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Environment Agency

River Medway Flood Storage Areas

Initial Assessment

Technical Report – ENVIMSE100377/R

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Glossary

Acronym	Meaning
AAD	Average Annual Damages
AEP	Annual Exceedance Probability
BC	Borough Council
BCR	Benefit Cost Ratio
CFMP	Catchment Flood Management Plan
CPI	Consumer Price Index
DI	Distributional Impact
DNO	Distribution Network Operator
EICA	Electrical, Instrumentation, Control and Automation
FCERM-AG	Flood and Coastal Erosion Risk Management – Appraisal Guidance
FDGiA	Flood Defence Grant in Aid
FRS	Floods & Reservoir Safety
FSA	Flood Storage Area
IA	Initial Assessment
IBCR	Incremental Benefit Cost Ratio
ICOLD	International Commission on Large Dams
KCC	Kent County Council
LEPs	Local Enterprise Partnerships
LiDAR	Light Detection and Ranging
m AOD	Metres Above Ordnance Datum
MCM	Multi-Coloured Manual
MMS	Middle Medway Strategy
NMOWL	Normal Maximum Operating Water Level
NRD	National Receptor Dataset
OBC	Outline Business Case
OS	Ordnance Survey
PF	Partnership Funding
PLC	Programmable Logic Controller
PV	Present Value
PVb	Present Value Benefits
PVc	Present Value Costs
PVd	Present Value Damages
QRA	Quantitative Risk Assessment
SOC	Strategic Outline Case
SoP	Standard of Protection
STW	Sewage Treatment Works

1. Introduction

1.1. Purpose

This Technical Report supports the Initial Assessment (IA) for the River Medway Flood Storage Areas (FSA), comprising an assessment of strategic catchment options for improved flood risk management in the River Medway catchment from Leigh to Maidstone. A majority of these options are reservoir storage – specifically at the existing Leigh FSA on the River Medway upstream of Tonbridge, and potential new FSAs located on the River Beult and River Teise catchments (major tributaries of the River Medway), upstream of the Yalding and Collier Street communities. Consideration has also been given to linear defence and conveyance options.

1.2. Objectives

The project has two main objectives, as follows:

1. To assess the technical and economic viability of an increase in the operational storage volume of the Leigh FSA to further reduce the risk of flooding to Tonbridge and downstream communities; and

2. To assess the technical and economic viability of a solution to reduce flood risk in the communities of Yalding and Collier Street utilising a single or cascade of FSAs or other solution on the lower reaches of the River Beult and / or the River Teise.

Subject to sufficient confidence in potential funding being evident, options which are viable will be recommended to proceed to detailed appraisal to justify further investment.

1.3. Staged Delivery

The project was divided into 3 stages:

Stage 1 comprised a desk study of all the existing information and data to provide an initial understanding of the issues and associated opportunities and constraints. This focussed on both the Leigh FSA site and new FSA(s) in the Beult / Teise catchments to make recommendations for the approach to the next stage. The findings of Stage 1 were documented in a technical report issued in June 2015.

Stage 2 developed the technical, economic and environmental appraisal of the identified options for flood risk management in the Medway catchment. This included an assessment of scheme costs, benefits, opportunities, risks, constraints and required monetary contributions from project partners.

Stage 3 comprises of preparation of an IA report which confirms, or otherwise, the viability of progressing with option development, and demonstrates confidence in a decision to fund the progression of a detailed appraisal. This Technical Report supports the IA report, providing further details regarding the option selection, hydraulic modelling and the technical, economic and environmental appraisal. The final part of Stage 3 will be the preparation of the Strategic Outline Case (SOC) to provide the necessary financial approval for progression to detailed appraisal (Outline Business Case (OBC)).

1.4. Strategic Linkages

The Leigh FSA primarily reduces flood risk to Tonbridge and Hildenborough on the River Medway but also to a reduced extent further downstream. There are a large number of properties at risk in the area of the confluence of the Rivers Medway, Beult and Teise, including the communities of Yalding, Laddingford and

Collier Street. The flood risk reduction due directly from the current Leigh FSA this far downstream is relatively small. However there are inter-linkages relating to the timing of the flood peak, with timing affected by catchment characteristics (particularly catchment area and slope) and both natural floodplain attenuation and man-made FSAs. As well as the flood peak timing inter-linkage between the Medway, Beult and Teise, combining flood risk management projects in a single strategic package will deliver enhanced opportunity for flood risk management across the whole catchment and is also anticipated to yield efficiency savings.

Separate IAs have been undertaken for the Hildenborough flood alleviation scheme and the East Peckham flood alleviation scheme. It is understood that the Environment Agency will take forward all viable options from this IA and the Hildenborough IA as a single appraisal package for the River Medway catchment. The benefits of the East Peckham scheme will continue to be appraised as part of a separate OBC.

1.5. Previous Work

Table 1-1 provides a summary of previous work undertaken for this part of the River Medway catchment. This previous work provided background information on flood risk in the catchment and aided identification and costing of flood risk management options, was well as determination of the opportunities and constraints associated with these options.

Table 1-1 Overview of previous work

Report	Summary of information relevant to the Medway FSAs IA
Medway Catchment Flood Management Plan (CFMP)	• First published in 2004 as a pilot study, and updated in 2008. • Sets out a high-level understanding of flood risk and flood processes in the Medway catchment. • Recommended long term sustainable policies to manage flood risk in the future, with identified actions to achieve these policies. Recommended further consideration of the following options: ▪ Increase storage volume at the Leigh FSA. ▪ Localised flood walls / embankments, upstream FSAs and property level protection to reduce flood risk in Yalding and Collier Street. • The 2004 pilot CFMP included several conveyance options including a flood bypass on the River Medway downstream of Yalding, a sluice gate to control inflow to the Lesser Teise, and both increasing and decreasing conveyance on the River Beult. The 2004 report concluded that while some benefits could be achieved in some locations, these were offset by worsening flood levels in other locations, and hence changes in conveyance were not included in the action plan in the 2008 update. The CFMP was used to provide background information on flood risk in the catchment and to aid identification of flood risk management options.
Middle Medway Strategy (MMS)	• Undertaken in 2005, submitted in 2007 and approved by Defra. • Recommended two strategic options (including additional storage at Leigh FSA), three local options (including flood walls in Yalding and flood walls and stream diversion in Collier Street) and a range of non-structural options (e.g. flood warning and resistance / resilience). • Flood storage on the River Beult and River Teise, and conveyance options were on the Strategy long list, but were not taken forward to the short list. The MMS was used to provide background information on flood risk in the catchment and to aid identification of flood risk management options.

Report	Summary of information relevant to the Medway FSAs IA
Middle Medway Strategy Review	• Undertaken by Halcrow in 2010. • High level assessment (including hydraulic modelling) of additional options (including Yalding bridge arch debris removal, Upper Teise storage, Upper Beult storage, Lower Beult storage and River Teise flow diversion). • Leigh FSA option: new trigger levels and outflows devised to make full use of the increased storage. • Upper Teise FSA: site upstream of Stonebridge needs a very high embankment to attenuate the 1% (1 in 100) AEP event flows. Detrimental upstream impact and only small reduction in downstream water levels. Second storage location (Cottage Wood) identified. Issue of delayed flood peak causing the River Teise peak to coincide with those of other rivers in Yalding, potentially worsening flood risk at this location. • Upper Beult FSA site upstream of Headcorn Aerodrome reduces flood level in Headcorn and Staplehurst but risk of upstream property flooding in Smarden. • Lower Beult FSA site at Chainhurst considered a more appropriate location than Stilebridge. Embankment across the River Beult in this location causes floodwater to be re-routed into the Lower Teise, therefore only partially delays and reduces peak flow, with properties at risk in / around Chainhurst. • River Teise flow diversion – combination of new embankments and amending culverts through the railway to re-direct flood flows towards lower populated areas. Provides some benefit but also detrimental impacts in other areas. • Economic appraisal and IA completed for Leigh FSA and Yalding local defence options. No economic appraisal of the River Beult or River Teise FSA options. Background information on flood risk in the catchment and opportunities and constraints associated with options.
Leigh FSA information	• Leigh FSA Additional Storage Railway Track Protection Preliminary Considerations report (Jacobs Babtie, 2006). Provides a conceptual design and cost for a mitigation option to protect the railway line if the storage water level were to be increased. • Railway berm drawings (Southern Water Authority, 1981). • Kent Reservoir Spillway Investigations – Leigh FSA report (Halcrow, 2010). Provides results of investigations of flow velocities and the required scope of embankment protection for the embankment to cope with overtopping during extreme flood events. • Leigh FSA condition data. • Leigh FSA mechanical improvements scope of work. • Leigh FSA operating procedures. Used to inform Leigh FSA options definition and costs.
Pre-feasibility study for “stand alone” flood defence scheme at Yalding	• Report issued by Babtie Brown & Root in May 2001. • High-level feasibility study into option of constructing a local flood defence (embankment or wall) around the left bank of Yalding. Included high-level economic appraisal for a range of design standards with all Benefit Cost Ratios (BCR) less than 1. • Preferred solution was individual property-level resistance and resilience measures.

Report	Summary of information relevant to the Medway FSAs IA
	Background information on Yalding flood history and previously considered route for a local flood defence.

2. Flood Risk Management Options: Leigh FSA

2.1. Introduction

The Leigh FSA is located 3km upstream of Tonbridge and attenuates floods on the River Medway, reducing the frequency and magnitude of flooding in Tonbridge and downstream communities. The impounding structure consists of a 1.3km long embankment up to 5.7m high, and a flow control structure with 3 gates to provide active flow control. Under normal river conditions, the gates do not impede flow on the Medway. When river flows are high, the gates can be operated to limit downstream flow, impounding water in the FSA until the peak inflow has passed and the impounded water can be released in a controlled manner. Gate operation is determined in accordance with the operating rules and output from flood forecast models and upstream gauging stations. If the inflows exceed the design capacity of the structure, the gates are operated to pass the full flow of the flood to ensure the FSA embankment does not overtop.

The current Normal Maximum Operating Water Level (NMOWL) fixed in the Final Certificate is 28.05m AOD, at which the storage capacity is 5.5 Mm^3. The CFMP, the MMS and the Strategy Review all investigated the option of increasing the NMOWL to the embankment crest level (confirmed as not less than 29.15m AOD in a recent survey), giving an additional 2.8Mm^3 of storage and thus improving the downstream Standard of Protection (SoP).

Three options have been assessed for the Leigh FSA: Do Nothing (undefended), Maintain (existing situation with the current NMOWL of 28.05m AOD) and Improve (NMOWL increased to 28.85m AOD).

2.2. Do Nothing

Do Nothing is the economic baseline against which all other options are compared. Under Do Nothing, operation of the Leigh FSA would cease, increasing flood flows on the River Medway and hence increasing flood risk to Tonbridge, Hildenborough and downstream communities. Flood risk would further increase in the future as a result of climate change. For the purpose of this IA, the Do Nothing option is considered broadly comparable to the undefended scenario and is assumed to have zero cost.

2.3. Maintain Leigh FSA

The Maintain option is as per the existing situation, with operation of the control structure to impound flood water in the FSA to the NMOWL of 28.05m AOD, reducing downstream flow and flood risk principally through Tonbridge and Hildenborough. However flood risk will increase over time as a result of climate change.

2.3.1. Included Works

Under the Maintain option, the following works are included:

- Mechanical and electrical refurbishment and improvement to the Control structure (see below) in years 1 - 2;
- Provision of southern embankment downstream slope protection in years 1 – 2, as recommended in the Kent Reservoir Spillway Investigations (Halcrow, 2010); see information provided in Appendix B;
- Annual maintenance and 10-yearly capital works to maintain structure operation; and
- Major capital works (replacement) in years 40 and 80.

Since the failure of a lead screw in 2007, detailed survey work and condition reviews identified a number of defects, and recommended solutions to improve the integrity and reliability of control structure operation. The current Emergency Lifting Scheme, installed in 2009, sought to provide some mechanical improvements, with phase II of the project deferred until strategic decisions had been made about the long term options for Leigh FSA. The Maintain option includes phase II of the Leigh Mechanical improvements which consists of:

- Installation of a winch rope system;
- EICA (Electrical, Instrumentation, Control and Automation) works including a new PLC (Programmable Logic Controller) system;
- Civils works to the kiosks; and
- Provision of a DNO (Distribution Network Operator) separate electricity supply.

A cost allowance has also been made for other sundry items identified as necessary to ensure the continued operation of the control structure. Under the Maintain option, major replacement works are delayed until year 40.

2.3.2. Option Costs

The option cash costs for individual works items for Maintain Leigh FSA are presented in Table 2-1. In accordance with Treasury guidance a 100 year appraisal period has been used and the Treasury variable discount rate has been applied to calculate total Present Value (PV) costs; also presented in Table 2-1. More detail about the method used and assumptions made when calculating these costs is provided in Appendix F.

Table 2-1 Maintain Leigh FSA Option Costs

Item	Cost (£k)
Appraisal, design & management	848
Southern embankment downstream slope protection	620
Control structure mechanical improvements	4,090
Initial capital cash costs	**5,558**
10-yearly works	500
Major replacement year 40 and year 80	10,000
All capital cash costs (100 years)	**29,058**
Annual Maintenance (yearly cash cost)	70
PV Capital costs (100 years, with 30% optimism bias)	**12,548**
PV Maintenance costs (100 years, with 30% optimism bias)	**2,713**
Total PV costs (100 years, with 30% optimism bias)	**15,261**

2.4. Improve Leigh FSA

2.4.1. Raised Storage Level

Increasing the NMOWL requires a balance of the resulting implications of a higher level directly impacting property and assets upstream, the operating reservoir safety due to wave overtopping, and the potential to reduce flood risk downstream with the enhanced storage volume.

Increasing the NMOWL to 29.15m AOD, and thus realising all of the potential Leigh FSA additional storage capacity, would require significant works at both the embankment (to mitigate the wave overtopping risk and to assess the hydraulic performance of the control structure) and mitigation works in upstream areas to protect existing assets. Following a review of these impacts it was considered that this maximum increase to NMOWL was not optimal – the cost and direct impacts upstream outweighed the additional potential benefit. The review concluded that the optimum Improve option was to increase the NMOWL to 28.85m AOD. While this option provides a slightly smaller increase in storage capacity compared to 29.15m AOD and hence will have lower benefits, the costs will also be significantly lower because it will reduce the required works at the embankment and upstream areas.

Should the IA show the option to be technically, economically and environmentally viable, further work to optimise the storage level could be undertaken as part of a detailed appraisal.

2.4.2. Benefits

Increasing storage at Leigh FSA will improve the SoP provided to the communities of Tonbridge and Hildenborough, and to a lesser extent, communities downstream on the River Medway. This flood risk benefit is described in more detail in Sections 4.3 and 6.3. It is however noted that flood risk is likely to increase over time as a result of climate change.

There may be opportunities to incorporate biodiversity enhancements within the design of the expanded FSA (for example improved floodplain connectivity or enhanced wetland habitats), although this is likely to be limited given that the option is for works to an existing flood risk management asset. Any opportunities to create and restore habitats will help to contribute to England's Biodiversity Strategy 2020 targets and funding Outcome Measure 4a. No specific opportunities have been identified at this stage, but this should be explored further as part of any detailed appraisal.

