates to QMED in the other development groups means there are four fewer properties predicted to be at risk of flooding and a decrease in the estimated damages of £200,300.

In the 3.33% event there is an increase in the estimated damages of £7,200 (seven additional properties at risk of flooding), while the 1% event results in a decrease in estimate damages of £200,300 (two fewer properties at risk of flooding) compared with the Present Day scenario.

4.3.9 Option 5b – Downstream Group 100-year greenfield runoff rate

With a 100-year GRR applied to the downstream group the reductions in flood depth in developed parts of the study area are broadly the same as those in the Post-2035 development scenario.

To the east of Hoo around Stoke Road flood depths are predicted to increase by up to 0.10m during both return periods tested. Additionally, there is a large area at the downstream extent of Hoo Stream where depths are predicted to increase by up to around 0.14m in the 3.33% AEP event and around 0.08m in the 1% AEP event.

Despite the increases in flood depths, the number of properties predicted to be at risk of flooding decreases by five properties and 11 properties for the 3.33% and 1% AEP events respectively. The widespread reductions in flood depths compared to the baseline scenario result in a £99,000 decrease in the estimated damages in the 3.33% AEP event, while in the 1% AEP event the decrease is £308,100.

4.3.10 Option 5c – Northeast Group 100-year greenfield runoff rate

As with Option 4c, when a GRR of 100-year is applied to the northeast group there are negligible differences in the decreased flood depths across the study area compared to those seen in the Post-2035 development scenario.

As a result, there is again similar decreases in the property counts and estimated damages, with estimated damages decreasing by £98,800 in the 3.33% AEP event and by £308,300 in the 1% AEP event.

Table 4-7: Changes in modelled flood damages for Options 4 and 5 in Hoo St. Werburgh compared to Present Day scenario

Option		Return period (AEP)	Number of properties flooded to a depth of 0.15m	Change in number of properties flooded to a depth of 0.15m	Change in total damages
Option 4 – Increase greenfield runoff rates to 30 year rate	Option 4a – Upstream group	3.33%	90	+5	-£20,100
		1%	112	-4	-£232,300
	Option 4b – Downstream group	3.33%	80	-5	-£97,300
		1%	105	-11	-£305,900
	Option 4c – Northeast group	3.33%	80	-5	-£98,800
		1%	106	-10	-£308,400
Option 5 – Increase greenfield runoff rates to 100 year rate	Option 5a – Upstream group	3.33%	92	+7	+£7,200
		1%	114	-2	-£200,300
	Option 5b – Downstream group	3.33%	80	-5	-£99,000
		1%	105	-11	-£308,100
	Option 5c – Northeast group	3.33%	80	-5	-£98,800
		1%	106	-10	-£308,300

4.3.11 Rainham

The Rainham options models were run for the 3.3% and 1% AEP events and compared against the Post-2035 Development Horizon scenario results for the same events. In the case of Options 3 and 4, which assess the impacts of varying surface water discharge rates from future development sites, results have been compared to the Present Day scenario for the 3.3% and 1% AEP events. An overview of the results is provided below.

It should be noted that no costings have been produced for the Rainham options, in contrast to Hoo St. Werburgh. This is due to the options tested in Rainham involving the method and discharge location of future development sites, which would be implemented by the site developer during the drainage design and construction phases. Therefore, it was not possible to quantify the cost of these options.

4.3.12 Option 1 – change in discharge location for development site 0872 (Siloam Farm)

Option 1 involves a change in discharge location of development site 0872 to a location in Mierscourt Road, adjacent to Cherry Tree Road, to understand the impact of the connection on local flood risk in Cherry Tree Road.

The option results in a decrease in surface water ponding on A2 High Street/Moor Street in both the 3.33% and 1% AEP events. Depth difference grids show a reduction in peak flood depth on Chichester Close and the High Street of up to 0.02m during the 3.3% and 1% AEP events.

- However, flood depths within the large flow path between Cherry Tree Road and Lower Rainham Road, as well as south of Moor Street, are shown to marginally increase during the 1% AEP event.
- This increase in flood depth over a considerable area of east Rainham is reflected in a £22,400 increase in flood damages when compared against the Post-2035 scenario 1% AEP event, and an additional 5 properties identified as at risk of flooding within Option 1.
- Therefore, results indicate that the discharge development site 0872 to the sewer network on Mierscourt Road would have a detrimental impact on flooding in East Rainham, leading to an increase in the risk of flooding to property.

4.3.13 Option 2 – all sites discharging to soakaway

In Option 2, all potential development sites are assumed to drain to soakaway, rather than the surface water or combined sewer networks. This leads to a notable reduction in flood extent on A2 High Street, west of the junction with Meresborough Road, as well as on Moor Street, during the 3.33% event.

The wholescale use of soakaways results in a more significant reduction in flood depths, particularly in east Rainham, where the larger development sites are concentrated. A decrease of 0.02m is predicted to occur on Chichester Lane and 0.1m on A2 Moor Street during the 3.3% AEP event. A reduction in flood depths of between 0.01m and 0.04m is also experienced within the surface water flow path in north east Rainham, between Ten Acre Way and Lower Rainham Road. In the north west of the study area, a decrease in flood depth of 0.02m is predicted behind the tidal defences at Sharps Green, downstream of the large development sites at Lower Rainham Road.

The decrease in flood depth and extent within Option 2, when compared against the Post-2035 scenario, results in one fewer property identified as at risk of flooding and a £119,800 reduction in flood damages. There is no reduction in the number of properties at risk within the 1% AEP event, which reflects the overall increase in flood depths, and a smaller reduction in flood damages of £23,200 is achieved.

However, there are also minor, localised increases in flood depth in the 3.3% AEP event, with the largest increase in depth (0.01m) seen at Arlington Road in north east Rainham.

Table 4-8: Change in modelled flood damages for Options 1 and 2 in Rainham

Option	Scenario	Return period (AEP)	Number of properties flooded to a depth of 0.15m	Change in number of properties flooded to a depth of 0.15m	Change in total damages
Option 1 – Change Site 0847 connection location	Post-2035 Development Horizon	3.33%	232	0	+£18,500
		1%	500	+5	+£22,400
Option 2 – All future developments to soakaway	Post-2035 Development Horizon	3.33%	231	-1	-£119,800
		1%	495	0	-£23,200

The changes in modelled flood damages and property counts for Options 3 and 4 in Rainham compared to the Present Day scenario are detailed in Table 4-9.

4.3.14 Option 3a – Northwest 30-year greenfield runoff rate

When a 30-year GRR is applied to the Northwest group of development sites, there are only very minor changes in flood extents during the 3.3% or 1% AEP events.

However, there is a localised increase in flood depths in east Rainham, at A2 High Street (0.01m in a 3.3% AEP event) and A2 Moor Street (0.11m in a 3.3% AEP event).

Elsewhere flood depths are significantly reduced. Ponded floodwater at the tidal defences is predicted to reduce by up to 0.25m in a 3.3% AEP event. Flood depths are also reduced in east Rainham, south of Moor Street (0.14m) and at the junction of Station Road and Lower Rainham Road (0.36m). Smaller reductions in flood depth are predicted within flow paths on Lower Rainham Road itself (0.03m in a 3.3% AEP event).

Option 3a sees a decrease in the number of properties at risk of flooding, with 16 properties at lower risk during the 3.3% event and 29 properties during the 1% AEP events. The 1% AEP event results in a £529,000 reduction in flood damages, making it the most effective scenario within Option 3.

4.3.15 Option 3b - Northeast Group 30-year greenfield runoff rate

When a 30-year GRR is applied to the north east group of development sites, there is an increase in flood extent within east Rainham. During the 3.3% AEP event, flood extents and depths increase at A2 High Street (0.02m) and A2 Moor Street (0.19m), when compared against the Present Day scenario. A smaller increase in flood extent and depth (0.17m at Moor Street) is seen in the location during a 1% AEP event.

However, overall reduction in flood depths within the 3.3% and 1% AEP events at A2 Moor Street, Otterham Quay Lane, and at the railway embankment.

There is a significant overall reduction in flood depths in east and north east Rainham when 30-year greenfield runoff rates are applied to the 3.3% and 1% AEP rainfall events. Reductions in flood depth are seen in the long flow path from Deanwood Drive to Lower Rainham Road, at the railway embankment, and on land east of Meresborough Road. The greatest reduction is seen on land at the junction between Station Road and Lower Rainham Road, with decreases in peak flood depth of 0.26m (3.3% AEP) and 0.18m (1% AEP).

The decrease in flood depths are reflected in the number of properties at risk of flooding and the potential damages incurred. In the 1% AEP event, 23 fewer properties are identified as at risk of flooding, when compared against the Present Day scenario, with 16 fewer predicted in the 3.3% AEP event. In both events, flood damages decrease significantly, with a maximum reduction of £497,900 experienced during the 1% AEP event.

Comparatively, Option 3b provides the least benefit of the three scenarios within Option 3.

4.3.16 Option 3c - Southeast Group 30-year greenfield runoff rate

- There is no notable increase in flood extent in the study area during a 3.3% or 1% AEP event when a 30-year GRR is applied to the south east group of development sites.
- As in the other Option 3 scenarios, some localised increases in flood depth are seen on A2 High Street (0.01m in a 3.3% AEP event) and A2 Moor Street (0.11m in a 3.3% AEP event). However, elsewhere in east Rainham flood depths are reduced, particularly during the 3.3% AEP event at Ten Acre Way (0.07m), land south of A2 Moor Street (0.13m) and upstream of the railway embankment on Otterham Quay Road (0.34m). In addition, a 0.24m reduction in flood depth south of the M2 in a 3.3% AELP event.
- These reductions in flood depth result in moderate changes in total flood damages to property, with a maximum decrease of £518,000 occurring in the 1% AEP event. As in the case of Option 3a and 3b, the number of properties at risk is notably reduced, with 16 fewer properties at risk during the 3.3% AEP event, and 28 fewer properties affected during the 1% AEP event.

4.3.17 Option 4a - Northwest Group 100-year greenfield runoff rate

There is no notable increase in flood extent in Rainham during the 3.3% AEP or 1% AEP events, when the 100-year GRR is applied to development sites.

However, there is a decrease in flood depths within north west Rainham, predominantly at Lower Rainham Road (up to 0.08m in a 1% AEP event) and against the tidal defences (0.23m in a 3.3% AEP event; 0.19m in a 1% AEP event). As in the case of all of the Option 4 scenarios, there is a localised increase in flooding at A2 High Street and A2 Moor Street.

A total of 15 properties are at lower risk of flooding during the 3.3% AEP event, when compared against the Present Day scenario, with 28 properties at lower risk during the 1% AEP event. This is reflected in a £525,700 reduction in flood damages within the 1% AEP event. As in the case of Option 3a, the greatest decrease in flood damages in seen within the Option 4a 1% AEP event.

4.3.18 Option 4b - Northeast Group 100-year greenfield runoff rate

The 100-year GRR leads to a greater increase in flood extent in east Rainham during the 1% AEP event, with A2 High Street and A2 Moor Street affected.

Flood depths are increased in east Rainham with the 100-year greenfield runoff rate, notably between A2 High Street and the railway embankment, where flood depths increase by up to 0.07m during the 1% AEP event. In the 1% AEP event, flood depths are also increased by 0.01 along the length of the extensive eastern surface water flow path, with a 0.01m increase in depth between Deanwood Drive and Mierscourt Road.

However, significant reductions in flood depth are also seen in east Rainham during a 1% AEP event, notably on Scott Avenue (0.07m), at the junction of Station Road and Lower Rainham Road (0.15m) and on land west of Meresborough Road (0.16m).

The overall decrease in flood depth, with some localised increases in depth, is reflected in a smaller reduction in flood damages than seen in the Option 4 scenarios. A £51,200 reduction in damages is predicted during the 3.3% AEP event, and £424,400 in the 1% AEP event. In addition, fewer properties are identified as benefiting from a reduction in flood risk, when compared against the Present Day scenario, with 11 properties identified in the 3.3% AEP event, and 19 properties in the 1% AEP event.

4.3.19 Option 4c - South East Group 100-year greenfield runoff rate

When a 100-year GRR is applied to the southeast development sites, no notable increase in flood extent is seen in the 3.33% or 1% AEP events.

As in the case of all three Option 4 scenarios, a localised increase in flood depth is seen at A2 High Street and A2 Moor Street. However, elsewhere flood depths are reduced. In the 1% AEP event, a reduction in flood depth is seen at land against the railway embankment at Winchester Way (0.24m), Scott Avenue (0.11m) as well as the junction between Station Road and Lower Rainham Road (0.21m). A reduction in flood depth of 0.13m is also seen at land south of the M2, during the 1% AEP event.

The decrease in flood depths within Option 4c results in the highest numbers of properties seeing a reduction in flood risk out of all three Option 4 scenarios. A total of 16 properties are identified in a 3.3% AEP event, with 29 properties identified with the 1% AEP event, when compared against the Present Day scenario. Flood damages are also predicted to significantly decrease, with the greatest reduction of £521,100 experienced during the 1% AEP event.

Table 4-9: Change in modelled flood damages for Options 3 and 4 in Rainham compared to the Present Day scenario

Option		Return period (AEP)	Number of properties flooded to a depth of 0.15m	Change in number of properties flooded to a depth of 0.15m	Change in total damages
Option 3 – Increase greenfield runoff rates to 30-year rate	Option 3a –	3.33%	232	-16	-£121,200
		1%	495	-29	-£529,000
	Option 3b –	3.33%	232	-16	-£79,900
		1%	501	-23	-£479,900
	Option 3c –	3.33%	232	-16	-£119,500
		1%	496	-28	-£518,100
Option 4 – Increase greenfield runoff rates to 100-year rate	Option 4a –	3.33%	233	-15	-£119,300
		1%	496	-28	-£525,700
	Option 4b –	3.33%	237	-11	-£51,200
		1%	505	-19	-£424,400
	Option 4c –	3.33%	232	-16	-£118,800
		1%	495	-29	-£521,100

4.4 Impacts on the Medway Estuaries and Marshes

4.4.1 Hoo St. Werburgh

In Hoo St. Werburgh all the surface water sewer network eventually discharges to Hoo Stream, the downstream extent of which is located within the Medway Estuaries and Marshes designated SSSI, SPA and RAMSAR site. During a storm event, surface water flows from overland flow paths, and out of bank flooding from Hoo Stream are predicted to build up in and around the network of ponds and creeks. Flood waters are attenuated behind the coastal embankments before slowly discharging to the River Medway via the Hoo Stream outfall. The modelling shows that there are large areas of the marshes predicted to store flood waters for several hours after the flood peaks have passed, demonstrating the potential of the wetlands for attenuating flows before discharging into the Medway Estuary.

During the modelled present-day scenarios (see Section 4.1.1 and Appendix D), predicted flood depths range from around 0.5m in the 50% AEP event to around 1.25m in the 1% AEP plus climate change event, with increased areas of the marshes predicted to flood during the larger events. In the Post-2035 development scenarios flood depths in the marshes are predicted to decrease by around 0.05-0.15m during all the modelled events, with the exception of the 50% AEP event during which flood depths are predicted to increase by up to 0.10m (see Section 4.2.1 and Appendix E).

Increasing the capacity of Hoo Stream (Option 1) is not predicted to notably impact flood depths at the downstream extent of Hoo Stream, though increasing the capacity of the existing storage area (Option 2) is predicted to result in reductions in flood depths of up to 0.05m during the Present Day and Post-2035 development horizons for the 3.33% and 1% AEP events. When the new storage area at Hoo Playing Fields (Option 3) is implemented, flood depths are predicted to decrease by up to 0.05m in the 3.33% AEP event and up to 0.10m in the 1% AEP event. Testing of the discharge rates from potential future development sites in Options 4 and 5 found that raising the outflows from sites upstream and downstream of Hoo leads to lower flood depths predicted in the area around the marshes than when the outflows are limited to QMED. The results of the option testing are presented in Section 4.3.1 and Appendix G.

The hydraulic modelling carried out for the Hoo St. Werburgh study area does not focus on potential water quality issues associated with storm events and potential future developments. There are no combined sewer overflows in the Hoo study area, meaning foul sewer flows are unlikely to enter the surface water network and reach the Medway Estuaries and Marshes area. Large areas of the surface water network drain to the Hoo Stream via storage ponds, which may provide opportunities for improvement of water quality by operating their outflows to allow sediments to settle out and pollutants to be treated by natural processes. Additionally, due to storage of surface water flows within the marshes after the peak flood flows have passed, the area of wetlands may provide an opportunity for the controlling water quality of flows discharging into the Medway Estuary.

4.4.2 Rainham

There are CSOs at 24 locations within the Rainham study area connecting foul and combined systems to four surface water network outfalls into the Medway Estuaries and Marshes designated SSSI, SPA and RAMSAR site, with the location of these outfalls shown in Figure 1-3. Of the 24 locations on the sewer network with CSOs, there are 19 locations where foul or combined flows are modelled to enter the surface water sewer network during the 3.33% and 1% AEP events in the Present Day scenario, with these 19 locations shown in Figure 4-3.

A direct assessment of the impact of the modelled scenarios on water quality has not been conducted as part of this study, though information on the volume of foul and combined flows entering the surface water system via CSOs demonstrates the risk of contaminated water discharging into the Medway estuary. It should be noted that increases in foul water flows associated with future developments have not been modelled.