2.4.3. Managing the Increase in NMOWL

Leigh FSA Control Structure and Embankment

Increasing the NMOWL has the potential to adversely affect the control structure and the embankment. Potential issues have been identified and further review as part of the detailed appraisal is recommended should this option be taken forward. The review should cover the following:

- Impact on the hydraulic performance of the control structure;
- Impact on access to the structure during a flood event (noting that the control structure bridge kerbs are at a level of 29.15m AOD and the concrete piers are at 29.82m AOD);
- Impact on embankment stability and safety because the upper parts of the embankment, which to date have remained dry, will be subject to wetting. The potential increase of the hydraulic gradient across the

embankment foundation should also be reviewed against the International Commission on Large Dams (ICOLD) guidance on internal erosion in embankment dams; and

- Requirement for embankment raising, construction of a wave wall and / or provision of embankment protection to offset the increase in mean overtopping discharge arising from the reduction in freeboard between the NMOWL and the embankment crest level. The current guidance published in Floods and Reservoir Safety (Defra, 2015) is based on recommend limits to the mean overtopping discharge (intermittent flows from wave overtopping) calculated from the static water level, the fetch length and the concurrent wind speed. An initial assessment using the new guidance has been undertaken, the results of which are provided in Appendix B.

Upstream Assets

A combination of site visits, Light Detection and Ranging (LiDAR) data, Ordnance Survey (OS) mapping and the National Receptor Dataset (NRD) have been used to identify assets which would be at risk of flooding if the Leigh FSA NMOWL was raised. The results of this work are summarised in Table 2-2 and illustrated on Figure 1 and Figure 2 in Appendix A. Mitigation measures to protect these assets have been proposed, the cost for which has been included in the option cost. Development restrictions in the area adjacent to the Leigh FSA to prevent any future increases in NMOWL being restricted should also be implemented.

Table 2-2 Upstream locations which could be affected by an increase in NMOWL at Leigh FSA

Location	Existing risk	Potential impact of raising the NMOWL	Identified actions and / or mitigation option(s)
Tonbridge Town Sailing Club clubhouse, Haysden Water	Ground levels around 26m AOD; site currently floods when water is impounded in the FSA. Sailing club has existing procedures in place (e.g. boats moved to downstream of FSA embankment) when flooding is expected.	Flood depths would be greater if NMOWL was increased. Although some survey has been undertaken, this was not sufficient to establish the potential increase in damage that would be caused by the increase in NMOWL.	Threshold level survey recommended to determine the potential impact for use when consulting with the Sailing Club regarding any required mitigation measures.
Railway line between the Leigh FSA embankment and Leigh station	Railway track to the west of Six Arches Bridge (towards Leigh Station) exceeds 30.6m AOD. Level of railway track falls in an easterly direction from 30.5m AOD at Six Arches Bridge to 29.25m AOD. Track (including ballast) is therefore not at risk. Stabilising berms were constructed as part of the original Leigh FSA works, with a maximum berm elevation of 28.64m AOD, providing a 0.59m freeboard above the existing NMOWL.	New NMOWL would still be 0.4m below the track level and 0.3m below the ballast at the lowest point. Existing berm crest would however be inundated (0.21m depth of water), exposing both sides of the railway embankment to wetting and drawdown during impounding events. New parts of the underside of the Six Arches Bridge would also be exposed to wetting.	Some raising of the existing protective berm (to a crest level of 29.45m AOD) likely to be required on both sides of the railway embankment to the east of the Six Arches Bridge. Mitigation measures should be discussed with Network Rail as part of any detailed appraisal.
A21 road bridge	Bridge is raised well above the floodplain and is not at risk of flooding.	Increase in NMOWL would increase the depth of water to which the bridge supports are submerged. This is not expected to have a significant impact. Carriageway still well above the flood level.	To be reviewed again at detailed appraisal, but no mitigation considered necessary at this stage.

Location	Existing risk	Potential impact of raising the NMOWL	Identified actions and / or mitigation option(s)
Area of woodland to the north-west of Haysden Water	Woodland already partially submerged during impounding events.	Potential ecological consequences of an increase in submerged depth.	Assessed as part of the environmental appraisal.
South-eastern corner of Leigh	Area of lower ground to the north of the railway bund in the south-east corner of Leigh (at the back of the Wyndham Close properties) with a minimum ground level (from LiDAR) of 29.05m AOD. No risk of flooding in this area at the current NMOWL (1m freeboard).	New NMOWL still below ground levels in this location, with no risk of flooding to properties in this part of Leigh.	Small flood bund (~30m length) tied into the railway berm to the south and high ground to the north could be constructed to the north of the railway line and immediately to the east of the cattle arch track to reduce the residual risk of flooding in this area.
Cattle arch, Leigh	Existing bund around the cattle arch with an average crest level of 28.95m AOD (2014 survey level adjusted to 1980 datum) providing a 0.9m freeboard on the current NMOWL and hence a very low residual risk of bund overtopping.	Freeboard reduced to 0.1m if NMOWL raised, increasing the risk of wave overtopping. If the bund was overtopped, the cattle arch provides a flood route under the railway line towards properties in Leigh.	Cattle arch bund (100m length) raised to around 29.45m AOD. This is currently based on provision of a 0.6m freeboard. Further work including a full overtopping assessment following the Flood and Reservoir Safety (Defra, 2015) guidance should be undertaken as part of the detailed appraisal. Initial work is presented in Appendix B. Depending on the findings of this assessment, crest and downstream slope reinforcement may be required in conjunction with crest raising.
Environment Agency pumping station, Leigh	Existing bund around the pumping station with a minimum crest level of 28.5m AOD (from LiDAR and survey), providing a 0.45m freeboard on the current NMOWL and hence a low residual risk of bund overtopping.	New NMOWL would be 0.35m above the crest level of the existing bund, resulting in flooding of the pumping station.	As per the cattle arch: raise bund (55m length) to around 29.45m AOD, based on provision of 0.6m freeboard, but to be confirmed following an overtopping assessment recommended as part of the detailed appraisal. Additionally need to consider the impact of the increased head of water on pump operation.
Southern Water pumping station, Leigh	Existing bund around the pumping station with a minimum crest level of 28.85m AOD (from LiDAR and survey), providing a 0.8m freeboard on the current NMOWL and hence a very low residual risk of bund overtopping.	New NMOWL would be level with the crest of the existing bund, with a high risk of wave overtopping, resulting in flooding of the pumping station.	As per the cattle arch: raise bund (110m length) to around 29.45m AOD, based on provision of 0.6m freeboard, but to be confirmed following an overtopping assessment recommended as part of the detailed appraisal. Additionally need to consider the impact of the increased head of water on pump operation.

Location	Existing risk	Potential impact of raising the NMOWL	Identified actions and / or mitigation option(s)
Pumping station's access track and south-western part of Leigh	Existing NMOWL reaches to the south of the pumping station's access track, with no flooding of the track, the road or properties in south-west part of Leigh because ground levels exceed 28.05m AOD.	New NMOWL would be 0.45m above the crest level of the access track embankment resulting in flooding of the track, and flood risk to Ensfield Road (under the railway bridge) and three buildings in this part of Leigh.	Raising of the access track embankment (to around 29.45m AOD as per the cattle arch and pumping station bunds) to prevent overtopping and water ingress towards Leigh. Some surface water drainage works required for the two minor watercourses that currently drain under the access track, potentially re-directing these to the Environment Agency pumping station to maintain drainage during impounding events.
Ensfield Bridge	Road already floods (minimum level 26mAOD) and is closed in flood events.	Increasing NMOWL would increase the depth of flood water, and result in a small increase in the length (<100m) of flooded road. This is not expected to have a significant impact.	To be reviewed again at detailed appraisal, but no mitigation considered necessary at this stage.
Access track from Penshurst to Place Barn Farm and Well Place Farm (day care centre)	Minimum track level of around 28.8m AOD (from LiDAR) for 150m near Place Barn Farm. Access track remains dry at existing NMOWL with a 0.75m freeboard.	Access track would be subject to shallow flooding at higher NMOWL, cutting off Well Place Farm.	Construction of a small counter wall (~150m long, 0.5m high) to protect the lowest-lying parts of the track.
Penshurst sewerage treatment works (STW)	Ground level at the STW is around 28m AOD. Existing low earth bund around the works with a minimum crest level of 28.3m AOD protects the site from flooding during impounding events.	New NMOWL would be up to 0.55m above the crest level of the existing bund, resulting in flooding of the STW. Access route would also be flooded. Note that most of the equipment is raised above ground level and so the site could be flooded with equipment unaffected.	Raise existing bund and / or construct wall around the site, approximately 250m long and 0.9m high. Works to raise access track also required. Mitigation measures should be discussed with Southern Water as part of any detailed appraisal.
Bridge House, Rogues Hill, Penshurst	Bridge House has a raised threshold level at the front of the residential property but is lower to the side and rear, with a minimum surveyed threshold of 29.03m AOD. Although this is almost 1m lower than the NMOWL, the house currently floods during impounding events.	NMOWL still lower than the minimum property threshold level, but property expected to flood, potentially to a higher depth.	Possible wall or bund solution to protect individual property. If not possible, flood depths likely to be too great for property-level resistance and resilience measures. Mitigation measures to be explored further in consultation with residents as part of any detailed appraisal.

Location	Existing risk	Potential impact of raising the NMOWL	Identified actions and / or mitigation option(s)
The Yews, Rogues Hill, Penshurst	Ground levels around 29.2m AOD. The residential property has a raised threshold level at the front (> 31m AOD) but a side cottage entrance with a surveyed threshold level of 29.24m AOD and a basement at a level of 28.79m AOD. Basement flooding currently occurs when the NMOWL is reached, and a pump is used to remove flood water.	NMOWL still lower than the minimum property threshold level, but basement flooding could worsen.	Mitigation measures to be explored further in consultation with residents as part of any detailed appraisal.
Leigh FSA	Landowners compensated for inundation caused by impounding when Leigh FSA was constructed. Total flooded area of around 2.6km2.	0.6km2 increase in flood extent (both on the edges of the existing FSA and upstream of Penshurst) as well as increases in flood depth and flood duration.	Provision of compensation to landowners as agreed with the Environment Agency.

2.4.4. Option Costs

The option costs for Improve Leigh FSA are presented in Table 2-3, both as cash costs for individual works items and as discounted PV costs over the 100 year appraisal period. The Improve Leigh FSA option includes all of the costs to maintain the asset (as described in Section 2.3). More detail about the method used and assumptions made when calculating these costs is provided in Appendix F.

Table 2-3 Improve Leigh FSA Option Costs

Item	Cost (£k)
All capital works required under "Maintain" option	See Table 2-1
Appraisal, design & management (additional for Improve option)	424
Raised crest or new wave wall	650
Railway line protection	500
Cattle arch and pumping station protection, works in south-west Leigh	395
Well Place Farm access, Penshurst STW protection and Bridge House	813
Initial capital cash costs for additional work required in Improve option	**2,782**
All capital cash costs for improve option (Maintain + Improve works, 100 years)	**31,840**
Annual Maintenance (yearly cash cost)	80
PV Capital costs (100 years, with 30% optimism bias)	**16,051**
PV Maintenance costs (100 years, with 30% optimism bias)	**3,075**
Total PV costs (100 years, with 30% optimism bias)	**19,125**

2.5. Hildenborough Flood Alleviation Scheme

A flood alleviation scheme to protect properties in Hildenborough from flooding from the River Medway has been developed separate to this IA. If any scheme at Hildenborough were taken forward to OBC stage it should be considered together with Improve Leigh FSA to ensure a strategic catchment-wide approach to flood plain management.

The scheme as currently conceptualised consists of construction of a 1.25km defence on the boundary of several sports pitches, comprising mostly earth embankment, some sheet-piling with two flood gates, a flow control structure, local drainage works, diversion of a water main and provision of a permanent area of hardstanding for mobile pumps. The proposed defence alignment is to the south of Hildenborough and to the east of the railway line. The capital cash cost (including 60% optimism bias) of the option has been calculated by AECOM as £3M and has been used to estimate a benefit cost ratio in this IA. Costs of £10k annual maintenance and £65k 10-yearly capital cash costs have also been included.

If the Hildenborough scheme were to be taken forward to detailed appraisal, it would be in combination with the Leigh FSA Improve scheme. Given the reduction in flood depths as a result of the increased storage at Leigh, an alternative shorter and lower defence alignment may be possible along the line of Hawden Lane. It is estimated that this could reduce the capital cash cost to about a third of the option described above. This lower cost will be used as a sensitivity test in this IA and further work to review defence alignments can be undertaken if the option is progressed to the detailed appraisal stage.

3. Flood Risk Management Options: River Beult and River Teise

3.1. Introduction

In the catchment, 965 residential properties are modelled to be currently at significant risk of flooding (defined by Defra as being at risk in the 1.3% (1 in 75) AEP event with some residential property flooding expected to occur, on average, every 5 to 10 years. A majority of the properties at risk are located in the area around the confluences of the Rivers Beult, Medway and Teise. While some properties are in village centres (including for example, those on the left bank of the River Beult in Yalding and those in Collier Street), many are isolated or in small clusters in the wider rural area.

The CFMP, the MMS and the Strategy Review all investigated options for upstream flood storage on the River Beult and the River Teise. For each location, storage resulted in a reduction in downstream flood risk but was typically outweighed by both the estimated significant cost of creating a FSA and the detrimental flooding of upstream properties when water was impounded. Flood storage options were therefore never progressed to a short list for full economic appraisal. The rural isolated nature of many of the properties at risk means that a catchment-wide flood risk management scheme such as upstream flood storage will potentially provide benefit to more properties compared with a local protection scheme. Upstream flood storage options have therefore been investigated further as part of this study.

There may also be opportunities to incorporate biodiversity enhancements within the design of any FSAs. Any opportunities to create and restore habitats will help to contribute to England’s Biodiversity Strategy 2020 targets and funding Outcome Measure 4a. No specific opportunities have been identified at this stage, but this should be explored further as part of any detailed appraisal if these options are taken forward.

Previous studies have also assessed a local protection scheme for Yalding and conveyance improvement options along the River Beult and the River Medway. These options have also been investigated further as part of this study.

3.2. Do Nothing

Do Nothing is the economic baseline against which all other options are compared. Under Do Nothing, operation of the Leigh FSA would cease, increasing flood flows on the River Medway and hence increasing flood risk to downstream communities. Flood risk would further increase in the future as a result of climate change. For the purpose of this assessment, the Do Nothing option is considered broadly comparable to the undefended scenario and is assumed to have zero cost.

3.3. Maintain

The Maintain option is as per the existing situation, with operation of the Leigh FSA control structure to impound flood water to the NMOWL of 28.05m AOD, reducing downstream flow on the River Medway. The costs of this option are as set out in Table 2-1 in the previous section. While the Maintain option has some flood risk benefits to communities on the River Medway downstream of Tonbridge, for those communities which flood from the River Beult and / or the River Teise, the Maintain option is equivalent to the Do Nothing option. Flood risk is expected to increase over time as a result of climate change.

3.4. Improve: River Beult Flood Storage

3.4.1. Required Storage Volumes

Results from the JBA hydraulic model were used to calculate the volume of water which would need to be stored to reduce flow in the River Beult, downstream of Stilebridge during flood events. These calculations assumed discharge of a peak throttled flow, with three maximum outflows tested: 20% (1 in 5), 10% (1 in 10) and 5% (1 in 20) AEP event flows. The results are given in Table 3-1. Storage volume requirement calculations for the Upper Beult at Headcorn are provided in Appendix C.

Table 3-1 River Beult at Stilebridge storage volume requirement calculations

Maximum throttled flow		Volume of storage required (m3) to store the specified design flood event			
Design event (AEP)	Flow (m3/s)	10% (1 in 10)	5% (1 in 20)	2% (1 in 50)	1% (1 in 100)
20% (1 in 5)	52	880,000	2,080,000	7,150,000	10,480,000
10% (1 in 10)	68	-	640,000	4,150,000	6,290,000
5% (1 in 20)	83	-	-	2,000,000	3,580,000

3.4.2. Potential Storage Locations

Appendix C describes the review of potential River Beult storage locations, with a summary provided below. These locations are illustrated on the figures provided in Appendix A.