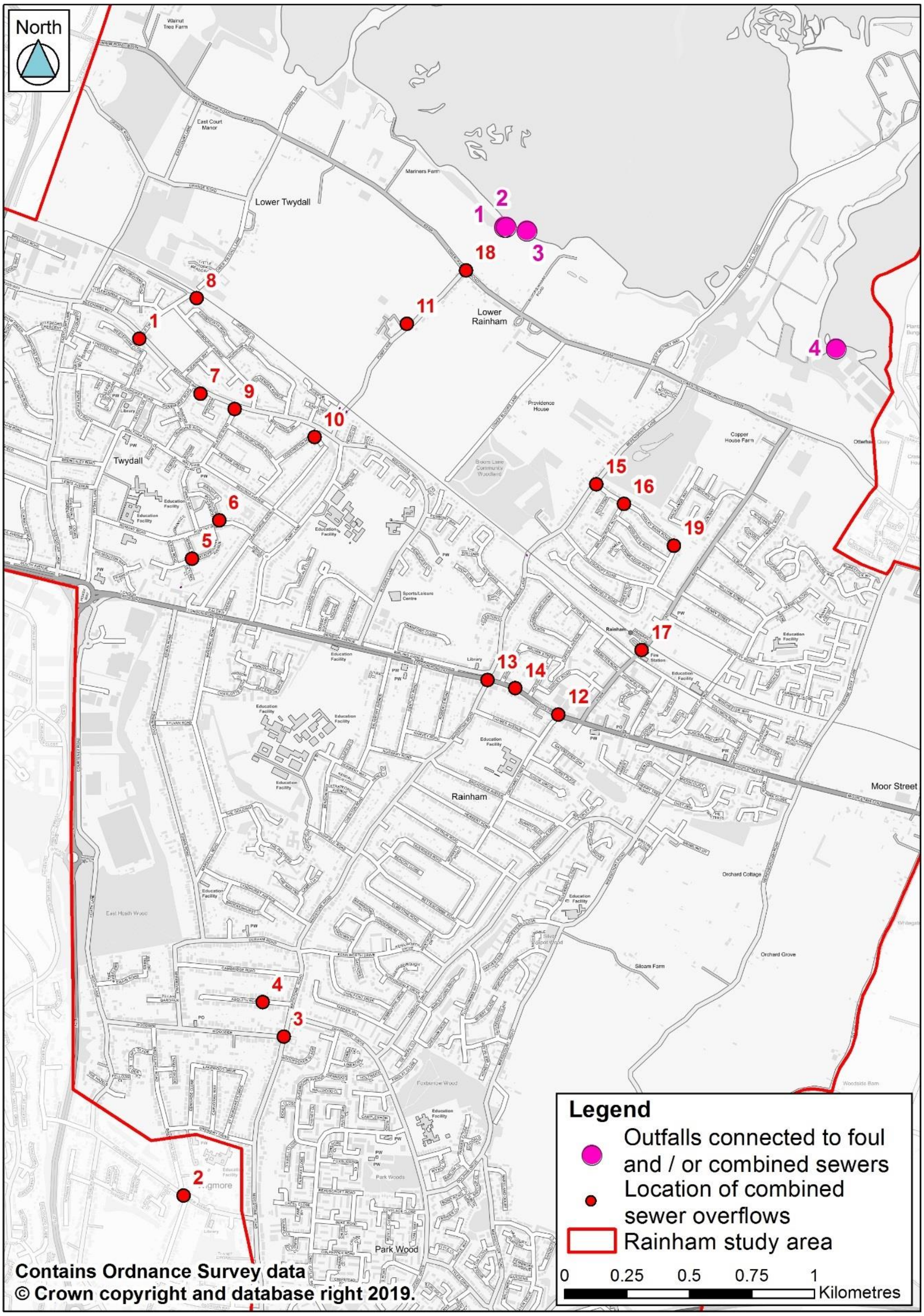
The total foul and combined flows entering the surface water network during each scenario compared to the Present Day scenario are detailed in Table 4-10. During the Present Day scenario, a total of 37,710m^3 and 55,220m^3 of foul and combined flows are predicted to enter the surface water system via CSOs during the 3.33% AEP and 1% AEP events respectively. These flows will be discharged into the Medway estuary via the outfalls shown in Figure 4-3, and therefore there may be a negative impact on water quality in the area during a storm event.

During the Post-2035 development scenario there is a slight reduction in the flow volume in the 3.33% AEP and 1% AEP of -140m^3 and 230m^3 respectively. The implementation of Option 1 results in a slightly higher total flow volume passing through CSOs than in the Post-2035 scenario (although still a decrease when compared with the Present Day scenario), while Option 2 results in a reduction in total flows. Increasing the outflows for sites in the northeast and southeast of Rainham (Options 3b/4b and 4b/4c) is modelled to have a limited impact of the total foul and combined flows entering the surface water network. However, increasing the outflows from sites in northwest of Rainham (Option 3a/3b) results in notable increases in the total volume, with increases of 1,440m^3 and 1,200m^3 predicted when outflows are raised to the 1% AEP GRR for the 3.33% and 1% AEP events respectively.

Table 4-10: Comparison of the total foul and combined flows into surface water sewer network via CSOs in modelled scenarios vs Present Day

Scenario	Difference in total foul / combined flow through CSOs vs Present Day (m^3)	
	3.33% AEP	1% AEP
Post-2035	-140 (-0.4%)	-230 (-0.4%)
Option 1	-50 (-0.1%)	-140 (-0.3%)
Option 2	-560 (-1.5%)	-691 (-1.3%)
Option 3a	+860 (+2.3%)	+680 (+1.2%)
Option 3b	-140 (-0.4%)	-220 (-0.4%)
Option 3c	-150 (-0.4%)	-230 (-0.4%)
Option 4a	+1440 (+3.8%)	+1200 (+2.2%)
Option 4b	-140 (-0.4%)	-220 (-0.4%)
Option 4c	-140 (-0.4%)	-230 (-0.4%)

Figure 4-3: Location of combined sewer overflows in Rainham



4.5 Summary

The results of the hydraulic modelling for the Present Day scenarios show that several areas within Hoo St. Werburgh and Rainham are predicted to be at risk of surface water flooding, with potential impacts for residential and commercial properties.

The modelled development horizon scenarios demonstrate that controlling surface water flows by limiting the outflows from potential future developments to the QMED greenfield runoff rates generally results in decreases in flood depths and extent in both study areas. In Hoo St. Werburgh there are gradual decreases in predicted flood depths throughout the development horizons, with the most notable decreases predicted to occur in the 2033-2035 scenario. In Rainham there are fewer decreases predicted to occur between the development horizons, with the most notable decreases predicted to occur in the Post-2035 scenario.

Testing of potential surface water mitigation options in Hoo St. Werburgh found increasing the capacity of Hoo Stream (Option 1) and increasing the capacity of an existing storage area (Option 2) provide limited benefits for flood risk given the associated costs. However, the construction of a new online storage area drained by gravity located at Hoo Sports Field (Option 3) could potentially result in notable reductions in flood depths and extents. Limiting the outflows from potential future development sites to the 3.33% AEP and 1% AEP greenfield runoff rates, instead of QMED, found that the higher rates from sites downstream (Options 4b and 5b) and northeast (Options 4c and 5c) of Hoo resulted in limited increases in flood risk to developed areas, but resulted in increased flood risk to Hoo when applied to the upstream sites (Options 4a and 5a).

Options testing in Rainham found that discharging all future development sites to soakaways (Option 1) results in moderate reductions in flood risk to the surrounding areas. Additionally, testing found that changing the connection location of the Siloam Farm development site (site 0872) to Mierscourt Road (Option 2) resulted in localised increases in surface water flood risk. Testing of the outflow rates from future development sites found that limiting the runoff rates in the south east (Option 3c and 4c) and north east (Options 3b and 4b) of Rainham has the greatest potential for reducing flood risk in the area, while there were limited changes in flood risk when outflows were limited to the 3.33% and 1% AEP rates from sites in the northwest of Rainham (Options 3a and 4a).

The modelling shows that the surface water drainage in Hoo St. Werburgh flows towards the Medway Estuaries and Marshes designated area via Hoo Stream, with the different options tested having an impact on flood depths in this area. In Rainham, there are several combined sewer overflows that are predicted to result in foul and combined flows entering the surface water sewer network before being discharged into the Medway Estuaries and Marshes area north of Rainham. The options tested all result in slight decreases in the total flows passing through CSOs, with the exception of the options 3a and 4a.

The results of the hydraulic modelling and options testing have been used to inform the actions recommended in Section 5.

5 Action plan

5.1 Introduction

This section sets a plan for managing the flood risk identified in this SWMP. The information collated during the study has been used to recommend measures to reduce or mitigate the flood risk in Hoo St. Werburgh and Rainham.

5.2 Monitoring the action plan

The Defra SWMP technical guidance recommends that the SWMP Action Plan should be review and updated once every six years as a minimum. However, there may be circumstances that initiate a review and/or update of the action plan in the interim period, for example:

Occurrence of a surface water flood event;

Additional data or modelling becoming available, which may alter the understanding of flood risk within the study area;

Investment decision by partner(s) is different to the preferred option within the action plan, which may require a revision of the action plan, and;

Additional (major) development or other changes in the catchment which may affect the surface water flood risk.

The action plan should act as a live document that is updated and amended as required. As a minimum the action plan should be agreed in the Medway Local Flood Risk Management Strategy and the recommendations accounted for when preparing the Local Plan for the study area.

5.3 Actions for Hoo St. Werburgh

Action / Option	Discussion	Recommendations	Actions
Increase capacity of Hoo Stream (Option 1)	Reductions in flood depths provide limited benefits to the number of properties in Hoo predicted to be at risk of flooding and the associated damages, notably resulting in slight increases in flood risk in the high risk area around Vicarage Lane. The benefits to properties at St. Werburgh Crescent in the Present Day scenario are not predicted in the Post-2035 scenario, with the restriction of runoff rates from potential future developments enough to reduce the flood risk in the area. Comparison of the estimated costs associated with this option with the limited benefits for flood risk mean this option is not considered a viable mitigation approach.	It is recommended that this option is not taken forward.	No further actions required.
Increase capacity of Southern Water storage area (Option 2)	The increased capacity of the storage area is predicted to only reduce flood depths in the area downstream of Hoo St. Werburgh, with negligible benefits to properties. The estimated costs of implementing this option are relatively high, limiting its viability as a flood risk mitigation strategy.	It is recommended that this option is not taken forward.	No further actions required.
Build new storage area at Hoo Playing Fields (Option 3)	The implementation of a new storage area at Hoo Playing Fields has a large impact on reducing flood depths downstream through the centre of Hoo, resulting in notable decreases in the numbers of properties predicted to be at risk of flooding and the estimated damages. As a	Given the potential benefits it is recommended this option is taken forwards for further assessment. Further work is required to assess the feasibility of the potential storage area,	Medway Council to investigate feasibility of storage area. Medway Council to investigate impacts

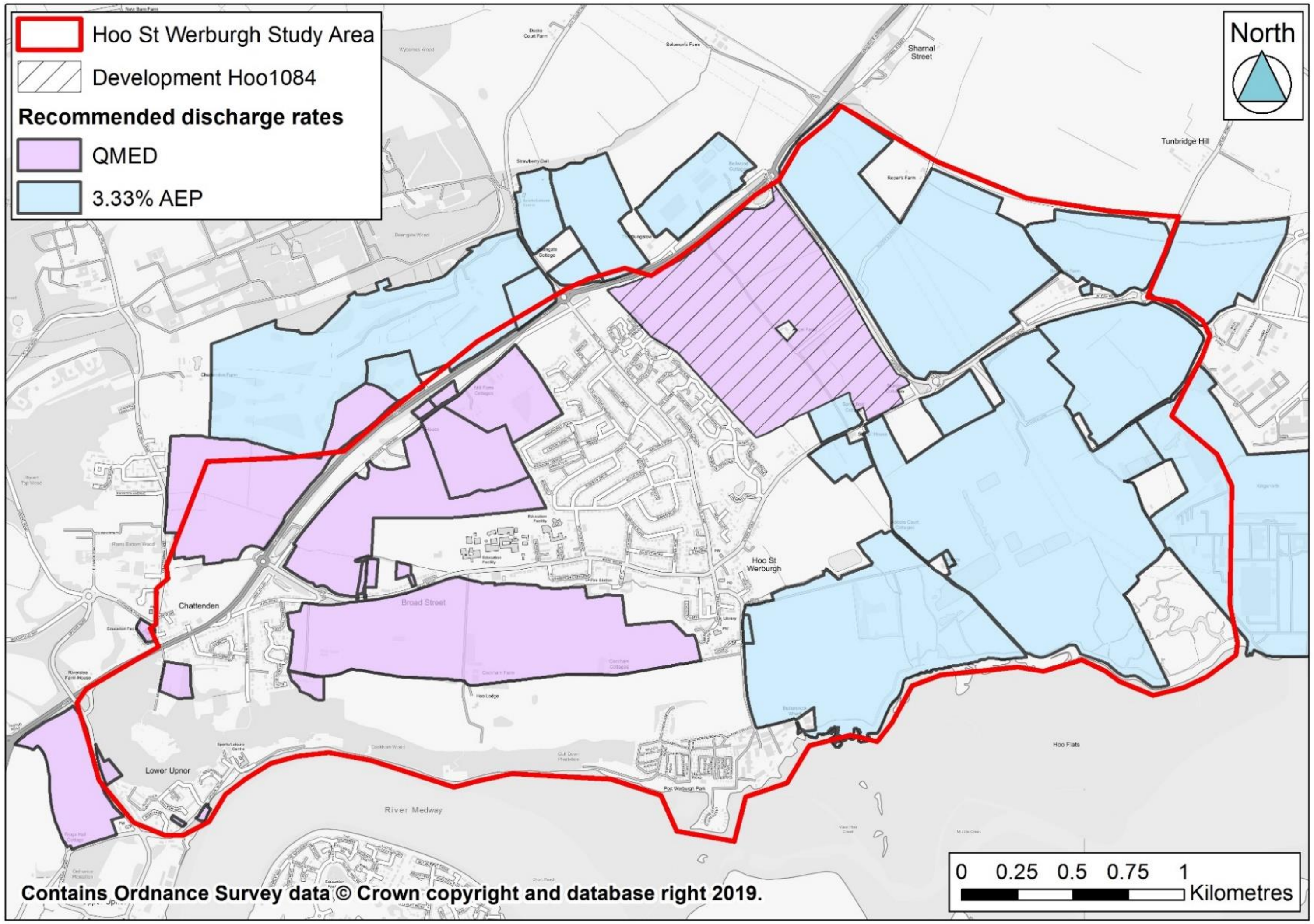
	result, this option has significant potential for managing flood risk in the study area. It is worth noting that the modelling and costing of the storage area was high level and does not constitute detailed design.	accounting for factors such as land ownership and planning permissions. Additionally, detailed design of a storage area is required to provide more accurate estimates of the potential storage capacity and viable outflow rates. This will enable a more accurate understanding of the potential benefits for flood risk.	on flood risk of detailed design.
Controlling discharge rates from future developments (Options 4 & 5)	The development time horizon modelling shows that limiting runoff from future developments generally reduces flood depths and extents across the study area. There are only relatively small decreases in flood depths from the 2033-35 scenario to the Post-2035 scenario, suggesting that only potential sites modelled in the 2033-35 scenario need to be developed to have a notable benefit for flood risk in Hoo St. Werburgh. The testing in Options 4 and 5 shows that runoff rates from potential future sites in the area upstream of Hoo will need to be restricted to QMED to provide the greatest benefits for flood risk to the town. There is predicted to be a limited impact on flood risk in developed areas when runoff rates are limited to the 3.33% or 1% AEP rates, compared to QMED. A notable exception to this is site Hoo1084, north of Stoke Road, which is predicted to cause an increase in flood depths around Stoke Road in the Post-2035, Option 4 and Option 5 scenarios, due to this large site being modelled	The development of the sites modelled in the 2033-35 development horizon scenario should be progressed as a measure for reducing surface water flood risk in Hoo St. Werburgh, with the recommended greenfield runoff rates for each site shown in Figure 5-1. Sites in the area upstream of Hoo should be developed with discharge rates limited to the QMED greenfield runoff rate (2.66l/s/ha). Sites downstream of Hoo and in the northeast of the study area should have discharge rates limited to the 3.33% AEP greenfield runoff rate (6.98l/s/ha). Where infiltration to ground is not possible due to geotechnical reasons, and where a runoff rate greater than the QMED greenfield runoff rate is required to prevent blockage supporting evidence should be provided to demonstrate it will not increase flood risk elsewhere and that all other options have been exhausted. Development Hoo1084 located north of Stoke Road should discharge at the QMED	Medway Council to formalise recommendations in a future Local Plan.

	to drain to a single location in the sewer network.	greenfield runoff rate, though should only be developed if it can be demonstrated through a drainage strategy that there are no increases in flood risk to the area around Stoke Road. It should be noted that where developments are intended to discharge to the surface water sewer network Southern Water may require further restrictions to discharge rates. Developers should demonstrate through drainage strategies that runoff rates will be limited in line with this recommendation. These recommendations should be formalised in a future Local Plan.	
Long term monitoring of flows / levels in Hoo Stream	The Hoo Stream is currently an ungauged watercourse, with no flow or level information available along its length. If a flow and / or level gauge was installed it would be possible to validate the results of the Hoo surface water model and potentially use the gauge data to calibrate model parameters that currently add uncertainty to the results (i.e. surface roughness). This would provide greater confidence in model results and help to target resources to the highest risk areas.	The reach of Hoo Stream around Vicarage Lane is likely to be the most appropriate location for the installation of a gauge, given the greatest flood risk from the watercourse is found in this area. It is likely that it would be most appropriate for the Environment Agency to implement, monitor and manage a flow / level gauge. It is recommended that the Environment Agency are contacted to discuss the feasibility of implementing a gauge along Hoo Stream. If a gauge is installed along Hoo Stream, it is recommended that the hydraulic model is revisited once several years of data have been recorded.	Medway Council to discuss feasibility with Environment Agency.