Identification Method

For each identified location, LiDAR, OS Mapping and the NRD was used to first assess the maximum feasible storage level. For those locations considered technically feasible, volumetric calculations were then undertaken using LiDAR and modelled flood extents and levels to understand the potential storage that would be available at this level, both above ground level and taking into account the volume already utilised by naturally-occurring floodplain storage. This storage was then compared with the calculated storage volume requirements described above.

Headcorn

A potential storage location on the Upper Beult was identified immediately upstream of Headcorn Aerodrome. The presence of properties both in Smarden and the surrounding area restricts the storage level which could be achieved without making property flooding worse, with the maximum feasible storage level estimated to be 21.75m AOD. This would require a 600m length embankment up to 2.25m high, with some local protection for upstream properties. With outflow throttled to the 10% (1 in 10) AEP flow (37m^3/s), an estimated 480,000m^3 of storage could be provided. This would be sufficient to store the 5% (1 in 20) flood event, but not sufficient to store the 2% (1 in 50) flood event. The full results for a range of throttled flows and standards are provided in Appendix C.

This analysis demonstrates that while this location could provide some local benefits to the villages of Headcorn and Staplehurst, and isolated properties / small communities immediately downstream, it would not provide a high SoP. Furthermore, the site is over 20km upstream of Yalding and encompasses only approximately 30% of the total River Beult catchment. It is therefore likely that storage in this location would provide negligible flood risk benefit to the downstream communities (including Yalding) which are the focus of this assessment. For this reason, flood storage in this area was not taken forward for detailed analysis and appraisal.

Headcorn to Stilebridge

LiDAR, OS Mapping, the NRD and hydraulic model results were used to determine whether any potential flood storage locations are available between Biddenden Road, Headcorn and Stilebridge. The natural floodplain is extensive in this area and stored water levels in any FSA would have to be higher than the existing flood level to achieve any additional storage volume. There are however numerous farms and clusters of properties on ground just above the natural floodplain level. The presence of all of the properties means that meaningful flood storage cannot be created in this area without significant adverse impacts which would be technically difficult and costly to mitigate. For this reason, flood storage in this area was not considered technically viable and was not be taken forward for further consideration. It is also noted that the very flat gradient on the River Beult means that a FSA created downstream at Chainhurst (see next section) will “back up” and store water in some of the area upstream of Stilebridge without the need to create a separate FSA upstream of Stilebridge.

Chainhurst

A potential storage location on the Lower Beult at Chainhurst was identified as part of the MMS Review (Halcrow, 2010) and has been further investigated as part of this study. The site is less than 5km upstream of Yalding and encompasses over 85% of the total River Beult catchment. Of all the locations considered, it is therefore the most likely site for a scheme which could reduce flood risk in and around Yalding.

The presence of properties in Chainhurst, Tilden and upstream of Stilebridge restricts the storage level which could be achieved without making property flooding worse, with the maximum feasible storage level estimated to be 15.75m AOD. This would require a 720m length embankment up to 3m high across the Beult valley upstream of Hunton Road / East Street, with some local protection for properties on Tilden Lane (immediately downstream of Stilebridge), and at Old Hertsfield, Hurst Green and Riverfield Fish Farm.

Flooding in the area around Chainhurst is complex, with floodwater from the River Beult flowing southwards and inundating the Tilden area. This same area can also flood from the River Lesser Teise located further to the south. Construction of an embankment at Chainhurst would re-route floodwater from the River Beult into the low-lying Tilden area and then into the Lesser Teise floodplain, from where it would re-join the River Beult upstream of Yalding. The embankment would therefore effectively only partially reduce and delay the peak flow in the River Beult at Yalding while increasing the risk of flooding to numerous properties around Chainhurst and Tilden. Preventing this re-routing of floodwater would require construction of around 3km of side embankments (1 – 2m high) to the south of the River Beult. These side embankments will also protect properties in this area and prevent any worsening of existing flood risk.

With outflow throttled to the 10% (1 in 10) AEP flow ($68m^3/s$), an estimated $3.4Mm^3$ of storage could be provided. This would be sufficient to store the 5% (1 in 20) flood event, but not sufficient to store the 2% (1 in 50) flood event. If outflow was throttled to the 5% (1 in 20) AEP flow ($83m^3/s$), an estimated $2.1Mm^3$ of storage could be provided, sufficient to store the 2% (1 in 50) flood event. The full results for a range of throttled flows and standards are provided in Appendix C.

3.4.3. Preferred Storage Location for Detailed Appraisal

The FSA at Chainhurst (15.75m AOD storage level with a passive outfall structure to throttle downstream flow to a maximum of 75m^3/s) is the preferred location for flood storage on the River Beult and has been taken forward for detailed analysis and appraisal. It will however require significant lengths of embankment to be constructed, prohibitively increasing scheme cost unless a local source of fill material can be secured. Provision for drainage through the side embankment will also need to be made to ensure that conveyance is maintained under non-flood conditions. Furthermore, the analysis summarised above and detailed in Appendix C demonstrates that while useful flood storage can be provided in this location, this option alone will not provide a high SoP to properties in and around Yalding.

In order to provide 10.5Mm^3 of storage (enough to store the 1% AEP flood event, while restricting downstream flow to the 20% AEP peak (50m^3/s)), water would have to be stored to a level of 17.25m AOD. Storage to this level would require a 4.5m high main embankment and 2.5 – 3.5m high side embankments and would flood up to 70 mainly residential properties between Hawkenbury Bridge and Chainhurst. Providing this volume of storage along the River Beult, and thus the higher SoP to downstream communities, is therefore not viable.

3.4.4. Option Costs

The option costs for the River Beult FSA at Chainhurst are presented in Table 3-2, both as cash costs for individual works items and as discounted PV costs over the 100 year appraisal period. It is noted that this option includes all of the costs to maintain the existing Leigh FSA (as described in Section 2.3). More detail about the method used and assumptions made when calculating these costs is provided in Appendix F.

Table 3-2 River Beult (Chainhurst) FSA Option Costs

Item	Cost (£k)
All initial capital works required under “Maintain Leigh FSA” option	See Table 2-1
River Beult FSA Appraisal, design & management	993
Estates purchase and landowner compensation for River Beult FSA	500
River Beult FSA construction	4,965
Initial capital cash costs for River Beult FSA	**6,458**
10-yearly works for River Beult FSA	263
Future capital works required under “Maintain Leigh FSA” option	See Table 2-1
All capital cash costs (Maintain Leigh FSA + River Beult FSA, 100 years)	**37,885**
Annual Maintenance for Leigh FSA	See Table 2-1
Annual Maintenance for River Beult FSA (yearly cash cost)	25
PV Capital costs (100 years, with 30% optimism bias)	**21,236**
PV Maintenance costs (100 years, with 30% optimism bias)	**3,618**
Total PV costs (100 years, with 30% optimism bias)	**24,854**

3.5. Improve: River Teise Flood Storage

3.5.1. Required Storage Volumes

Results from the hydraulic model were used to calculate the volume of water which would need to be stored to reduce flow in the River Teise at Stonebridge during flood events. These calculations assumed discharge of a peak throttled flow, with three maximum outflows tested: 20% (1 in 5), 10% (1 in 10) and 5% (1 in 20) AEP event flows. The results are given in Table 3-3.

Table 3-3 River Teise storage volume requirement calculations at Stonebridge

Maximum throttled flow		Volume of storage required (m3) to store the specified design flood event			
Design event	Flow (m3/s)	10% (1 in 10)	5% (1 in 20)	2% (1 in 50)	1% (1 in 100)
20% (1 in 5)	49	200,000	700,000	1,610,000	2,930,000
10% (1 in 10)	63	-	290,000	1,020,000	1,930,000
5% (1 in 20)	83	-	-	420,000	1,080,000

3.5.2. Potential Storage Locations

Appendix C describes the review of potential River Teise storage locations, with a summary provided here. These locations are illustrated on the figures provided in Appendix A. The method used to identify locations was as per that described for the River Beult above.

Cottage Wood

A potential storage location at Cottage Wood on the River Teise (about 2km downstream of Stonebridge) was identified as part of the MMS Review (Halcrow, 2010). This has been further investigated as part of this study. The site is upstream of the split into the Lower and Lesser Teise, about 4km upstream of Collier Street and 11km upstream of Yalding. It encompasses 78% of the total River Teise catchment. Locations further downstream are unsuitable for flood storage because of the significant increase in width of the floodplain and the presence of many low-lying properties.

The floodplain upstream of the proposed embankment location is rural and so a storage level of 27.5m AOD was selected on the basis on a reasonable maximum embankment height for this location and to prevent any increase in the risk of flooding of Goudhurst Road. This would require a 470m length embankment up to 3.5m high across the Teise valley.

With outflow throttled to the 10% (1 in 10) AEP flow ($63m^3/s$), an estimated $1Mm^3$ of storage could be provided. This would be sufficient to store the 2% (1 in 50) flood event, but not sufficient to store the 1% (1 in 100) flood event. The full results for a range of throttled flows and standards are provided in Appendix C.

The analysis carried out in this Initial Assessment has shown that flood storage on the River Teise could lower the level of flooding in downstream communities if a suitable site is identified. The only flood storage areas suitable on the River Teise have spatial and technical limitations that would need to be assessed and overcome. The flood event size and distribution in the downstream areas are dependent on the location and passage of the weather events experienced and this would need to be considered. There is potential for reduction of flows in Chainhurst from the Teise storage areas, however, this would also require storage on the Beult to be implemented.

Stonebridge

Previous work has also investigated a storage location 500m upstream of Stonebridge. Taking into account upstream properties and assets, and maximum recommended embankment heights, the recommended storage level at this location is 30.5m AOD. This would require a 460m embankment up to 3.5m high across the Teise valley upstream of Stonebridge. Storage to this level would also require mitigation to prevent detrimental impact to properties.

The full volumetric calculation results (provided in Appendix C) indicate that this site alone does not provide sufficient storage volume to attenuate flows on the River Teise. It could however be considered in combination with the downstream Cottage Wood FSA.

Cottage Wood and Stonebridge Cascade System

With outflow throttled to the 10% (1 in 10) AEP flow (63m3/s), an estimated 1.8Mm3 of storage could be provided by the two FSAs. This is the maximum storage volume that could be achieved without adverse effects, however this falls short of that required to store a 1% (1 in 100) event. The full results for a range of throttled flows and standards are provided in Appendix C.

In order to provide 2.9Mm3 of storage (enough to store the 1% AEP flood event, while restricting downstream flow to the 20% (1 in 5) AEP peak (50m3/s)), water would have to be stored to a level of 27.5m AOD at Cottage Wood and to a level of 32m AOD upstream of Stonebridge. Storage to this higher level upstream of Stonebridge would require a 4.5m high embankment and would flood a number of residential properties and a pumping station. Providing this volume of storage along the River Teise, and thus the higher SoP to downstream communities is therefore not viable.

Preferred Storage Locations for Detailed Appraisal

The Cottage Wood and Stonebridge options have been taken forward for detailed analysis and appraisal within this initial assessment study. Both Cottage Wood and Stonebridge could provide flood storage on the River Teise, with recommended storage levels of 27.5m AOD and 30.5m AOD respectively, and outfall structures that throttle downstream flow to a maximum of 60m3/s. Storage on the River Teise could either be provided as a single FSA at Cottage Wood, or as a dual cascade of both Stonebridge and Cottage Wood FSA.

It is noted here that the River Teise typically responds quicker to rainfall than either the River Beult or the River Medway. There is therefore a risk that flood storage on the River Teise with a passive control structure will act to delay the flood peak such that it would then coincide with one or both of the flood peaks on the other rivers, worsening flood risk for some areas downstream. The chance of this occurring is dependent on the amount and spatial pattern of rainfall received, antecedent conditions, operation of Leigh FSA and resulting flows on each of the rivers for any given event at any given location. Providing worthwhile flood risk reduction through the means of passive flood storage on the River Teise is dependent on the rainfall event happening in a particular manner. It is not possible to design a passive structure that provides the same level of risk reduction across the normal variety of rainfall events experienced in the catchment. If flood storage on the River Teise is taken forward to the OBC stage, a detailed consideration of the risk of coincident flood peaks and worsening of flood risk will be required.

3.5.3. Option Costs

The option costs for the River Teise FSAs at Cottage Wood and Stonebridge are presented in Table 3-4, both as cash costs for individual works items and as discounted PV costs over the 100 year appraisal period. It is noted that these options include all of the costs to maintain the existing Leigh FSA (as described in Section 2.3). More detail about the method used and assumptions made when calculating these costs is provided in Appendix F.

Table 3-4 River Teise FSA Option Costs

Item	Cost (£k)	
	Cottage Wood	Cottage Wood and Stonebridge
All initial capital works required under "Maintain Leigh FSA" option	See Table 2-1	
River Teise FSA(s) Appraisal, design & management	421	704
Estates purchase and landowner compensation for River Teise FSA(s)	200	400
River Teise FSA(s) construction	2,479	4,365
Initial capital cash costs for River Teise FSA(s)	3,101	5,470
10-yearly works for River Teise FSA(s)	131	231
Future capital works required under "Maintain Leigh FSA" option	See Table 2-1	
All capital cash costs (Maintain Leigh FSA + River Teise FSA(s), 100 years)	33,342	36,610
Annual Maintenance for Leigh FSA	See Table 2-1	
Annual Maintenance for River Teise FSA(s) (yearly cash cost)	5	10
PV Capital costs (100 years, with 30% optimism bias)	16,727	19,917
PV Maintenance costs (100 years, with 30% optimism bias)	2,894	3,256
Total PV costs (100 years, with 30% optimism bias)	19,621	23,173

3.6. Improve: Yalding Local Defence Scheme

The MMS and the subsequent 2010 review by Halcrow short-listed a local defence option protecting properties on the left bank of the River Beult in Yalding. The findings of the 2010 economic appraisal indicated that the preferred option was for walls providing a 0.5% (1 in 200) AEP SoP. The viability of the option was however dependent on securing partnership funding and significant uncertainty was associated with the defence alignment, affecting landscaping and compensation costs to the multiple private landowners affected. The option to provide a local defence on both the western and eastern sides of Yalding has been taken forward for high-level analysis and appraisal.

The Yalding local defence option has significant technical constraints. By obstructing flow and removing flood plain storage, local walls around Yalding would displace food water and result in worsening of flood risk to residents upstream of Yalding. It is unlikely that this worsening of risk could be mitigated.

3.6.1. Required Works

JBA Consulting have modelled a local defence option, from which the length and height of the required defence can be calculated for a range of SoPs. The option was modelled in combination with the works to increase storage at Leigh and required defence height results are given in Table 3-5.

It is noted that these are for a present day SoP (without climate change) and exclude any freeboard allowance. They are also based on average modelled water levels along the entire defence length. For the western defence 1.3% (1 in 75) AEP SoP for example, the required defence height is less than 1m along the southern section, but 2.5 – 3m in the northern corner alongside the River Beult to the south of Yalding Bridge.

Table 3-5 Yalding Local Defence Scheme required defence heights

SoP (AEP)	Required average defence height (without freeboard)	
	West (left bank)	East (right bank)
5% (1 in 20)	1.10	1.33
2% (1 in 50)	1.40	1.63
1.3% (1 in 75)	1.78	1.74
0.4% (1 in 250)	2.01	1.79

The west (left bank) defence is estimated as 1.5km long, include two road crossings and would entirely circle the left bank Yalding community for SoP greater than 1.3% AEP (1 in 75). It would also include two road crossings. The east (right bank) defence is estimated as 275m long. A combination of earth embankments and walls would be required, with space particularly limited on the left bank to the north and south of Yalding Bridge where it is assumed that a piled solution would be required.