Provision of Flood Warnings and / or Alerts for Hoo Stream	This action would likely be supported by the installation of a flow / level gauge along Hoo Stream. Currently Flood Alerts and Warnings are only available for the southern extent of the Hoo St. Werburgh study area that is considered at risk of flooding from the River Medway. If a gauge were installed along Hoo Stream, properties predicted to be at risk of flooding from the watercourse could be notified via Flood Alerts or Warnings when flooding may occur. This could help reduce potential damages by providing more time to implement resilience measures (i.e. Property Flood Resilience measures) and allow for evacuation to reduce the risks to life.	Medway Council should discuss the feasibility of developing Flood Alerts or Warnings for the area along Hoo Stream with the Environment Agency, as they are responsible for the national Flood Information Service that currently provides this information for other watercourses.	Medway Council to discuss feasibility with Environment Agency.
Continued maintenance of Hoo Stream culverts	Culverts along Hoo Stream, notably those passing under Church Street and Vicarage Lane, have been identified as constricting flows within the watercourse during large storm events, resulting in out of bank flooding. It is important these culverts are regularly maintained to prevent blockages further constricting the flows that can be conveyed.	It is recommended that Medway Council maintain flows through culverts and prevent blockages along Hoo Stream, particularly around Church Street and Vicarage Lane.	Medway Council have confirmed some stretches of culvert along the Hoo Stream are Medway Council assets and on the structures asset register with a rolling inspection and maintenance regime.
Confirm ownership and maintenance responsibilities of flood storage assets	It would be beneficial to establish the owners responsible for storage areas within the study area, such as those draining the Peninsula Way and the large storage area east of Hoo (referred to in the reporting as the Southern Water storage area). Once the owners of storage areas have been confirmed it would be possible	Medway Council have confirmed the storage areas draining Peninsula Way belong to Medway Council while the large storage area east of Hoo belongs to Southern Water. It is recommended that plans for the maintenance of the storage areas within the Hoo St Werburgh area are established.	Medway Council have added the storage ponds to their asset register for regular inspection.

	to develop maintenance plans to ensure the storage areas are appropriately maintained.		
Assessment of water quality	The surface water drainage network in Hoo St. Werburgh drains via Hoo Stream to the Medway Estuaries and Marshes SSSI, SPA and RAMSAR site. Therefore, it is important that future developments do not discharge flows to Hoo Stream that reduce water quality during the construction and lifetime of the developments.	It is recommended that Medway Council encourage developers to account for water quality control so measures can be implemented to prevent detrimental impacts. Additionally, it is recommended that Medway Council discuss with the owners of flood storage areas in Hoo how they can be managed to control water quality.	Medway Council to include recommendations for water quality control in a future Local Plan. Medway Council to discuss operation of flood storage assets with owners.

Figure 5-1: Recommended discharge rates for future development sites in Hoo St. Werburgh



5.4 Actions for Rainham

Action / Option	Discussion	Recommendations	Actions
Connection location of development site 0847 – Siloam Farm (Option 1)	Changing the connection location to Mierscourt Road results in an increase in flood risk to properties in East Rainham, particularly during a 1% AEP event. The initially tested connection location at Moor Street is therefore considered to be more appropriate.	It is recommended that, should the development site be taken forward, surface water drainage from the site is connected to the Moor Street sewer network, if it is demonstrated that drainage to soakaway is not viable (See Option 2). Infiltration should be the first preference for discharge of surface water from the site, in line with the CIRIA SUDS Manual discharge hierarchy, and the limited capacity of the combined sewer network on Moor Street/High Street. Southern Water and potential developers of the site should be made aware of this at the pre-application stage of planning, so the requirement can be incorporated into the site drainage strategy.	Medway Council to inform Southern Water and potential site developers of preferred connection location on Moor Street, in the event that discharge by infiltration is not possible.
Connecting all future developments to soakaway (Option 2)	The discharge of all potential development sites to soakaway leads to a reduction in flood depths in the vicinity of the sites during the 3.3% AEP event. However, flood depths are increased in the same locations during the 1% AEP event. This reflects the modelled capacity of the soakaways, which are exceeded during a 1% AEP event. Overall, there is a moderate reduction in flood damages for both the 3.3% and 1% AEP events. It should be noted that management of flows produced in the event of blockage/exceedance	It is recommended that planning applications submitted for development of the modelled potential sites are strongly encouraged to discharge by soakaway, unless it is demonstrated through site-specific infiltration testing that this is not viable. To prevent increases in flood risk off-site, measures should be identified to safely manage exceedance flow within the site boundary, in the event that the capacity of the soakaways is overwhelmed.	Medway Council to formalise recommendation for these future sites to drain via infiltration within a future Local Plan and planning advice for SUDS.

	of the soakaways was not represented within the model scenario.	Where infiltration is proven to be infeasible, it must be demonstrated that connecting the site to the drainage network does not increase flood risk elsewhere.	
Controlling discharge rates from future developments (Options 3 & 4)	The development time horizon modelling shows that limiting runoff from future developments generally reduces flood depths and extents across the study area. There is a small decrease in flood depths in the 2019–2021 scenario, and a significantly larger decrease within the Post-2035 scenario, suggesting that potential sites modelled in these two development horizons are expected to benefit the management of surface water flood risk in Rainham most. The testing in Options 3 and 4 shows that limiting runoff rates from Post-2035 development sites in south east and north east Rainham to greenfield rates, has the potential to provide the greatest benefits for managing flood risk in the town. In contrast, development of sites in north west Rainham provided the least reduction in flood risk. It should be noted, this is partly due to the majority of potential development land being concentrated in the eastern Rainham, which therefore leads to a greater reduction in surface water flood risk when greenfield runoff rates are applied. In Options 3 and 4, there are localised increases in flood depth at A2 High Street / Moor Street. These are caused by an increase	The restriction of surface water discharge from development sites modelled in the 2019–2021 and Post-2035 development horizon scenarios should be progressed as a measure for reducing surface water flood risk in Rainham. Across the majority of Rainham, surface water from proposed development sites can be discharged at the 3.3% AEP or 1% AEP greenfield runoff rates (2.05l/s/ha or 2.84l/s/ha). Development sites in south east Rainham, immediately upstream of A2 High Street/Moor Street, should seek to manage runoff on site, by discharging to soakaway. Where this is not possible, discharge should be limited to the QMED greenfield runoff rate (0.78l/s/ha), to manage the increase in flood risk at this location. Where infiltration to ground is not possible due to geotechnical reasons, and where a runoff rate greater than the QMED greenfield runoff rate is required to prevent blockage supporting evidence should be provided to demonstrate it will not increase flood risk elsewhere and that all other options have been exhausted.	Medway Council to formalise recommendations for discharge rates of future development sites within a future Local Plan and planning advice for SUDS.

	in flooding from manholes, where additional pressure is placed on the combined sewer network by discharge from sites at 30-year and 100-year greenfield runoff rates. This identifies the restriction in sewer capacity at this location, and the need to strictly limit discharge rates from the proposed development sites. However overall, when greenfield runoff rates are applied to sites within Options 3 and 4, there is an overall reduction in flood depths, damages and properties at risk. This is particularly the case in lower-lying areas in north Rainham, including against the railway embankment, tidal defences, as well as on Lower Road and Station Road.	It should be noted that where developments are intended to discharge to the surface water sewer network Southern Water may require further restrictions to discharge rates. Developers should demonstrate through drainage strategies that runoff rates will be limited in line with these recommendations. Due to the limited capacity in the sewer network and the relatively permeable underlying geology, it is recommended that future development sites discharge by infiltration, subject to the results of site-specific soakage testing. These recommendations should be formalised in a future Local Plan and LLFA SUDS guidance.	
Assessment of water quality	The modelling shows that there are a large number of CSOs within Rainham that discharge foul and combined flows into the surface water sewer network during storm events, which are then discharged into the Medway Estuaries and Marshes designated area. This could result in detrimental impacts on water quality in this sensitive environment.	It is recommended that surface water flows are drained via soakaways (Option 2) from future developments to avoid increasing flows within combined sewers. Additionally, developers should work with Southern Water and Medway Council to ensure there is capacity within the foul sewer network to support the developments, mitigate the risk of increased foul and combined flows entering the surface water sewer network and prevent deterioration of water quality within the designated wetlands. Modelling could be undertaken with development populations included to	Medway Council to formalise recommendations in a future Local Plan and planning advice for SUDS. Medway Council to discuss with Southern Water using the SWMP modelling and growth horizon datasets to estimate the impact of development on CSO

		understand the impact of these (in conjunction with surface water flows) on CSO spills.	spills and water quality.
Management of surface water flow paths in open spaces	Several surface water flow paths in Rainham initially develop, or pass through, grassed open spaces, such as flow paths 5, 8 and 9 in Figure 4-2. Source control and mitigation measures could be implemented in these areas to temporarily store water and reduce the volume and velocity of surface water runoff that then goes onto impact developed areas downslope.	It is recommended that the feasibility of implementing source control and mitigation measures for high risk surface water flow paths is considered and investigated in response to any increased flood incidents. These measures would need to be developed alongside the landowners.	Consideration to be given to source / pathway control in future.
Retrofitting of SUDS features to allow source control	A number of surface water flow paths in Rainham are generated on impermeable surfaces and follow the route of the road network. It may be possible to retrofit SUDS features along these roads, such as permeable surfaces, to reduce the surface water runoff that is generated. As many developments in Rainham drain to soakaway, there may be potential to use infiltration based SUDS features, such as infiltration trenches or filter drains.	It is recommended that Medway Council consider the potential for retrofitting SUDS features to the road network in Rainham. Potential works could be targeted towards roads that currently require maintenance works.	Medway Council to consider feasibility.
Options modelling of potential Flood Storage Areas	There may be potential to store surface water flows within Flood Storage Areas in open spaces within Rainham. Figure 5-3 shows eight locations where it may be possible to implement Flood Storage Areas in Rainham as potential mitigation measures to reduce flood risk to developed areas downslope.	It is recommended that Medway Council consider the need for modelling potential Flood Storage Areas in response to any increased flood incidents in the area.	Medway Council to review requirements for further modelling as appropriate.