3.6.2. Option Costs

A construction cost estimate of £2.9M has been provided by the Environment Agency, based on a 1.78km defence length, a 70/30 split for embankment / wall and a 2m defence height (to provide a minimum of a 1.3% (1 in 75) SoP with freeboard allowance). This cost includes allowances for site investigation, compensation, a piled solution around the bridge and other construction and design costs (including design and supervision, landscaping, road raising and service diversion). A cost breakdown is included in Appendix F.

Optimism bias of 60%, reflecting the higher level of uncertainty associated with the costings, results in a total capital cash cost to £4.6M. An estimate of £8k annual maintenance and £50k every 10 years for active structure maintenance (e.g. flood gate refurbishments) has also been included in order to determine a present value cost.

3.7. Improve: Conveyance

3.7.1. Yalding Bridge Arch Opening

The CFMP, MMS and 2010 review (Halcrow, 2010) assessed the effectiveness of conveyance improvements in reducing flood risk. One of these conveyance improvements was to provide an additional open arch in Yalding Bridge. Model results in 2010 indicated that for a 1% (1 in 100) flood event, the additional arch reduced upstream water levels by 10mm, with a corresponding negligible reduction in flood damages. The bridge is a

Scheduled Monument and the anticipated difficulty of obtaining consent for the work combined with the negligible impact on flood risk meant that the option was not taken forward for further investigation. Simulation of this option in the updated model is not expected to change the 2010 conclusion and therefore the bridge arch option was not taken forward for detailed analysis and appraisal in this IA.

3.7.2. River Medway Deepening and Widening

Another proposed conveyance improvement in the CFMP was the deepening and / or widening of the River Medway channel between Yalding and Maidstone. Previous studies have concluded that backwater effects from the Medway are a key contributing factor to flood risk in Yalding. Improving conveyance in the River Medway may therefore improve outflow from the River Beult during a flood event, reducing water levels in / around Yalding. The Environment Agency have estimated that this option could cost in the region of £95M.

Given the prohibitively high cost, the construction challenges and the potentially significant adverse environmental impacts (see Section 5), a full economic appraisal of this option was not undertaken. It was however simulated in the hydraulic model for a single design flood event, in order to better understand the scale of benefits which could be achieved. The results of this hydraulic modelling are provided in Section 4.3.

4. Option Modelling

4.1. Background and Scope

The Environment Agency commissioned JBA Consulting to undertake the ‘Medway Catchment Mapping and Modelling Study’ in 2013 to update the River Medway 2D hydraulic model to use the most up-to-date technology, methods and historic flood information. The new model results were notably different to those available at the time of the MMS Review (Halcrow, 2010). This IA has therefore made full use of the new model to obtain output for the Do Nothing (undefended) and Maintain options. The model was also adapted to simulate the following options:

- Improve Leigh FSA (NMOWL increased to 28.85m AOD);
- River Beult FSA at Chainhurst, with Leigh FSA maintained;
- River Beult FSA at Chainhurst and River Teise FSA at Cottage Wood, with Leigh FSA maintained;
- River Beult FSA at Chainhurst and River Teise FSAs at Cottage Wood and Stonebridge, with Leigh FSA maintained;
- River Beult FSA at Chainhurst and River Teise FSAs at Cottage Wood and Stonebridge, with Improve Leigh FSA (NMOWL increased to 28.85m AOD); and
- Conveyance improvements along the River Medway downstream of Yalding (2% (1 in 50) AEP event only).

As this IA was being completed, the Environment Agency commissioned some additional option modelling for use in public consultation. This included the following:

- River Teise FSAs at Cottage Wood and Stonebridge (passive control structures), with Improve Leigh FSA (NMOWL increased to 28.85m AOD);
- River Teise FSAs at Cottage Wood and Stonebridge (active control structures), with Improve Leigh FSA (NMOWL increased to 28.85m AOD); and
- Improve Leigh FSA (NMOWL increased to 28.85m AOD) with local defence walls along both the left and right bank of the River Beult through Yalding.

4.2. Option Modelling Summary

Appendix D provides full details of the updates made to the hydraulic models to simulate the flood risk management options under six AEP events: 20% (1 in 5), 5% (1 in 20), 2% (1 in 50), 1.33% (1 in 75), 1% (1 in 100) and 0.4% (1 in 250).

4.2.1. Models, Output Zones and Hydrology

In each case, options were simulated in the appropriate models and output zones from the following list:

- Model 2 (single output zone): Downstream of Leigh FSA to Hartlake Bridge, including the River Medway, Hilden Brook and Hawden Stream;
- Model 3, sub-divided into:
    - Output Zone 1: River Medway – Cannon Lane / Vale Road to upstream of the River Bourne confluence (East Peckham);

  - Output Zone 2: River Medway – Upstream of the River Bourne confluence (East Peckham) to downstream of the A228 including the River Bourne and the Coult Stream;
  - Output Zone 3: Confluence of River Medway, River Beult and River Teise around Laddingford and Yalding to the River Medway at East Farleigh;
  - Output Zone 4: River Beult – Smarden to Headcorn;
  - Output Zone 5: River Beult – Headcorn to upstream of Yalding; and
  - Output Zone 6: River Teise – Stonebridge (Horsmonden) to the confluence of the Lesser Teise and River Beult (Benover) and the River Teise upstream of Laddingford.
- Model 4 (single output zone): River Medway from Teston to Allington Lock, Maidstone, including the River Len.

The original hydrology from the mapping and modelling study was maintained for use in the option modelling.

A set of hydrological inputs on each modelled watercourse, derived using the continuous simulation methodology (see model reporting for more information) provides the design event hydrology for each output zone in Model 3. The relative flows on each watercourse therefore varies both by location and design event, with the final results for the Model 3 area, a composite of the resulting flood risk mapping outputs in each output zone.

The contribution to flooding from the tributaries around the River Medway, River Beult and River Teise confluences can influence the predicted flooding in the area, even if for instance the cumulative flow downstream of their confluence is the same. This is particularly true for Yalding, situated at the confluence of these watercourses. In Output Zone 3 (which includes Yalding) for example, the 5% (1 in 20) AEP event has been simulated to be River Beult and River Teise dominated, with comparably lower flows on the River Medway. In contrast, the 2% (1 in 50) AEP event has been simulated to be River Medway dominated, with comparably lower flows on both the River Beult and River Teise. Appendix D provides tables and graphs which document this type of information for each model output zone and each design flood event, with contributing flows on each watercourse expressed as return periods to enable direct comparisons.

There is also connectivity between the River Beult and the Lesser Teise in the Chainhurst area, such that a significant event on the River Beult could lead to floodplain flow in this area, worsening flooding in the Collier Street and Benover communities regardless of flood flows in the River Teise catchment. In Output Zone 6 (which includes Collier Street) for example, the 2% (1 in 50) and 1% (1 in 100) AEP events have been modelled with a comparatively low flow on the River Beult, but both the 5% (1 in 20) and 1.3% (1 in 75) AEP events have been modelled with a much higher River Beult flow, worsening predicted flooding in this area.

The modelled contribution to flooding from each watercourse is important to understand because of the impact it could have on the modelled benefits of each of the options. Using the Output Zone 3 example from above, the modelled Medway-dominated 2% (1 in 50) AEP event with the lower flows on the River Beult and River Teise, would not be expected to show as significant a reduction in flood risk with the new FSAs implemented, compared with if this event were to be modelled with higher flows on the River Beult and River Teise. If any of these new FSA options are taken forward to the OBC stage, further modelling will be required to test option benefits under a range of different watercourse flow combinations.

Inflows to Model 4 are not predicted flows cascaded down from Model 3, but are instead extracted from the continuous simulation hydrological modelling at the model node representing East Farleigh gauging station. To understand how the new FSAs on the River Beult and River Teise would reduce flood depths through Maidstone, the peak flows predicted at East Farleigh gauging station for each of the design events and for each option within Model 3, Output Zone 3 were compared, and the percentage reduction in peak flows were applied to the Medway inflow implemented within Model 4 for that given design event. The scaling factors are provided in Appendix D.

4.2.2. Option Modelling Methods

Improve Leigh FSA

The logical rules controlling the Leigh FSA gate operation were updated to raise the water level at which the gates open to pass forward all inflow from the existing NMOWL of 28.05m AOD to the new proposed NMOWL of 28.85m AOD. This was the only edit made to the existing model and resulted in revised outflows from the Leigh FSA, giving revised inflows into the Model 2 flood risk mapping model.

River Beult and River Teise FSAs

Four embankments for the Chainhurst FSA were simulated in the model: the main embankment with an elevation of 15.75m AOD, and side embankments with an elevation of 16.5m AOD south of the River Beult in the Tilden / Chainhurst area, protecting properties along Tilden Lane (downstream of Stilebridge) and protecting properties at Old Hertsfield. Flows passing downstream through the main embankment were restricted to 75m^3/s.

On the River Teise, embankments were simulated in the model with elevations of 27.5m AOD at Cottage Wood and 30.5m AOD upstream of Stonebridge. Flows passing downstream through the main embankment were restricted to 60m^3/s.

All embankments were implemented in the model using Z-shapes which raise the model grid cells (to the elevations listed above), preventing water from flowing across the floodplain past the embankment location until floodplain water levels exceed the embankment elevation. The flow control structures implemented at the location of the channel/embankment intersection were implemented in the model using flow-head units, with flow-head relationships derived from the baseline modelling.

River Medway Conveyance Improvements

Conveyance improvements were simulated in the hydraulic model as a 5m widening of the River Medway channel between the confluence with the River Beult near Yalding and Lock Meadow Footbridge in Maidstone with 15% increases in flow area at Teston Bridge and East Fairleigh Bridge (see Appendix D for more details). The option was simulated for the 2% (1 in 50) AEP event and the December 2013 calibration event.

4.3. Option Modelling Results

4.3.1. Reduction in Flood Depths

As described in Section 2 and 3, the flood storage options do not provide a specific SoP to whole communities, but instead act to reduce flood depths over large parts of the catchment. This reduction in flood depth will provide an improvement in the SoP, but the magnitude of this improvement varies on a property-by-property basis depending on variables such as property location and threshold level. For areas at risk from multiple watercourses (for example Yalding), it will also depend on the relative contribution of each watercourse to flooding during any given event.

Table 4-1 documents the reductions in flood depths modelled to occur for the 1% (1 in 100) AEP event for five specific locations within key communities in the study area. Model results were taken from the following locations:

- Tonbridge: Tonbridge High Street near the junction of New Wharf Road;

- Hildenborough: Road junction between Leybank and Brookmead;
- East Peckham: Junction between Old Road and Hale Street / Branbridges Road;
- Collier Street: B2162 (Collier Street) north of Moat Farm; and
- Yalding: Junction between Yalding Bridge (B2010) and Benover Road / Lees Road (B2162).

Table 4-1 Modelled flood depths

Option	Flood depth at specific locations in key communities - 1 in 100 (1%) event (m)				
	Tonbridge	Hildenborough	East Peckham	Collier Street	Yalding
Do Nothing	0.78	0.75	1.04	0.41	1.64
Maintain	0.22	0.38	0.71	0.41	1.47
Improve Leigh FSA	0.10	0.23	0.67	0.41	1.40
Maintain Leigh FSA Beult FSA	-	-	-	0.41	1.35
Maintain Leigh Beult & Teise FSAs	-	-	-	0.26	1.32
Maintain Leigh Beult & Teise x 2 FSAs	-	-	-	0.20	1.31
Improve Leigh FSA Teise x 2 FSAs	-	-	-	0.20	1.35
Improve Leigh FSA Beult & Teise x 2 FSAs	-	-	-	0.20	1.17

Table 4-1 illustrates the benefit of the existing Leigh FSA, with flood depths (at the locations identified above) reduced by 0.56m in Tonbridge, 0.37m in Hildenborough, 0.33m in East Peckham and 0.17m in Yalding. The proposed increase in storage at Leigh would reduce these depths further. FSAs on the River Beult and the River Teise have been modelled to reduce flood depths in Yalding by up to 0.3m when constructed in combination with the Leigh FSA improvements. Flood depths in Yalding however remain high at over 1m. Collier Street would not benefit from Improve Leigh FSA, but flood depths would reduce if FSAs were constructed on the River Teise. It is noted that Collier Street is a dispersed community, with properties across the floodplain, and the flood depth reduction achieved can vary significantly by location.

For the conveyance improvement scenario in the 2% (1 in 50) AEP event, the average reduction of in-channel water level from Yalding Marina to Barning Bridge was 0.23m. This decreased to an average reduction of 0.12m from Barning Bridge to Allington Lock, with a negligible benefit (<0.01m reduction) through Maidstone. In Yalding (at the same location as above) the conveyance improvement scenario reduced floodplain water depths from an existing 1.09m AOD to 0.85m AOD for the 2% (1 in 50) AEP event; a reduction of 0.24m.

5. Environmental Appraisal

5.1. Overview

An environmental appraisal of the six improve options was undertaken as part of this IA. For each option, risks, constraints, opportunities, enhancements and potential mitigation measures were identified for seven environmental topic areas, as follows:

- Air and climate;
- Archaeology and cultural heritage;
- Biodiversity, flora and fauna;
- Land quality, soils and geology;
- Landscape and visual amenity;
- Population and human health; and
- Water, including likely Water Framework Directive (WFD) compliance.

The full appraisal matrices are provided in Appendix E and a summary of the assessment is included below. At this IA stage it was not possible to state an environmental preferred option.

5.2. Environmental Assessment of Options

5.2.1. Improve Leigh FSA

No significant air and climate effects have been identified. The higher storage level has been set by consideration of upstream assets and has not explicitly been designed to accommodate climate change, although the increase in storage volume will contribute to a reduction in flood risk, mitigating short-term climate change impacts.

There are no statutory heritage sites or historical assets within the FSA, although more work should be undertaken to review the increased risk to Penshurst Bridge, which is Grade II listed. While the option reduces flood risk to many properties in Tonbridge and Hildenborough, only two are listed buildings.

There are no statutory designated nature conservation sites within the FSA, although there is the *River Medway South of Leigh* Site of Nature Conservation Interest (SNCI) and several Habitats of Principal Importance. These may be adversely affected by the increase in flood depth and duration caused by the higher impoundment water level. Opportunities for habitat improvement and biodiversity enhancement should be explored at the next stage. Protected species surveys would be required at an appropriate stage of scheme design and mitigation strategies developed where these species are likely to be affected.

Impact on agricultural land is anticipated to be small and limited to minor land losses for embankment construction and / or widening, and the effect of the increase in flood depth and duration within the FSA. The option primarily benefits downstream properties, with only a small reduction in the extent of agricultural land at risk of flooding.

The visual impact of works to the main embankment and defences protecting upstream assets is unlikely to be significant because most of these embanked structures are already present in the landscape. Visual impacts on the *High Weald* Area of Outstanding Natural Beauty (AONB) and from properties and rights of way should however still be considered as part of a Landscape and Visual Impact Assessment, with the use of careful landscaping and sympathetic designs to minimise impact.

Section 2.4.3 documented the locations upstream of the Leigh FSA embankment which could be affected by an increase in NMOWL and identified actions and / or mitigation options to prevent any worsening of flood risk to these assets. It is recommended that development restrictions in the area adjacent to the Leigh FSA are implemented to prevent any future increases in NMOWL being restricted by the presence of upstream assets. The option reduces flood risk to properties in Tonbridge and Hildenborough, and to a lesser extent, East Peckham and further downstream. As well as a reduction in material damage (valued in the economic appraisal in Section 6), there will be local economic benefits associated with reduced business disruption.

5.2.2. River Beult FSA at Chainhurst

No significant air and climate effects have been identified. Depending on the source of embankment material, the large volumes of fill material required means that there are potentially high carbon costs associated with construction. It is difficult to design this option to accommodate likely future climate change because of restrictions on the maximum feasible storage level set by the presence of upstream assets.

There are two listed buildings in the proposed FSA, as defined by the 15.75m AOD contour, for which localised flood protection would need to be provided so that flood risk was not increased to these heritage assets. There are also a number of listed buildings immediately downstream/adjacent to the proposed embankments whose settings could be indirectly affected by the scheme. A number of listed buildings between Chainhurst and Yalding will benefit from the reduction in flood risk achieved by the River Beult FSA, although benefits are limited to relatively few buildings.

The River Beult is designated as a SSSI, which is currently in unfavourable condition due to a decline in water quality and change in habitat structure. The proposed FSA may alter the functioning of the clay-river habitats during large flood events and this will need to be investigated further, with any solution combined with the River Beult Restoration Plan, maximising opportunities to incorporate condition improvements and biodiversity enhancements. Protected species surveys would be required at an appropriate stage of scheme design and mitigation strategies developed where these species are likely to be affected.

Construction of the FSA embankments will result in a direct loss of agricultural land. Furthermore, while land within the FSA is already at risk of flooding, flood depth and duration will be higher if water is deliberately impounded. These adverse impacts may be partially offset by the reduction in flood risk to agricultural land downstream.

While this area is not subject to any statutory landscape designations, the extensive nature of the required embankments is likely to have a significant impact on the local landscape and visual environment. This would need to be mitigated through careful landscaping and screening.

Localised defences would be required to prevent any worsening of flood risk to properties at Stile Bridge, Old Hertsfield and Hurst Green. There are a number of footpaths within the FSA which are already at risk of flooding but would be subjected to a greater flood depth and duration. Flood storage on the River Beult could reduce flood risk to properties downstream including those in Yalding. Benefits are however limited to relatively few properties and the option generally reduces flood depth across a wide area instead of entirely preventing property flooding.

5.2.3. River Teise FSA at Cottage Wood

No significant air and climate effects have been identified. It is difficult to design this option to accommodate likely future climate change because of restrictions on the maximum feasible storage level set by the presence of upstream assets.

There are no designated sites of archaeological or cultural significance within the FSA and the nearby listed buildings are unlikely to be directly affected. A number of listed buildings will benefit from the reduction in flood risk achieved by the River Teise FSA, although benefits are limited to relatively few properties.

There are no statutory designated nature conservation sites within the FSA. There are several Habitats of Principal Importance which may be adversely affected by the increase in flood depth and duration caused by the deliberate impoundment. Opportunities for habitat improvement and biodiversity enhancement should be explored at the next stage. Protected species surveys would be required at an appropriate stage of scheme design and mitigation strategies developed where these species are likely to be affected.

Construction of the FSA embankment will result in a direct loss of agricultural land. Furthermore, while land within the FSA is already at risk of flooding, flood depth and duration will be higher if water is deliberately impounded. These adverse impacts may be partially offset by the reduction in flood risk to agricultural land downstream.

While this area is not subject to any statutory landscape designations, the new embankment is likely to have a moderate impact on the local landscape and visual environment. This would need to be mitigated through careful landscaping and screening.

The floodplain upstream of the proposed embankment is rural and at this stage, no localised protection has been identified as necessary to protect upstream assets. If this option is taken forward, further review of the properties and road with ground levels around 28m AOD is recommended. There are a number of footpaths within the FSA which are already at risk of flooding but would be subjected to a greater flood depth and duration. As described in Section 3.5.3, there is a risk that flood storage on the River Teise with a passive control structure will act to delay the flood peak on the River Teise such that it would then coincide with one or both peaks on the Beult and / or Medway, worsening flood risk for some areas downstream.

5.2.4. River Teise FSA at Stonebridge

No significant air and climate effects have been identified. It is difficult to design this option to accommodate likely future climate change because of restrictions on the maximum feasible storage level set by the presence of upstream assets.

The *Medieval moated site at Share Farm*, a Scheduled Monument, is situated approximately 100m upstream of the proposed embankment. The *Share Farm* Grade II listed building is also located approximately 250m upstream of the embankment. These would be indirectly affected by the construction of the new embankment within their valley setting, and directly affected by an increase in the depth and duration of flooding due to impoundment within the FSA. This could pose a significant constraint to the progression of the option and would require early consultation with the relevant heritage consultees and careful mitigation. A number of listed buildings will benefit from the reduction in flood risk achieved by the River Teise FSA, although benefits are limited to relatively few properties.

There are no statutory designated nature conservation sites within the FSA and few Habitats of Principal Importance. Opportunities for habitat improvement and biodiversity enhancement should be explored at the next stage. Protected species surveys would be required at an appropriate stage of scheme design and mitigation strategies developed where these species are likely to be affected.

Construction of the FSA embankment will result in a direct loss of agricultural land. Furthermore, while land within the FSA is already at risk of flooding, flood depth and duration will be higher if water is deliberately impounded. These adverse impacts may be partially offset by the reduction in flood risk to agricultural land downstream.

The proposed FSA falls entirely within the *High Weald* AONB and the embankment is likely to have a significant impact on the AONB and the historic landscape as viewed from Share Farm and the adjacent Scheduled Monument. It is also likely that the embankment would be visible from Goudhurst Road. These landscape impacts could pose significant constraints to the progression of a FSA in this location unless carefully managed and mitigated.

The floodplain upstream of the proposed embankment is predominantly rural and localised protection has only been identified as necessary for Share Farm. There are however a number of other upstream assets for which further review is recommended if this option is taken forward. A public right of way runs parallel to the proposed embankment and while it is already at risk of flooding, it would be subjected to a greater flood depth and duration. As for the FSA at Cottage Wood, there is a risk that flood storage here could cause coincident flood peaks, worsening downstream flood risk and potentially necessitating an actively controlled flow structure. A high volume of flood storage cannot be achieved in this location alone, but when combined with an FSA at Cottage Wood, this option could reduce flood risk to properties downstream including those in Collier Street and Yalding.

5.2.5. Yalding Local Defence Scheme

No significant air and climate effects have been identified. The desired SoP can be achieved through varying the defence height, taking current climate change projections into account. It is therefore possible to design the option to accommodate future climate change and / or to allow future adaptation to manage the realised impacts of climate change.

There are a number of listed buildings in Yalding and Town Bridge is designated as a Scheduled Monument. While the walls would not directly physically impact any cultural heritage assets, there may be impacts on the setting of these assets depending on the location, height and construction type of the proposed defence. A number of listed buildings in Yalding could benefit from the reduction in flood risk achieved by the local defences.

The River Beult is designated as a SSSI, and while the new defences are unlikely to have any direct impacts on the river, opportunities to incorporate condition improvements and biodiversity enhancements should be maximised where possible. Protected species surveys would be required at an appropriate stage of scheme design and mitigation strategies developed where these species are likely to be affected.

There will be some direct loss of agricultural land due to the footprint of the new defences, but this loss will be limited because the proposed defence alignment is on the boundary of the urban area.

The historic village of Yalding has a high landscape quality and the introduction of new flood walls and embankments has the potential to detract from this. A high visual impact is anticipated for residents and visitors / recreational users. Furthermore, space is limited through the private land along the River Beult, with careful design and landowner consultation required.

The local defence scheme has the potential to significantly reduce the risk of flooding to many properties in Yalding. The proposed defence alignment crosses several roads, at which it is assumed that temporary defences will be required, utilised during a flood event. The ring-fence style of the alignment also means that pumps are likely to be needed to remove flood water should the defences be overtopped during an event which exceeds the design standard. There is a risk that the loss of floodplain storage in the urban area of Yalding will increase flood risk to neighbouring areas, increasing the extent and depth of flooding on adjacent agricultural land.

5.2.6. River Medway Conveyance Improvements

The widening of the channel would generate large quantities of waste material which would either have to be reused on site (if possible) or disposed of at an off-site facility. Conveyance improvements can reduce water levels during flood events but would not be specifically designed to accommodate future climate change.

The most significant constraint to the proposals would be the required works to the Medway bridges at Teston and East Farleigh, both of which are designated as Scheduled Monuments and therefore require consent to undertake any works. Without major alterations to these bridges the intended increase in conveyance is unlikely to be achieved, but the required alterations are unlikely to be acceptable from a heritage perspective. There are also numerous listed buildings likely to be indirectly affected by conveyance improvement works, particularly in Wateringbury and East Farleigh.

The linear nature of the option means that impacts on biodiversity, flora and fauna are likely to be high, requiring tree removal, loss of established bankside vegetation, disturbance to bankside habitats, disturbance to fish migration and significant changes to existing instream habitats. Flow alterations could result in longer term changes to instream habitats post-construction. Conversely, with careful mitigation, there may be opportunities to improve the habitat diversity along the riverbanks, contributing to England’s Biodiversity Strategy 2020 targets.

The widening work and associated excavation presents a risk of encountering contamination along the route. This risk would need to be accounted for in planning for any material re-use or disposal.

Although there are no statutory landscape designations, the extensive nature of the works, changes to established mature vegetation patterns and changes to the channel and historic structures would create a highly significant short-term change to the landscape and visual environment of the river. The current setting of the Medway is largely rural and undeveloped and so opportunities for significant improvement over and above the current landscape quality are likely to be limited.

The principal benefit of this option is the reduction in flood risk to properties in Yalding. The option is however likely to have significant adverse effects on recreational users of the Medway with temporary impacts for residents living close to the river, and likely requirements for service diversion.

5.3. WFD Compliance

The environmental appraisal matrices (Appendix E) identify the waterbodies which could be affected by the options. A preliminary WFD compliance assessment was undertaken as part of the MMS review (Halcrow, 2010) for the Improve Leigh FSA and Yalding local defence scheme options. This concluded that both options are likely to be compliant, with no anticipated waterbody deterioration and no prevention of implementation of the mitigation measures.

Compliance checks for the other four options (River Beult and River Teise FSAs and River Medway conveyance improvements) were not undertaken as part of the MMS review and so brief consideration of likely compliance has been made as part of this IA.

For the new FSAs, channel form or function will not be directly affected and so it is considered unlikely that the option will prevent waterbody objectives from being met. Furthermore, out-of-bank flows and floodplain inundation already regularly occurs in these area and 'normal' flows in the rivers will be unaffected, with only the highest flood flows throttled by the new control structure. There will however be a loss of the natural river channel where the rivers flow through the new embankments, albeit over a very short distance relative to the overall waterbody lengths. All of these options would probably require consideration of, or a need to include some WFD mitigation to ensure that there was no change to the 'normal' flow regime, ensure that any sediment transport issues were addressed and that any natural channel losses were compensated for. Structures conveying the channel through the embankment would need to allow for passage of fish, and FSA drawdown would also need to ensure escape routes for fish to avoid stranding on the floodplain following drawdown of the flood water.

For the River Medway conveyance improvements, there is however a high risk of non-compliance with the requirements of the WFD because the option conflicts with a number of the mitigation measures identified in the River Basin Management Plan (RBMP). These mitigation measures are listed in the matrix in Appendix E. This risk of WFD non-compliance presents a significant constraint to the progression of this option.

As well as ensuring that options cause no deterioration in waterbody status, and do not prevent the implementation of mitigation measures, any work relating to the WFD should seek to identify opportunities for contributing towards the RBMP waterbody objectives.

A full preliminary WFD compliance assessment should be undertaken to examine the potential impacts and opportunities associated with all of the options, with confirmation of in-principle compliance recommended for those options being taken forward. A full WFD assessment is then recommended at the next stage to include more detailed examination of the potential impacts and opportunities, and liaison with the relevant internal functions of the Environment Agency.

6. Flood Economic Appraisal

6.1. Introduction

The economic assessment has followed the principals of the Flood and Coastal Erosion Risk Management – Appraisal Guidance (FCERM-AG) (Environment Agency, 2010), as updated by supplementary guidance on the Defra website. Depth damage data has been taken from the Multi-Coloured Manual (MCM) (Flood Hazard Research Centre, 2015). In accordance with Treasury guidance a 100 year appraisal period has been used and the Treasury variable discount rate has been applied.

The full economic flood damage methodology is detailed in Appendix F. This chapter summarises the methodology and presents and discusses the results.

6.2. Methodology Overview

The baseline economic flood damage assessment included calculation of the following:

- Property damages for the Medway catchment study area. This used the:
    - NRD (version 4, 2015) and Mastermap building outlines to derive the property dataset;
    - maximum flood depth extracted at each property location from the hydraulic model results for a range of design flood events and for each modelled scenario;
    - MCM methodology and depth damage curves (as updated in 2015);
    - threshold survey information where available, and where not available, assumed thresholds of 150mm for residential properties and 50mm for non-residential properties; and
    - Cap on property damages at their current market value calculated either from residential property price data uplifted by the Distributional Impact (DI) factor, or from non-residential rateable values factored by the gross annual rental yield.
- Evacuation costs for residential properties experiencing above floor level flooding.
- Vehicle damages, using the average value of a UK motor vehicle of £3,100.
- Cost of emergency services, estimated as 5.6% of the total property damages.
- Risk to life, estimated as a 1% addition to the total calculated flood damages.

The benefits of a reduced risk of flooding on the human intangible effects of health and stress were also included. These are measured directly as a benefit and so are listed separately in the option comparison tables.

At this IA stage there was no inclusion of damages from agriculture or infrastructure (for example traffic disruption due to road closure, damage to railways or utility transmission infrastructure).

The impact of climate change was incorporated into the economic appraisal in accordance with the Environment Agency guidance (Environment Agency, 2011) current at the time of the assessment and using a high-level approach suitable to the stage of this appraisal. The implication of the recently published revised guidance (Environment Agency, 2016) is considered in Appendix F.

For the purpose of economic assessment Average Annual Damages (AADs) are discounted over a period of 100 years using a discount factor to generate a Present Value Damage (PVd).

6.3. Results

6.3.1. Property Counts

Property counts have been sub-divided into the two Local Authority (LA) areas: Tonbridge & Malling BC and Maidstone BC. This method of sub-division was undertaken solely to help funding partners understand the benefits of each of the potential schemes in their respective areas and use this to inform any decisions made about partnership funding contributions.

Do Nothing and Maintain

Table 6-1 lists the number of residential properties at risk of internal (above floor level) flooding, for a range of design flood events for the Do Nothing and Maintain options. The bottom part of the table highlights the number of properties that benefit from the existing Leigh FSA. For example, in the 1.3% (1 in 75) AEP event, the existing Leigh FSA provides protection to 400 residential properties. A majority of these (more than 90%) are in the Tonbridge and Malling BC area, including Hildenborough, Tonbridge and East Peckham.

Table 6-1 Internal flooded residential property counts: Do Nothing and Maintain

Location and Option	Residential properties at risk of internal flooding					
	20% (1 in 5)	5% (1 in 20)	2% (1 in 50)	1.3% (1 in 75)	1% (1 in 100)	0.4% (1 in 250)
Do Nothing (undefended)						
Tonbridge & Malling Borough	79	357	705	855	1,039	1,368
Maidstone Borough	46	269	492	683	707	886
Total	**125**	**626**	**1,197**	**1,538**	**1,746**	**2,254**
Maintain (Existing situation with Leigh FSA storing to 28.05m AOD)						
Tonbridge & Malling Borough	47	62	216	490	593	1,196
Maidstone Borough	34	223	436	648	642	799
Total	**81**	**285**	**652**	**1,138**	**1,235**	**1,995**
Maintain	**Residential properties benefiting (no longer at risk of internal flooding under Maintain compared with Do Nothing)**					
Tonbridge & Malling Borough	32	295	489	365	446	172
Maidstone Borough	12	46	56	35	65	87
Total	**44**	**341**	**545**	**400**	**511**	**259**

Options

Table 6-2 lists the number of residential properties that benefit from the various improve options compared with the Maintain option (existing situation). Following the example given above in which 400 residential properties benefit from the existing Leigh FSA in the 1.3% (1 in 75) AEP event, a further 213 residential properties would benefit if storage was increased in the Leigh FSA. Over 20% of these are located further downstream in the Maidstone BC area.