Figure 5-2: Recommended discharge rates for future development sites in Rainham

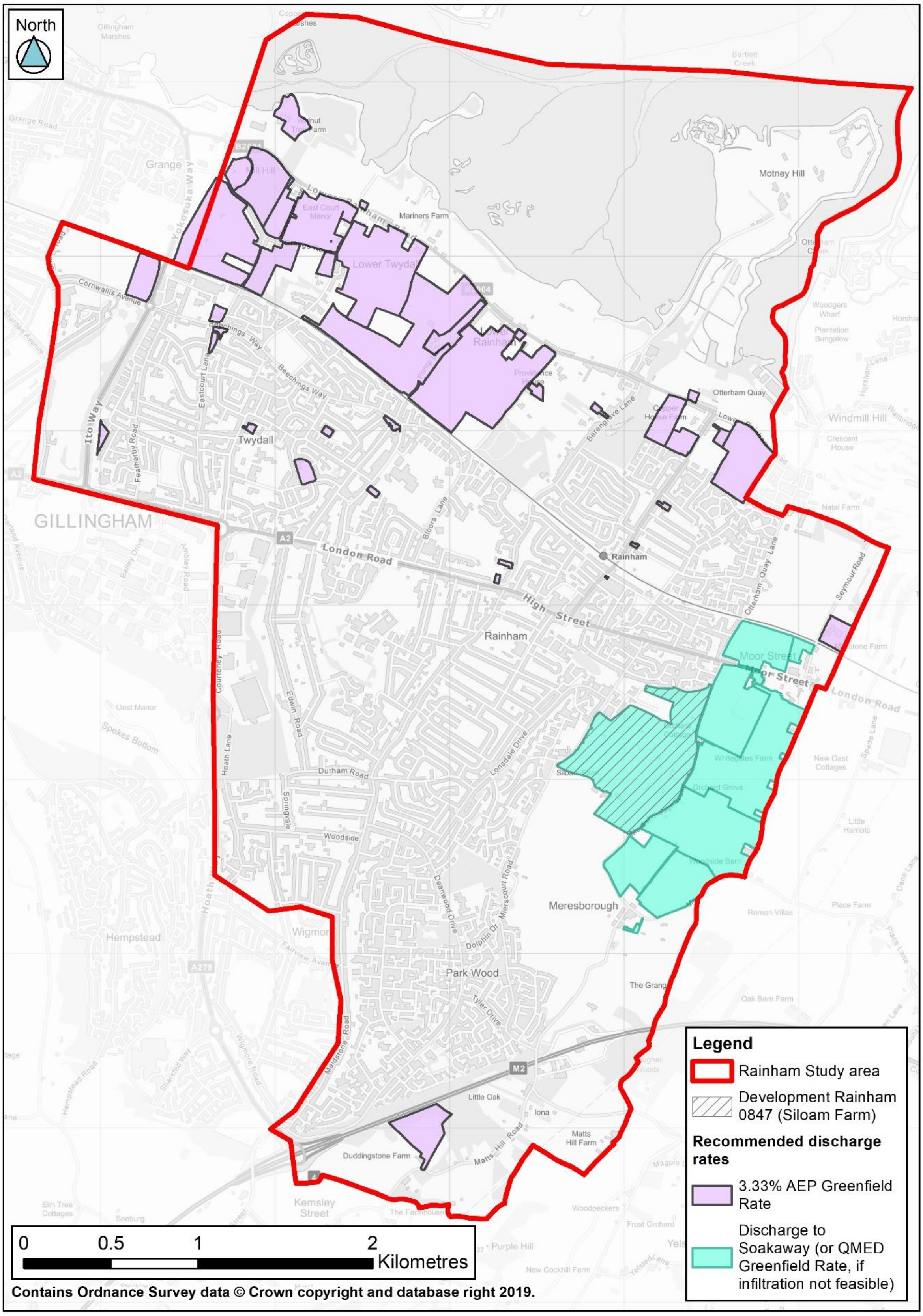
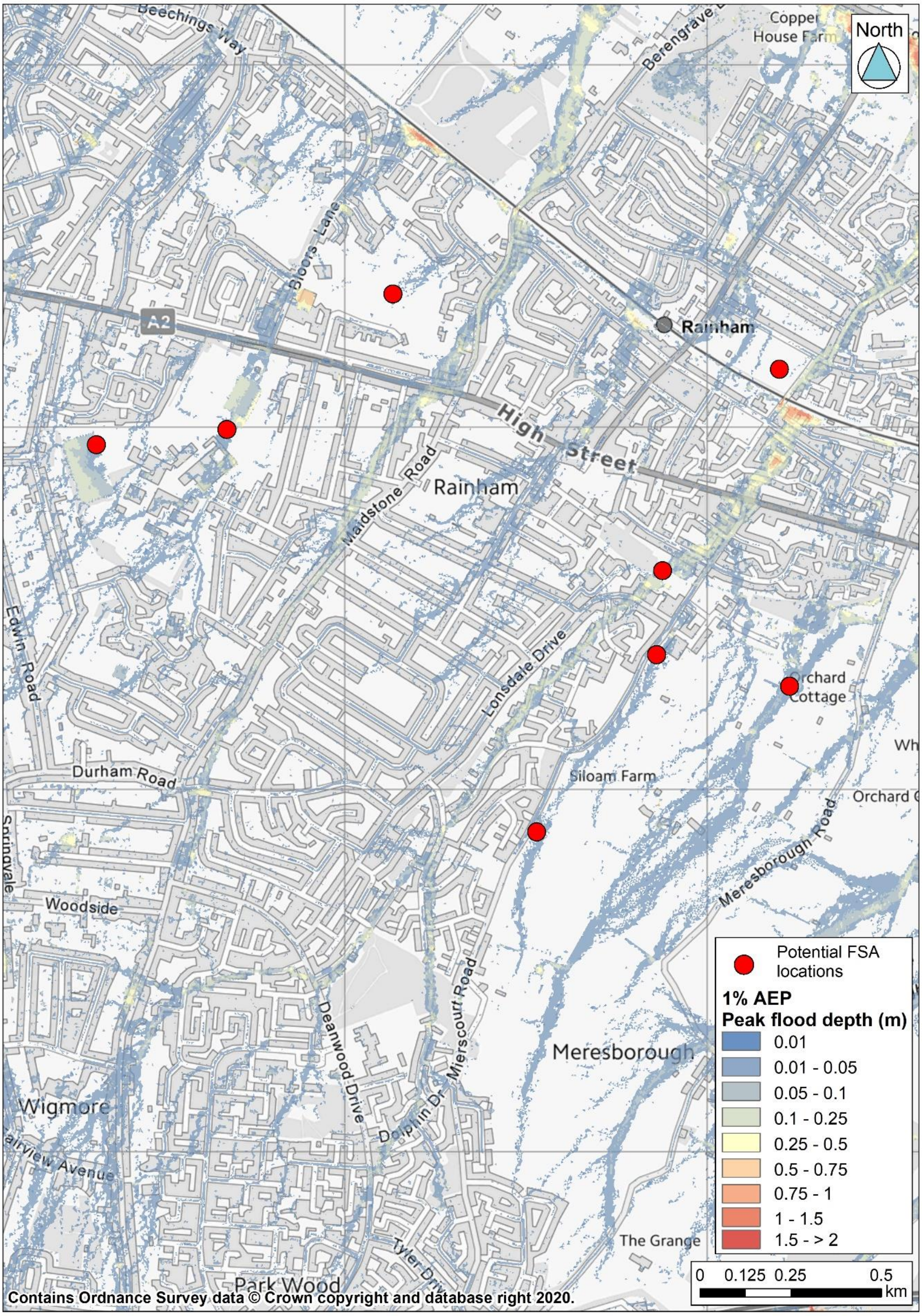


Figure 5-3: Potential Flood Storage Area locations in Rainham



5.5 General actions for Hoo St. Werburgh and Rainham

Action / Option	Discussion	Recommendations	Actions
Property Flood Resilience measures	Property Flood Resilience (PFR) measures are a relatively low-cost approach to mitigate the risk of internal property flooding, with measures including the installation of flood doors or temporary flood barriers. These could be particularly valuable for properties at risk of flooding along flow paths through urbanised areas where it is difficult to implement major mitigation measures due to the developed nature of the area. Potential areas that could benefit from PFR measures could include properties along flow path 3 (Figure 4-1) in Hoo and along flow paths 1 and 2 (Figure 4-2) in Rainham.	The model results should be examined to identify properties and businesses that would benefit from PFR measures. The feasibility of receiving funding to support the implementation of PFR measures should be investigated.	Medway Council to identify properties and businesses that would benefit from PFR measures. Medway Council to investigate potential for receiving funding for a PFR scheme.
Detailed modelling of high-risk areas	The hydraulic model built as part of this SWMP does not contain localised surface water drainage features, such as road gullies or drainage through the railway embankment in Rainham. Additionally, threshold levels of buildings were not known so were also not modelled. In areas identified as being at a high risk of flooding from surface water flow paths it would be beneficial to update the model to include local drainage features and threshold levels to better understand the key flow paths and areas at risk.	It is recommended that Medway Council consider the need for further detailed modelling in areas considered to be at a high risk of surface water flooding.	Medway Council to review requirements for further modelling in high risk areas.