Property counts are not shown for the Tonbridge & Malling BC area for the River Beult and River Teise FSA options as no properties in this area would benefit from the new FSAs. Of the 648 residential properties currently at risk of fluvial flooding in the Maidstone BC area in a 1.3% (1 in 75) AEP event, Table 6-2 indicates that only 32 properties would be protected by a new FSA on the River Beult. This increases to 128 properties if all three FSAs were constructed; still only 20% of the total number of properties currently at risk.

Table 6-2 Reduction in residential properties at risk of flooding with improve options

Location and Option	Residential properties benefiting (no longer at risk of internal flooding compared with Maintain)					
	20% (1 in 5)	5% (1 in 20)	2% (1 in 50)	1.3% (1 in 75)	1% (1 in 100)	0.4% (1 in 250)
New River Beult FSA, Leigh FSA unchanged						
Maidstone Borough	**0**	**36**	**18**	**32**	**49**	**24**
New River Beult FSA and new River Teise FSA, Leigh FSA unchanged						
Maidstone Borough	**0**	**49**	**78**	**76**	**126**	**48**
New River Beult FSA and two new River Teise FSAs, Leigh FSA unchanged						
Maidstone Borough	**0**	**55**	**94**	**128**	**164**	**88**
Improve Leigh FSA (increase stored water level to 28.85m AOD)						
Tonbridge & Malling Borough	0	0	36	165	94	94
Maidstone Borough	0	21	56	48	88	57
Total	**0**	**21**	**92**	**213**	**182**	**151**
Improve Leigh FSA, Hildenborough flood alleviation scheme						
Tonbridge & Malling Borough	0	1	37	227	210	343
Maidstone Borough	0	21	56	48	88	57
Total	**0**	**22**	**93**	**275**	**298**	**400**
Improve Leigh FSA, new River Beult FSA						
Tonbridge & Malling Borough	0	0	36	165	94	94
Maidstone Borough	0	57	74	80	137	81
Total	**0**	**57**	**110**	**245**	**231**	**175**
Improve Leigh FSA, two new River Teise FSAs						
Tonbridge & Malling Borough	0	0	36	165	94	94
Maidstone Borough	1	40	132	144	203	121
Total	**1**	**40**	**168**	**309**	**297**	**215**
Improve Leigh FSA, new River Beult FSA and two new River Teise FSAs						
Tonbridge & Malling Borough	0	0	36	165	94	94
Maidstone Borough	0	76	150	176	252	145
Total	**0**	**76**	**186**	**341**	**346**	**239**
Improve Leigh FSA, Yalding local defence scheme 1.3% (1 in 75) SoP						
Tonbridge & Malling Borough	0	0	36	165	94	94
Maidstone Borough	2	52	124	178	88	57
Total	**2**	**52**	**160**	**343**	**182**	**151**

As is evident in the numbers in Table 6-1 and Table 6-2, while all options reduce the risk of property flooding, some properties will remain at risk. The number of properties remaining at risk can be calculated by subtracting the "Total" row property counts in Table 6-2 from the total number of properties at risk of flooding in the Maintain option (existing situation). In the 1.3% (1 in 75) AEP event, for example, with the Improve Leigh FSA option, 925 residential properties remain at risk of flooding (calculated: 1138 – 213).

6.3.2. Present value damages

Table 6-3 summarises the PVd calculated for each of the options. The final row in the table provides the human intangible results which are expressed as a PVb.

Table 6-3 Summary of prevent value damages

	PVd (£m) (over 100 year appraisal period)							
	Residential	Non Residential	Evacuation Costs	Emergency Services	Vehicles	Risk to Life	Total PVd	Human Intangible PVb
Do Nothing	116.8	288.8	22.6	15.7	9.9	3.3	**457.0**	0
Maintain	65.3	175.2	12.5	9.8	7.5	2.1	**272.4**	3.4
Maintain Leigh Beult FSA	61.4	172.6	11.7	9.6	7.4	2.0	**264.7**	3.6
Maintain Leigh Beult & Teise FSAs	58.9	167.2	11.2	9.3	7.3	2.0	**255.9**	3.8
Maintain Leigh Beult & Teise x 2 FSAs	57.5	164.7	10.9	9.2	7.3	1.9	**251.4**	4.0
Improve Leigh FSA	59.8	157.3	11.4	8.8	7.1	1.9	**246.2**	4.6
Improve Leigh FSA Hildenborough flood alleviation scheme	57.1	156.9	10.8	8.6	6.9	1.8	**242.2**	5.3
Improve Leigh FSA Beult FSA	55.9	154.7	10.6	8.5	7.0	1.8	**238.5**	4.8
Improve Leigh FSA Teise x 2 FSAs	55.8	149.4	10.6	8.4	7.0	1.8	**232.9**	5.0
Improve Leigh FSA Beult & Teise x 2 FSAs	51.9	146.8	9.8	8.2	6.9	1.7	**225.2**	5.2
Improve Leigh FSA Yalding local defence scheme 1.3% (1 in 75) SoP	55.1	155.8	10.5	8.5	6.7	1.8	**238.6**	5.1

6.3.3. Present Value Benefits and Benefit Cost Ratios

For a scheme to be considered viable for funding, the economic benefits have to be greater than the scheme costs. Economic viability can therefore be described using BCR where the ratio between the benefits (PVb) and the scheme cost (PVc) needs to be greater than 1.

The benefit of implementing a flood alleviation option (i.e. the scheme PVb) is the difference between the Do Nothing PVd and the scheme PVd. The scheme PVd is described as the residual damages that remain following implementation of a flood alleviation scheme, arising because it is unlikely that the scheme protects all properties or protects against all flood events.

The BCR has been calculated for the Maintain and the various Improve options, the results of which are provided in Table 6-4. The final column is the Incremental Benefit Cost Ratio (IBCR) which is calculated as the additional benefit achieved by a scheme option compared with the additional cost that would be incurred. In this case the IBCR has been determined with respect to the Improve Leigh FSA option.

Table 6-4 Present Value costs, benefits and Benefit Cost Ratios

Option	PVc (£k)	PVd (£k)	PVb (£k)	BCR	IBCR (against Maintain)	IBCR (against Improve Leigh FSA)
Do Nothing	-	457,028	-	-	-	-
Maintain	15,261	272,414	188,000	12.3	-	-
Maintain Leigh FSA Beult FSA	24,854	264,709	195,938	7.9	0.8	-
Maintain Leigh FSA Beult & Teise FSAs	29,213	255,943	204,913	7.0	1.2	-
Maintain Leigh FSA Beult & Teise x 2 FSAs	32,766	251,431	209,610	6.4	1.2	-
Improve Leigh FSA	19,125	246,196	215,442	11.3	7.1	-
Improve Leigh FSA Hildenborough flood alleviation scheme	22,546	242,202	220,084	9.8	4.4	1.4
Improve Leigh FSA Beult FSA	28,718	238,491	223,379	7.8	2.6	0.8
Improve Leigh FSA Teise x 2 FSAs	27,037	232,919	229,114	8.5	3.5	1.7
Improve Leigh FSA Beult & Teise x 2 FSAs	36,630	225,214	237,051	6.5	2.3	1.2
Improve Leigh FSA Yalding local defence scheme 1.3% (1 in 75) SoP	24,121	238,556	223,607	9.3	4.0	1.6

6.3.4. Sensitivity Testing

The FCERM-AG (Environment Agency, 2010) states that sensitivity testing should be undertaken to determine whether the choice of the economically preferred option is sensitive to the main sources of uncertainty. The following sensitivity tests have been undertaken:

- Sensitivity test 1: Optimism Bias increased from 30% to 50%, increasing costs of all options to reflect possible uncertainty. Note that a higher Optimism Bias of 60% had already been included in the costs for the schemes at Hildenborough and Yalding to reflect the higher level of cost uncertainty for these options;
- Sensitivity test 2: Leigh Maintain and Improve costs reduced by £620k; the cost of works recommended for reservoir safety purposes and hence could be included as a Measure in the Interest of Safety instead of a FCERM activity; and
- Sensitivity test 3: PVb reduced by 10% across all options to reflect the uncertainty associated with the capping value used for properties with MCM code 400 (warehouses).

The results of the sensitivity testing are provided in Table 6-5 and are discussed in Section 6.3.4 below.

A fourth sensitivity test was undertaken for the Leigh FSA Improve with Hildenborough option only, with the capital costs for the Hildenborough scheme reduced to reflect the potential shorter defence alignment (as described in Section 2.5). The result was an increase in the BCR to 10.7 and increases in the IBCRs to 6.0 (against the Maintain option) and 3.2 (against Improve Leigh FSA).

Table 6-5 Sensitivity testing: BCR and IBCR

Result		Maintain	Improve Leigh FSA	Improve Leigh FSA Hildenborough flood alleviation scheme	Improve Leigh FSA Teise x 2 FSAs	Improve Leigh FSA Beult & Teise x 2 FSAs	Improve Leigh FSA Yalding local defence scheme 1.3% (1 in 75) SoP
BCR	**Best estimate**	**12.3**	**11.3**	**9.8**	**8.5**	**6.5**	**9.3**
	Sensitivity test 1	10.7	9.8	8.6	7.3	5.6	8.3
	Sensitivity test 2	13.0	11.7	10.1	8.7	6.6	9.6
	Sensitivity test 3	11.1	10.1	8.8	7.6	5.8	8.3
IBCR (M)*	**Best estimate**	-	**7.1**	**4.4**	**3.5**	**2.3**	**4.0**
	Sensitivity test 1		6.2	4.0	3.0	2.0	3.8
	Sensitivity test 2		7.1	4.4	3.5	2.3	4.0
	Sensitivity test 3		6.4	4.0	3.1	2.1	3.6
IBCR (I)**	**Best estimate**	-	-	**1.4**	**1.7**	**1.2**	**1.6**
	Sensitivity test 1			1.3	1.5	1.1	1.6
	Sensitivity test 2			1.4	1.7	1.2	1.6
	Sensitivity test 3			1.2	1.6	1.1	1.5

* IBCR for improve option calculated against Maintain option

** IBCR for improve option calculated against Improve Leigh FSA option

6.3.5. Choice of the Preferred Option

The choice of economically preferred option should be based on the FCERM-AG decision rule (Environment Agency, 2010). This rule consists of six decision stages which have been applied to this study in Table 6-6 and in the discussion below.

Table 6-6 Application of the FCERM-AG decision rule

Decision Stage	Analysis and outcome
1: Test for benefits exceeding costs	The BCRs of all the options are greater than 1, indicating that the benefits outweigh the costs.
2: Identify the leading option using BCR and IBCRs	The initial leading option is Maintain, as this has the highest BCR of 12.3. With the exception of the Hildenborough flood alleviation scheme and the Yalding local defence scheme, the improve options appraised in this study do not aim to provide a specific SoP to whole communities, but instead act to reduce flood depths over large parts of the catchment. While some properties will have a SoP greater than 1.3% (1 in 75), others will still flood during this event. Given this SoP, to "step up" and identify one of the Improve options as the leading option, the decision rule states that an IBCR greater than 1 is required. Improve Leigh FSA has the second highest BCR (11.3) and a strong IBCR of 7.1, more than sufficient to justify selecting this option. Combining the Leigh FSA improvement works with the Hildenborough flood alleviation scheme gives the third-highest BCR (9.8) and an IBCR (compared with improve Leigh FSA in isolation) of 1.4. Under the FCERM-AG decision rule, this is sufficient for the leading option to become Improve Leigh FSA with the Hildenborough scheme. A majority of the benefits of this combined option are to properties in Hildenborough and Tonbridge. Combining the Leigh FSA improvement works with a local defence solution in Yalding and / or the new FSAs on the River Teise would bring wider community benefits to the downstream area. These options have the next highest BCRs of 9.3 and 8.5 respectively, and IBCRs (compared with improve Leigh FSA in isolation) of 1.6 and 1.7. Under the FCERM-AG decision rule, these additional options could be selected, subject to funding availability. Adding the new River Beult FSA to the Improve Leigh FSA option gives a lower BCR (7.8) and IBCR below 1 (0.8). This option is therefore not included in the list of leading options.
3: Consider how contributions could affect the BCRs and the IBCRs.	Contributions have not been confirmed at this stage, but possible sources include Kent County Council (KCC), Tonbridge & Malling BC, Maidstone BC, Southern Water (for Penshurst STW), Network Rail (for works to the railway embankment in Leigh FSA) and local businesses. Contributions towards the Improve options would strengthen the case for the options to be taken forward.

Decision Stage	Analysis and outcome
4: Consider whether uncertainty could affect the choice of option	Sensitivity testing is described in Section 6.3.4 above and the results given in Table 6-5. While the BCRs and IBCRs change, the changes are not sufficient to change the leading economic options. A shorter Hildenborough defence alignment could significantly reduce scheme costs, with an IBCR of 3.2, strengthening the economic case for selecting this option.
5: Consider whether wider objectives are met by the leading option	The objectives of this study were to assess the viability of options to reduce the risk of flooding to Tonbridge and the downstream communities including Collier Street and Yalding. The existing Leigh FSA reduces flood risk to Tonbridge and Hildenborough and to a lesser extent, East Peckham. This risk can be further reduced by the proposed Leigh FSA improve option combined with the Hildenborough flood alleviation scheme, meeting the study objectives for this area. While increasing storage at Leigh FSA does provide some benefit to the downstream communities, benefit reduces with distance downstream, with further risk from the River Beult and the River Teise. The Collier Street community would be the principal beneficiary of FSAs on the River Teise, however, flooding would still occur during high flows on the River Beult because of floodplain interconnectivity in the Chainhurst area. Yalding could also benefit from flood storage on the River Teise, although flooding would still occur from the River Beult and / or the River Medway. The Teise FSAs would therefore only ever partially reduce the risk of flooding to these communities and model results indicate a comparatively small number of properties benefiting. The greatest benefits to Yalding would be achieved by the local defence option, but this option would increase flood risk to properties upstream of Yalding.

The sixth stage of the decision rule is to make an option choice, recommending either the leading option or an alternative option. As set out in Table 6-6, the leading economic option is Improve Leigh FSA combined with the Hildenborough FAS. This combined option would reduce flood risk to properties in Hildenborough and Tonbridge, and, to a lesser extent, some downstream communities which are the focus of the second objective.

Significant flood risk improvement for Yalding, Collier Street and the wider community in the surrounding area cannot be achieved through construction of new FSAs on the River Teise and Beult. The limitations of potential storage volumes available, in combination with the technical difficulties of avoiding coincident flood peaks mean that flood storage is not recommended. The Yalding local defence option, by obstructing flow and removing flood plain storage, would result in worsening of flood risk to residents upstream of Yalding.

6.3.6. Funding considerations

Capital works schemes can be (partially) funded through the Flood Defence Grant in Aid (FDGiA) funding stream. The Partnership Funding Score provides an indication of the scheme costs which will be eligible for central Government funding and hence the likely financial viability of the option. The results of the funding calculations[1] for the various options are presented in Table 6-7, with the leading economic options in bold.

The duration of benefits was set at 40 years for all options, driven by the need for significant works to the existing Leigh FSA control structure at the end of this period. PV costs and benefits were calculated over this

[1] Carried out using v8 (2015 – 2016) of the Partnership Funding Calculator spreadsheet provided on the Environment Agency website.

duration for the partnership funding calculations, and hence are different to those previously reported for the full 100-year appraisal period.

Outcome Measure (OM) 2 residential property counts “Before” were taken from the Do Nothing (undefended) scenario and “After” from each of the option scenarios. At this IA stage it was not possible for these property counts to incorporate climate change. Nearly all the properties at risk within the study area are located in the lowest category (60% least deprived) for the index of multiple deprivation and therefore only contribute the basic rate in the partnership funding calculator. No properties are at risk from erosion.