Raise awareness of urban creep	The loss of permeable surfaces within urban areas leads to increased surface water runoff, increasing flood risk. Referred to as urban creep, this process occurs at property scales through the construction of extensions or conservatories, as well as paving of front and back gardens for car parking and patios.	It is recommended that Medway Council provide policy or guidance on urban creep that might consider: 1. Raise public awareness of the restrictions on paving of front gardens. 2. Raise awareness of the restrictions on paving of front gardens and provide best practice advice to contractors who undertake the work on behalf of residents 3. Education on the issue of household drainage and misconnections. 4. Advice with respect to drainage of small developments. 5. Identify how Development Control can implement this policy without creating large amounts of additional activity	Medway Council to review the need for and methods of awareness raising.
Encourage residents and businesses to sign up to weather warnings	The Met Office currently issues weather warnings of varying severity when heavy rainfall is anticipated. These warnings give an indication of when storm events that could lead to surface water flooding will occur. By encouraging residents and businesses to sign up to weather warnings it could help them to take measures to mitigate the risks to people and property (i.e. implement PFR measures)	It is recommended that Medway Council investigate potential approaches to encourage residents and businesses to sign up to receive Met Office weather warnings.	Medway Council to review methods of awareness raising.
Continue programme of cleaning road gullies	While road gullies have not been included in the surface water models developed as part of this study, they contribute to the drainage of developed areas during surface water events. It is important they are maintained to prevent blockages resulting in increased surface water flood risk to roads and surrounding properties.	It is recommended that Medway Council continue to maintain and clean road gullies. The public should be made aware of the existing system for reporting blocked gullies, particularly in areas identified in the SWMP as being at a high risk of surface water flooding.	Medway Council to review the need and methods of awareness raising.

Ensure the SWMP findings are available to users of Medway Council's SFRA	It is important that the findings of the SWMP are disseminated to users of the local SFRA, particularly developers, to enable considerations of how to reduce surface water flood risk at the earliest possible opportunity.	It is recommended that the findings of the SWMP are summarised within the next update to the Medway Council SFRA. This could be included either as an addendum to the existing SFRA or as part of an updated SFRA.	Medway Council to include findings of the SWMP within the next update of the SFRA.
Surface water warnings	Medway Council may wish to discuss the possibility of creating surface water warnings for high risk areas. These could either be generated through live modelling or based on rainfall triggers.	It is recommended that Medway Council discuss options for creating surface water warnings with Southern Water and the Environment Agency.	Medway Council to discuss with Southern Water and Environment Agency.

5.6 Way forward

It is recommended, as part of an iterative process of revision, the outputs of the SWMP should be incorporated into future revisions of the Medway Local Flood Risk Management Strategy and Strategic Flood Risk Assessment.

Of particular note in this respect are the proposed maximum Greenfield Runoff Rates for individual sites, identified within this study.

Further investigation into the feasibility of Option 3 (new storage area at Hoo Playing Fields) in Hoo St. Werburgh should be conducted, particularly with reference to factors such as potential storage capacity, viable outflow rates, land ownership and planning permissions.

Appendices

A Project Data Register

B Model Operation Manual

C Estimation of flood damages and options costings

C.1 Overview

The number of properties predicted to be impacted during the Present Day and Post-2035 Design Horizon scenarios have been estimated for the 3.33% and 1% AEP flood events, along with the associated potential economic damages to properties. Property counts and damages have also been estimated for all the options scenarios in Rainham and Hoo St. Werburgh to provide an understanding of the potential benefits associated with each option.

Additionally, potential costings of implementing Options 1, 2 and 3 for Hoo St. Werburgh which involve structural measures have been estimated to provide a comparison of the benefits of each option against the associated costs of implementing the measures.

The analysis conducted as part of the SWMP does not constitute a full economic appraisal as there is no costing of do nothing or do minimum options, and a number of assumptions have been made in the costings of the options due to the high-level nature of the study.

C.2 Property counts and damage calculations

Property counts and damage estimates have been calculated using FRISM, JBA's in-house flood metrics software.

C.2.1 Flooding data

The FRISM calculation was run for the 3.33% and 1% AEP flood events for the Present Day scenario, Post-2035 Design Horizon scenario and every option scenario using the model results from the Rainham and Hoo models. The results were annualised assuming a first flood with a return period of one year to obtain average annual damages.

All return periods were queried for depths greater than 0.15m, with this depth threshold used to generate a flood outline. The property count and damage calculations only accounted for building footprints within the flood outline. Properties intersecting small surface depressions in the 2D mesh may be counted as flooding although road gullies and other local surface drainage features that were not modelled may reduce the risk of flooding in these areas. As a result, the estimated property counts and damages may be higher than those experienced in an actual flood event, particularly during the 50% AEP event.

C.2.2 Receptor data

The receptor datasets used for the calculations were the NRD 2014 property points shapefile along with the building footprints derived from OS MasterMap polygons. The full NRD data was used in the assessment of damages, including receptor points that did not have a building footprint. These receptors included features like public telephones and electricity sub stations and have been retained to ensure that the value of lost services is included in the damage counts.

C.2.3 Property counts

Property counts were undertaken using the detailed counting method, which utilises the building footprints in conjunction with the NRD property points. A property point is counted as flooded if its corresponding building footprint is within the flood outline, even if the point itself does not fall within the flood outline. The property counts do not include properties classed as potential upper flood properties or buildings with an MCM code of 999 (Unknown).

C.2.4 Damages

Each flood property point is attributed with a minimum, maximum and mean depth value, corresponding to the values of the depth grid within the property footprints. If the footprint contains less than half of a depth grid cell it will not receive any depth values but will be included in the property counts.

A damage value is calculated for each flood property point, with minimum, maximum and mean damages calculated based on the depth values within the property. The damage value is calculated by obtaining a unit damage value (£/m^2) using the depth damage curves from the Multi Coloured Manual 2013[4], with the curves adjusted to account for inflation using the CPI index value for October 2019[5]. The unit damage value is dependent on the flood depth at the property and the property type, with the value then multiplied by the floor area field of the NRD data to provide an absolute damage value. The mean flood damages have been presented in the analysis in Section 4.

A threshold level for the damage calculations has been applied so that only flood depths within properties greater than 0.15m contribute to the damages. This threshold represents an assumed building threshold of 0.15m, above which flood water can enter a property and cause damages.

Damages have not been calculated for properties with a floor level of 'pU', which represent potential upper floor properties, such as in flats.

Additionally, indirect damages have not been included in the analysis, such as response and recovery costs or costs of alternative accommodation for impact residents.

C.3 Long term costing of options

The proposed Options 1, 2 and 3 that have been considered in the Hoo St. Werburgh modelling would involve structural flood risk management (FRM) measures. Option 1 considers the potential to widen Hoo Stream to increase its capacity, Option 2 involves the expansion of an existing Southern Water storage area, while Option 3 considers the construction of a new storage area.

The whole life costs of the potential measures associated with these options have been estimated to compare the possible costs against the benefits in reducing damages to properties in the study area. The options in Hoo (Options 4 and 5) and Rainham (Options 3 and 4) that involve altering the discharge rate from potential development sites have not been costed as these are considered to expenses associated with development. Similarly, Options 1 and 2 in Rainham involve changes to the drainage of potential development sites so have not been costed as they do not involve structural flood risk management measures.

It should be noted that the modelling of the options for the SWMP is strategic in nature, with elements of the modelling simplified and the implementation of the measures not constituting detailed design. Instead, the modelling is configured to provide an understanding of whether the conceptual flood risk management measures investigated in outline demonstrate benefits for reducing flooding and the associated damages.

C.3.1 Costing methodology

To produce the cost estimates for each scenario, the Environment Agency's Long-Term Costing Tool has been used, which can be downloaded from the

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4 Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal, Flood Hazards Research Centre, 2013.

5 CPI Index, Office for National Statistics. Available: https://www.ons.gov.uk/economy/inflationandpriceindices/timeseries/d7bt/mm23

data.gov.uk website. The tool is intended to provide high-level cost estimates for schemes by relating basic measurement quantities to a cost database of previously delivered FRM schemes. More information about the tool can be found in the accompanying DEFRA science reports (https://www.gov.uk/government/publications/long-term-costing-tool-for-flood-and-coastal-risk-management).

The tool provides both capital costs based on simple dimensional properties of the proposed schemes and maintenance costs based on typical maintenance rates for different types of structures. All costs are converted to Present Value (PV) costs discounted according to Treasury guidance.

In brief, the Present Value cost comprises:

Capital costs (not discounted) + Enabling costs (not discounted) + Maintenance costs (discounted)

In producing the cost estimates it is necessary to consider the lifetime of the scheme, which for this assessment has been assumed to be 100 years. Within that lifetime it is also necessary to determine whether the asset will need to be replaced which will depend on an estimate of design life.

C.3.2 General assumptions

The following are assumptions that apply across each of the FRM measures:

Enabling costs have been estimated assuming the measures are delivered and operated by the Local Authority.

All costs are base dated to October 2019 using the CPI inflation index to relate to costs within the database.

No allowance for land purchase costs have been made.

The target condition grade is 2 (Good) for the lifetime of the scheme. This assumes a robust regime of maintenance.

Maintenance costs have used the default weighting provided and have not been adjusted for site specific information.