No OM4 Environmental Improvements were quantified. This is because, at this IA stage, environmental improvements have not been scoped and therefore no specific costs to deliver improvements have been included, and nor has there been any quantification of environmental benefits. Furthermore, it was considered that the scale of potential OM4s that could be possible was likely to be very small in relative terms to the options; at best it is only likely to add ~1% of additional GiA. It was therefore not going to affect decision making at an IA stage. Opportunities for environmental enhancements should be fully explored when options are taken forward for development at OBC stage, at which point it would be appropriate to include OM4s.

Table 6-7 Partnership funding calculations (raw scores prior to receipt of any contributions)

Option	% score	PV cost for approval (£m)	PV cost for duration of benefits (£m)	Contribution required (£m)	PV GiA for approval (£m)	PV GiA for future spend (£m)
Maintain	94%	7.0	10.0	0.6	6.4	3.0
Maintain Leigh FSA Beult FSA	48%	14.9	19.1	9.2	5.7	4.2
Maintain Leigh FSA Beult & Teise FSAs	45%	18.7	23.3	12.9	5.8	4.6
Maintain Leigh FSA Beult & Teise x 2 FSAs	40%	21.6	26.6	16.0	5.6	5.0
Improve Leigh FSA	**79%**	**10.5**	**13.8**	**2.9**	**7.6**	**3.3**
Improve Leigh FSA Hildenborough flood alleviation scheme	**66%**	**13.5**	**17.1**	**5.8**	**7.7**	**3.6**
Improve Leigh FSA Beult FSA	50%	18.4	22.9	11.5	6.9	4.5
Improve Leigh FSA Teise x 2 FSAs	**55%**	**17.2**	**21.3**	**9.6**	**7.6**	**4.1**
Improve Leigh FSA Beult & Teise x 2 FSAs	40%	25.1	30.4	18.2	6.9	5.3
Improve Leigh FSA Yalding local defence scheme 1.3% (1 in 75) SoP	**61%**	**15.1**	**18.7**	**7.2**	**7.9**	**3.6**

The Partnership Funding Raw Score for all options is less than 100%; contributions from other sources would therefore need to be secured for any of the options to be implemented. There are a number of potential sources of funding, including KCC, Tonbridge & Malling BC, Maidstone BC, Southern Water (for Penshurst STW), Network Rail (for works to the railway embankment in Leigh FSA) and local businesses.

Sensitivity testing was also undertaken on the partnership funding calculations and is reported in Table 6-8 for the leading economic options. In all cases the lower estimates arose from using a higher Optimism Bias allowance (sensitivity test 1 described in Section 6.3.4). For all but the Hildenborough option, the upper estimates arose from excluding the Leigh reservoir safety costs (see sensitivity test 2 described in Section 6.3.4). The Hildenborough upper estimate assumes a reduced Hildenborough scheme cost.

Table 6-8 Sensitivity testing: partnership funding calculations

Option	Best estimate		Lower estimate		Upper estimate	
	% score	Contribution required (£m)	% score	Contribution required (£m)	% score	Contribution required (£m)
Improve Leigh FSA	79%	2.9	69%	5.0	85%	2.0
Improve Leigh FSA Teise x 2 FSAs	55%	9.6	48%	12.9	57%	9.0
Improve Leigh FSA Hildenborough flood alleviation scheme	66%	5.8	59%	8.0	75%	3.8
Improve Leigh FSA Yalding local defence scheme 1.3% (1 in 75) SoP	61%	7.2	55%	9.3	64%	6.4

7. Summary and Conclusions

This IA has assessed strategic catchment options for improved flood risk management in the River Medway catchment from Leigh to Maidstone, with the key objectives to assess the viability of:

- Increasing the operational storage volume of the Leigh FSA to further reduce the risk of flooding to Tonbridge and downstream communities; and
- Solutions to reduce flood risk in the communities of Yalding and Collier Street utilising a single or cascade of FSAs or other solution (linear defence and / or conveyance improvements) on the lower reaches of the River Beult and / or the River Teise.

Flood risk management option viability has been assessed technically, economically and environmentally, with this technical report providing details regarding the option selection, hydraulic modelling and the technical, economic and environmental appraisal.

Maintaining Leigh FSA has a viable business case, with a benefit cost ratio of 12.3. It reduces flood risk to over 1,200 residential properties, with 341 of these moved out of the very significant risk category (at risk of flooding in a 5% (1 in 20) annual chance event). The Maintain option includes refurbishment and improvements to the existing Leigh FSA control structure. Although the Partnership Funding Raw Score is just less than 100%, the option cost also includes provision of southern embankment downstream slope protection which should be funded as a Measure in the Interest of Safety under the Reservoirs Act, instead of a FCERM activity.

Improving the flood risk benefit provided by the Leigh FSA can be achieved by raising the NMOWL to 28.85m AOD. This reduces flood risk to around 213 residential properties, and with a BCR of 11.3 and a strong IBCR of 7.1, this option can be selected under the FCERM-AG decision rule. Under current funding arrangements, around £2.9M of contributions would have to be sourced to take this option forward. No significant environmental constraints have been identified for this option.

Significant flood risk improvement for Yalding, Collier Street and the wider community in the surrounding area cannot be achieved through construction of new FSAs on the River Teise and Beult. The limitations of potential storage volumes available, in combination with the technical difficulties of avoiding coincident flood peaks mean that flood storage is not recommended. Under current funding arrangements, about £7.2m and £9.6m of contributions would be required for the assessed flood storage areas. The outline cost assumes that local site won material is available and that passive outflow structures are used on both sites. Out of the 965 properties at risk in the confluence area, only 128 would benefit leaving 837 homes at risk of flooding.

The Yalding local defence option has significant technical constraints. By obstructing flow and removing flood plain storage, local walls around Yalding would result in worsening of flood risk to residents upstream of Yalding. It is unlikely that this worsening of risk could be mitigated. The technical challenge of providing additional storage and mitigating the obstruction to flow is considered insurmountable in this location. The rejection of this option on technical grounds means that it has not been included in the economic assessment. Environmental constraints have been identified for the Yalding local defence option. These relate to work close to Town Bridge Scheduled Monument, likely adverse visual and landscape impacts and technical design challenges associated with the required alignment. These challenges are significant.

A fully integrated approach to incorporating environmental opportunities into scheme design is recommended for those options taken forward to OBC in order to best realise wider benefits. This could include opportunities for river restoration and habitat creation, potentially valued through an ecosystem services approach and contributing to England's Biodiversity Strategy 2020 targets and funding Outcome Measure 4a.

There are areas of uncertainty relating to the River Teise FSAs associated with the assumed cost of imported fill for embankment construction and the potential for storage to result in a peak flow on the River Teise. A flood storage area constructed on the River Teise would be heavily dependent on the passage of weather events within the catchment. Given the known timing of the flood peaks, the available storage would have to be able to store sequential events on the faster reacting River Teise. Given the volume of storage available there is considerable likelihood that for a given event the flood storage area will not provide the reduction in risk expected. The structure may delay the flood peak in a particular event, allowing it to coincide with the peak flow on the River Medway and / or the River Beult, worsening flood risk in some areas. There are environmental constraints associated with the proposed Stonebridge FSA location, particularly in relation to the cultural heritage assets at one location and the potential for visual impacts in a location designated as an AONB.

A separate IA has recently been prepared for Hildenborough, comprising an alignment following the boundary of nearby sports pitches. This scheme would reduce flood risk to a further 62 properties (potentially more depending on optimum SoP), with a BCR of 9.8 and IBCR of 1.4, calculated as part of this IA. An alternative shorter alignment should be investigated since the associated reduction in scheme cost could increase the IBCR to around 3.2, improving the justification for taking this option forward. The contribution required for this option (including Improve Leigh FSA) is £3.8 to £5.8m, depending on preferred defence alignment. It would be essential to combine this option with the improvement works to Leigh FSA to ensure the mitigation for loss of Hildenborough floodplain was accommodated strategically.

An additional separate IA has also been recently prepared for East Peckham. Specific values for this option have not been incorporated into this IA, but the proposed Improve Leigh option would strategically benefit this scheme.

The Partnership Funding Raw Score for all options is less than 100% with contributions from other sources required for the options to be implemented. There are a number of potential sources of funding, including KCC, Tonbridge & Malling BC, Maidstone BC, Southern Water (for Penshurst STW), Network Rail (for works to the railway embankment in Leigh FSA) and local businesses. The economic appraisal has aligned with FCERM-AG and the HM Treasury ‘Green Brook’. The options will however also provide local economic benefits, particularly in Tonbridge and East Peckham. These cannot currently be quantified under Treasury rules or be used for FDGiA funding, but are important for other funding sources (e.g. Local Enterprise Partnerships (LEPs)) and could contribute to benefit calculations used when obtaining partnership funding.

This IA recommends that, subject to the potential for securing sufficient partnership-funded contributions together with community and key landowner support, the Improve Leigh FSA, and the Hildenborough flood alleviation scheme options should be taken forward for detailed appraisal as part of a combined SOC. The technical limitations of flood storage on the River Beult and River Teise mean that out of the 965 properties at risk in the confluence area, only 128 would benefit, leaving 837 homes at risk of flooding. The reduction of risk is not evenly distributed within the communities and is dependent on property threshold level, the schemes would not be able to demonstrate a reduction in risk commensurate with that provided by the Leigh FSA. It is not recommended that these flood storage options are taken forward beyond the SOC. Should sufficient funding be available, it is recommended that the Improve Leigh FSA and Hildenborough flood alleviation scheme options are progressed, with a separate project focused on improving the flood resilience to homes and communities in the area surrounding Yalding and Collier Street.

8. References

AECOM. (2015). SPON'S; Civil Engineering and Highway Works Price Book.

ARLA. (2015). Buy-to-Let Reviews 2014. Retrieved from http://www.arla.co.uk/info-guides/buy-to-let-reviews/2014.aspx

Defra. (2004). Supplementary Note to Operating Authorities: Appraisal of Human Related Intangible Impacts of Flooding.

Defra. (2015). Flood and Reservoir Safety Guidance.

Department for Communities and Local Government. (2012). National Planning Policy Framework.

Department for Communities and Local Government. (2012). Tables on commercial and industrial floorspace and rateable value statistics. Retrieved from https://www.gov.uk/government/statistical-data-sets/live-tables-on-commercial-and-industrial-floorspace-and-rateable-value-statistics

Environment Agency. (2010). Flood and Coastal Erosion Risk Management Appraisal Guidance.

Environment Agency. (2011). Adapting to climate change: Advice for Flood and Coastal Erosion Risk Management Authorities.

Environment Agency. (2016). Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities.

Environment Agency. (2016). Flood Risk Assessments: Climate Change Allowances. Retrieved from https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#what-climate-change-allowances-are

Flood Hazard Research Centre. (2015). Flood and Coastal Risk Management: Handbook and Data for Economic Appraisal (Multi-Coloured Handbook and Data). Middlesex University Press.

Halcrow. (2010). Leigh FSA report .

Halcrow. (2010). Middle Medway Strategy Review.

Home.co.uk. (2015). House price reports. Retrieved from www.home.co.uk

Jacobs Babtie. (2006). Leigh FSA Additional Storage Railway Track Protection Preliminary Considerations Report.

Nomis. (2015). Social class data by Local Authority Area: Approximate Social Grade (UV50) (2011). Retrieved from Nomis Official Labour Market Statistics: http://www.nomisweb.co.uk/

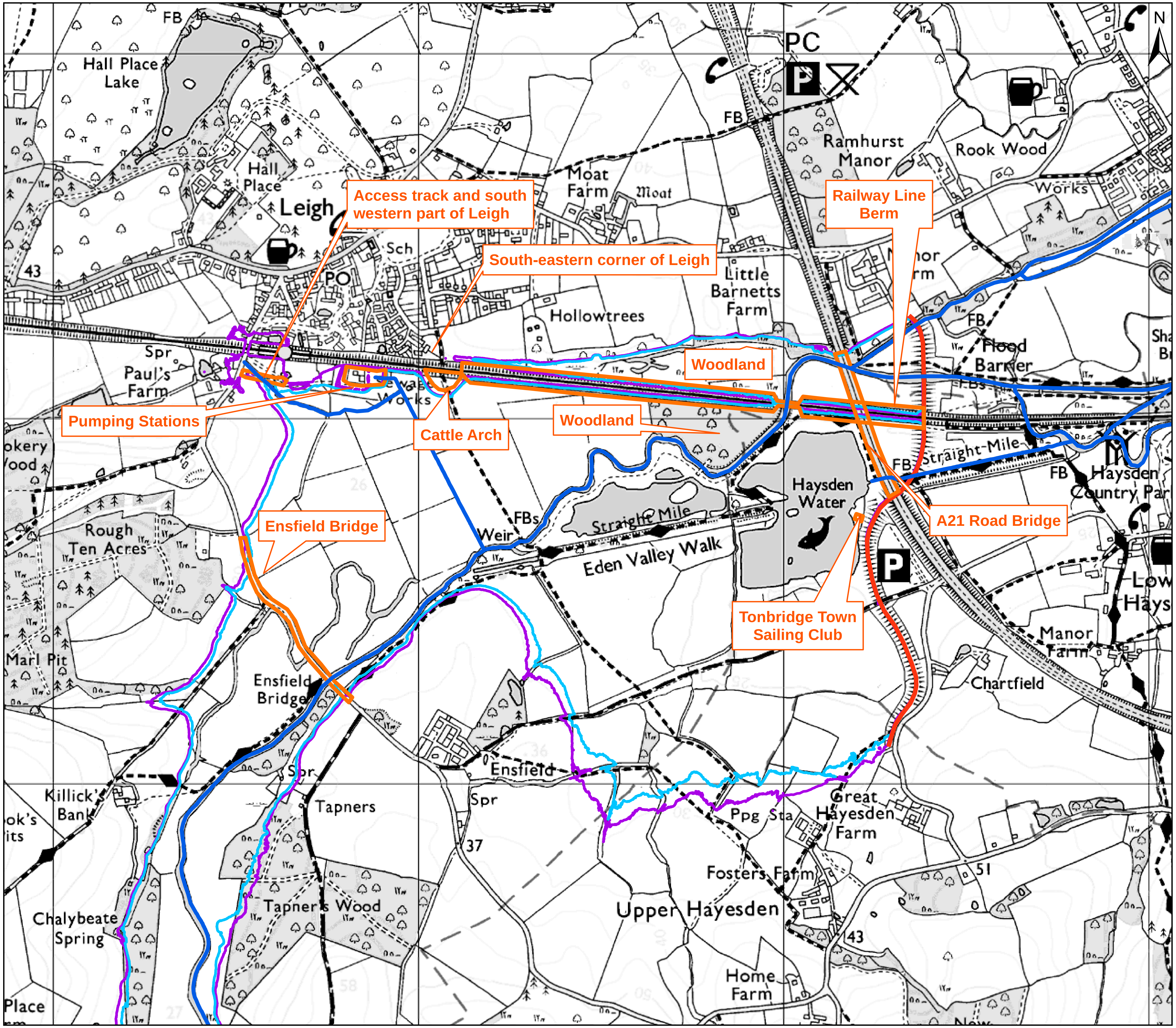
Root, B. B. (2001). Pre-feasibility Report for “stand alone” flood defence scheme at Yalding.

Southern Water Authority. (1981). Railway Berm Drawings.