An optimism bias of 60% is applied to the whole life costs in line with the typical value used for high level strategic projects according to HM Treasury guidance[6]. Optimism bias describes the propensity for appraisers to be overly optimistic in early assessments of project costs compared to the final values, with the percentage applied to increase costs to account for uncertainty in the estimates.

C.3.3 Option 1 costing approach – Increase Hoo Stream capacity

This measure comprises widening of 860m of Hoo Stream. Widening of existing channels is not included as an item within the tool so we have assumed that is equivalent to the additional construction of a quarter of this channel length (215m).

In preparing the costs it has been assumed that the channels will be earthen channels, rather than concrete. It has also been assumed that maintenance will be manual instead of utilising mechanical plant.

C.3.4 Options 2 and 3 costing approach – Storage areas

The EA costing tool is used to estimate the costs associated with construction of new storage areas, such as in Option 3. As Option 2 involves doubling the capacity of the existing Southern Water storage area it has been assumed that

[6] Environment Agency, (March 2010), Flood and Coastal Erosion Risk Management appraisal guidance.

the cost of implementing the measure would be similar to constructing a new storage area with the same capacity as the existing area.

The volume capacity of the existing Southern Water storage area was estimated using from the DTM in InfoWorks ICM as 27,434m^3, by applying a storage node and storage area to the existing structure. Therefore, the costing for Option 2 has been carried out assuming a new storage area is constructed with this capacity, though there is no account for any freeboard allowances that would reduce the available capacity of a potential storage area.

The capacity of the proposed storage area for Option 3 has been estimated using the modelled peak flood level within the storage area during the 1% AEP event in the Post-2035 Development Horizon scenario of 12.6m AOD. Based on elevations derived from the 2018 1m DTM, there is a potential capacity of 11,175m^3 below 12.6m AOD in the storage area at Hoo Field. As this is a high-level assessment, any potential storage volume lost through the construction of embankments to form the storage area has not been modelled or accounted for in the volume calculations. Additionally, any freeboard allowances that would be required have not been accounted for.

In preparing the cost estimates of both options the following assumptions apply:

No land acquisition costs are assumed

No adjustment factors are allowed to account for:

- Suitability of site and geology
- Material type
- Balancing cut and fill
- Source of material and disposal of waste material
- Site access and presence of services
- Contaminated land and environmental impacts

Maintenance costs have been assumed to be 2.5% of the capital costs per year

C.4 Summary

Both the damage calculations and option costings have provided high level cost estimates to inform the potential impacts of flooding in the study areas and the viability of possible FRM measures. These costs are indicative and based on simplistic assessments of the damages and the requirements for FRM measures, and it is expected the future studies seek to refine these values.

D Present Day scenario modelled depths

D.1 Hoo St. Werburgh

Plan 1 – 50% AEP

Plan 2 – 3.33% AEP

Plan 3 – 1.33% AEP

Plan 4 – 1% AEP

Plan 5 – 1% AEP +40% Climate Change Uplift

D.2 Rainham

Plan 6 – 50% AEP

Plan 7 – 3.33% AEP

Plan 8 – 1.33% AEP

Plan 9 – 1% AEP

Plan 10 – 1% AEP +40% Climate Change Uplift

E Post-2035 Development Horizon Scenario vs Present day modelled depth comparison mapping

E.1 Hoo St. Werburgh

Plan 11 – 50% AEP

Plan 12 – 3.33% AEP

Plan 13 – 1.33% AEP

Plan 14 – 1% AEP

Plan 15 – 1% AEP +40% Climate Change Uplift

E.2 Rainham

Plan 16 – 50% AEP

Plan 17 – 3.33% AEP

Plan 18 – 1.33% AEP

Plan 19 – 1% AEP

Plan 20 – 1% AEP +40% Climate Change Uplift

F Tabulated development horizon flood depths

F.1 Hoo St. Werburgh

F.2 Rainham

G Options scenario modelling depth comparisons

G.1 Hoo St. Werburgh

Plan 21 – Hoo Option 1

Plan 22 – Hoo Option 2

Plan 23 – Hoo Option 3

Plan 24 – Hoo Option 4 (3.33% AEP)

Plan 25 – Hoo Option 4 (1% AEP)

Plan 26 – Hoo Option 5 (3.33% AEP)

Plan 27 – Hoo Option 5 (1% AEP)

G.2 Rainham

Plan 28 – Option 1

Plan 29 – Option 2

Plan 30 – Option 3 (3.33% AEP)

Plan 31 – Option 3 (1% AEP)

Plan 32 – Option 4 (3.33% AEP)

Plan 33 – Option 4 (1% AEP)

H Tabulated flood damages

H.1 Hoo St. Werburgh 1% AEP flood damages

Option	Scenario	Return period (AEP)	Number of properties flooded to a depth of 0.15m	Change in number of properties flooded to a depth of 0.15m	Change in total damages
n/a	Present Day	1%	116	n/a	n/a
n/a	Post 2035 Development Horizon	1%	105	-11	-£308,000
Option 1 – Increase Hoo Stream capacity	Present Day	1%	118	2	-£57,100
	Post-2035 Development Horizon	1%	105	0	£800
Option 2 – Increase Southern Water storage area capacity	Present Day	1%	117	+1	£400
	Post-2035 Development Horizon	1%	105	0	-£100
Option 3 – New storage area at Hoo Sports Field	Present Day	1%	109	-7	-£156,800
	Post-2035 Development Horizon	1%	99	-17	-£58,200
Option 4 – Increase greenfield runoff rates to 30-year rate	Option 4a – Upstream group	1%	112	-4	-£232,300
	Option 4b – Downstream group	1%	105	-11	-£305,900
	Option 4c – Northeast group	1%	106	-10	-£308,400
Option 5 – Increase greenfield runoff rates to 100-year rate	Option 5a – Upstream group	1%	114	-2	-£200,300
	Option 5b – Downstream group	1%	105	-11	-£308,100
	Option 5c – Northeast group	1%	106	-10	-£308,300

H.2 Hoo St. Werburgh 3.33% AEP flood damages

Option	Scenario	Return period (AEP)	Number of properties flooded to a depth of 0.15m	Change in number of properties flooded to a depth of 0.15m	Change in total damages
n/a	Present Day	3.33%	85	n/a	n/a
n/a	Post 2035 Development Horizon	3.33%	80	-5	-£99,000
Option 1 – Increase Hoo Stream capacity	Present Day	3.33%	85	0	-£900
	Post-2035 Development Horizon	3.33%	80	0	£800
Option 2 – Increase Southern Water storage area capacity	Present Day	3.33%	85	0	£100
	Post-2035 Development Horizon	3.33%	80	0	£0
Option 3 – New storage area at Hoo Sports Field	Present Day	3.33%	79	-6	-£80,400
	Post-2035 Development Horizon	3.33%	78	-7	-£18,700
Option 4 – Increase greenfield runoff rates to 30-year rate	Option 4a – Upstream group	3.33%	90	5	-£20,100
	Option 4b – Downstream group	3.33%	80	-5	-£97,300
	Option 4c – Northeast group	3.33%	80	-5	-£98,800
Option 5 – Increase greenfield runoff rates to 100-year rate	Option 5a – Upstream group	3.33%	92	7	£7,200
	Option 5b – Downstream group	3.33%	80	-5	-£99,000
	Option 5c – Northeast group	3.33%	80	-5	-£98,800

H.3 Rainham 1% AEP flood damages

Option	Scenario	Return period (AEP)	Number of properties flooded to a depth of 0.15m	Change in number of properties flooded to a depth of 0.15m	Change in total damages
n/a	Present Day	1%	524	n/a	n/a
n/a	Post 2035 Development Horizon	1%	495	-29	-£524,000
Option 1 – Change Site 0847 connection location	Post-2035 Development Horizon	1%	500	5	£22,400
Option 2 – All future developments to soakaway	Post-2035 Development Horizon	1%	495	0	-£23,200
Option 3 – Increase greenfield runoff rates to 30-year rate	Option 3a –	1%	495	-29	-£529,000
	Option 3b –	1%	501	-23	-£479,900
	Option 3c –	1%	496	-28	-£518,100
Option 4 – Increase greenfield runoff rates to 100-year rate	Option 4a –	1%	496	-28	-£525,700
	Option 4b –	1%	505	-19	-£424,400
	Option 4c –	1%	495	-29	-£521,100

H.4 Rainham 3.33% AEP flood damages

Option	Scenario	Return period (AEP)	Number of properties flooded to a depth of 0.15m	Change in number of properties flooded to a depth of 0.15m	Change in total damages
n/a	Present Day	3.33%	248	n/a	n/a
n/a	Post 2035 Development Horizon	3.33%	232	-16	-£122,000
Option 1 – Change Site 0847 connection location	Post-2035 Development Horizon	3.33%	232	0	£18,500
Option 2 – All future developments to soakaway	Post-2035 Development Horizon	3.33%	231	-1	-£119,800
Option 3 – Increase greenfield runoff rates to 30-year rate	Option 3a –	3.33%	232	-16	-£121,200
	Option 3b –	3.33%	232	-16	-£79,900
	Option 3c –	3.33%	232	-16	-£119,500
Option 4 – Increase greenfield runoff rates to 100-year rate	Option 4a –	3.33%	233	-15	-£119,300
	Option 4b –	3.33%	237	-11	-£51,200
	Option 4c –	3.33%	232	-16	-£118,800

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