Valuation Office Agency. (2015). Valuation Office Agency and business rates (non-domestic rates). Retrieved from https://www.gov.uk/guidance/valuation-office-agency-and-business-rates-non-domestic-rates

Appendix A Figures

A.1 Figures

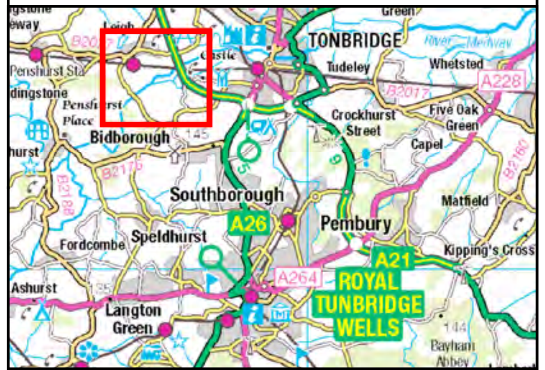


River Medway Flood Storage Areas Initial Assessment

Figure 1: Leigh FSA Upstream Assets at Risk Downstream of Ensfield Bridge

Key

- Main River
- Upstream assets / areas which might be at increased risk of flooding if the NMOWL was increased
- Leigh FSA Control Structure and Embankment
- 28.05m AOD contour (existing NMOWL)
- 28.85m AOD contour (proposed NMOWL under the Leigh FSA Improve option



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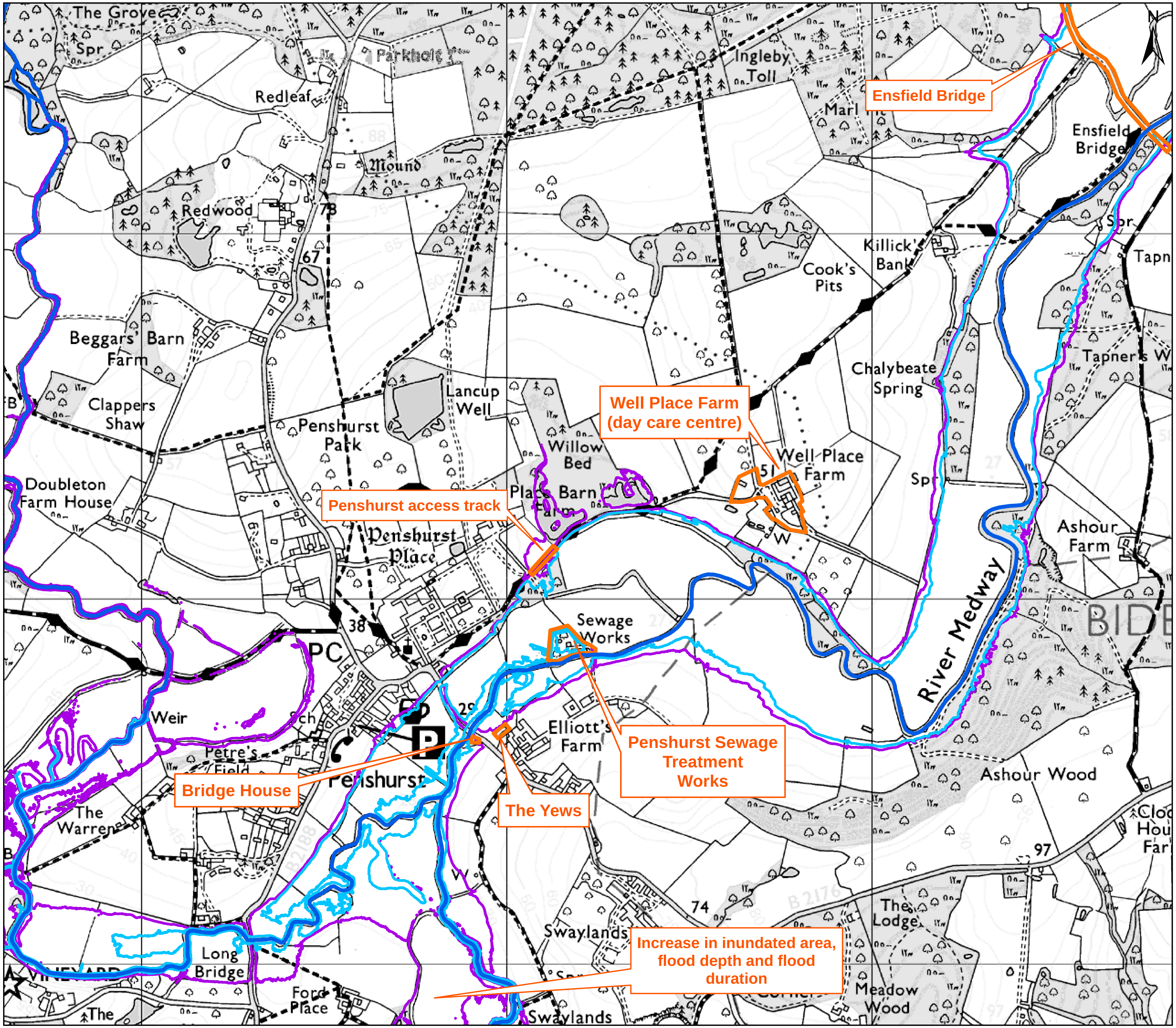
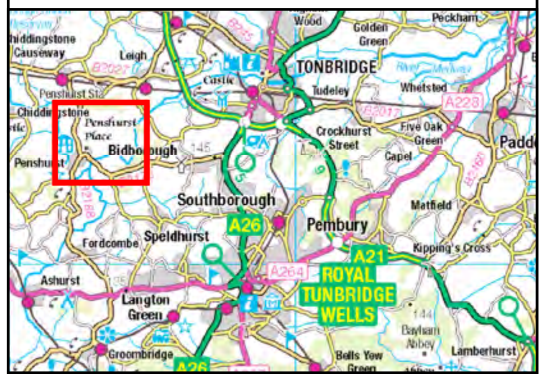


River Medway Flood Storage Areas Initial Assessment

Figure 2: Leigh FSA Upstream Assets at Risk Upstream of Ensfield Bridge

Key

- Main River
- Upstream assets / areas which might be at increased risk of flooding if the NMOWL was increased
- 28.05m AOD contour (existing NMOWL)
- 28.85m AOD contour (proposed NMOWL under the Leigh FSA Improve option



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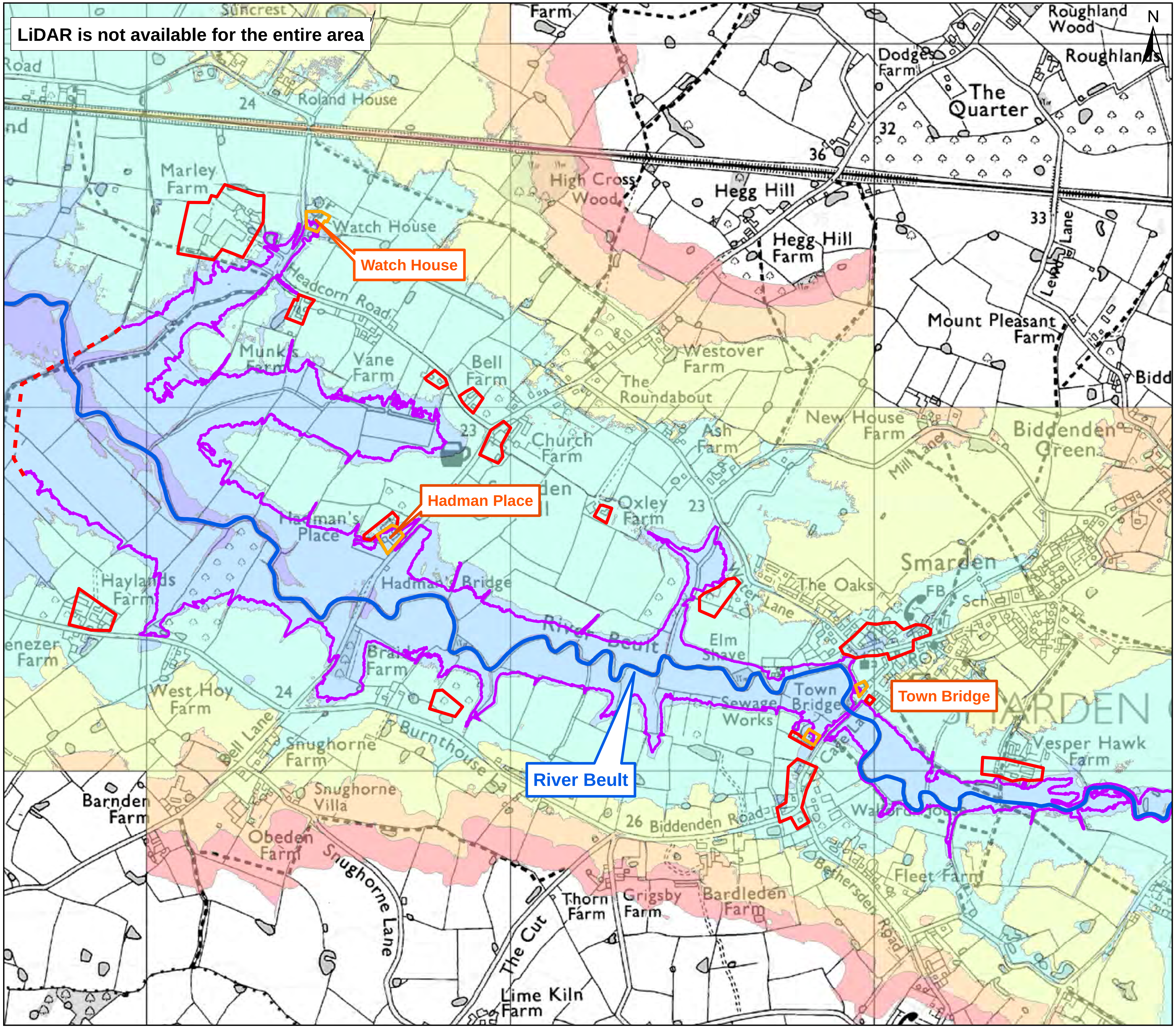


River Medway Flood Storage Areas Initial Assessment

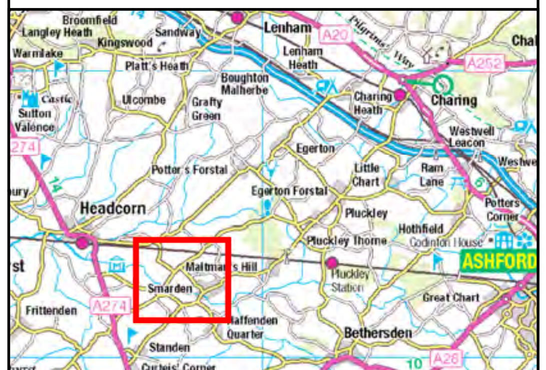
Figure 3: Potential River Beult FSA Location Headcorn

Key

- Main River
- Proposed location for FSA embankment
- 21.75m AOD contour (recommended maximum storage level)
- Properties at risk at 21.75mAOD
- Properties between 22 and 23m AOD

Ground Levels from LiDAR

- 16 - 18m AOD
- 18 - 20m AOD
- 20 - 22m AOD
- 22 - 24m AOD
- 24 - 26m AOD
- 26 - 28m AOD



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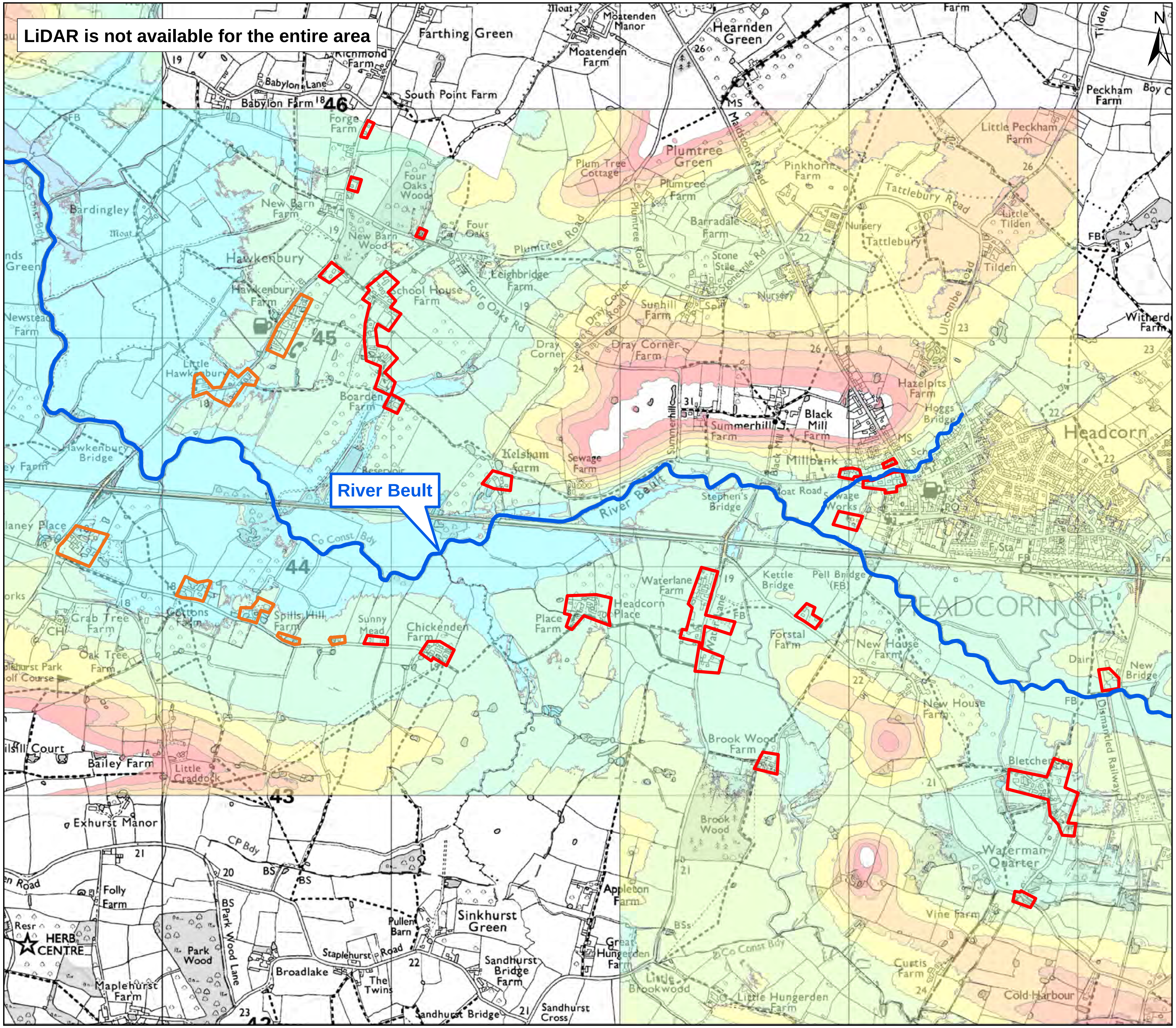

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River Medway Flood Storage Areas Initial Assessment

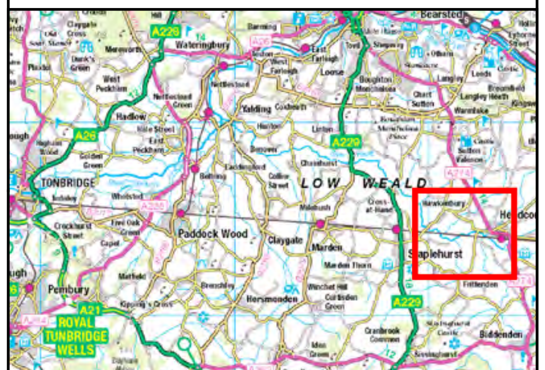
Figure 4: Potential River Beult FSA Headcorn to Hawkenbury

Key

- Main River
- Properties with ground levels at or below 18.5m AOD
- Properties with ground levels 18.5 - 20m AOD

Ground Levels from LiDAR

- 8 - 10m AOD
- 10 - 12m AOD
- 12 - 14m AOD
- 14 - 16m AOD
- 16 - 18m AOD
- 18 - 20m AOD
- 20 - 22m AOD
- 22 - 24m AOD
- 24 - 26m AOD
- 26 - 28m AOD



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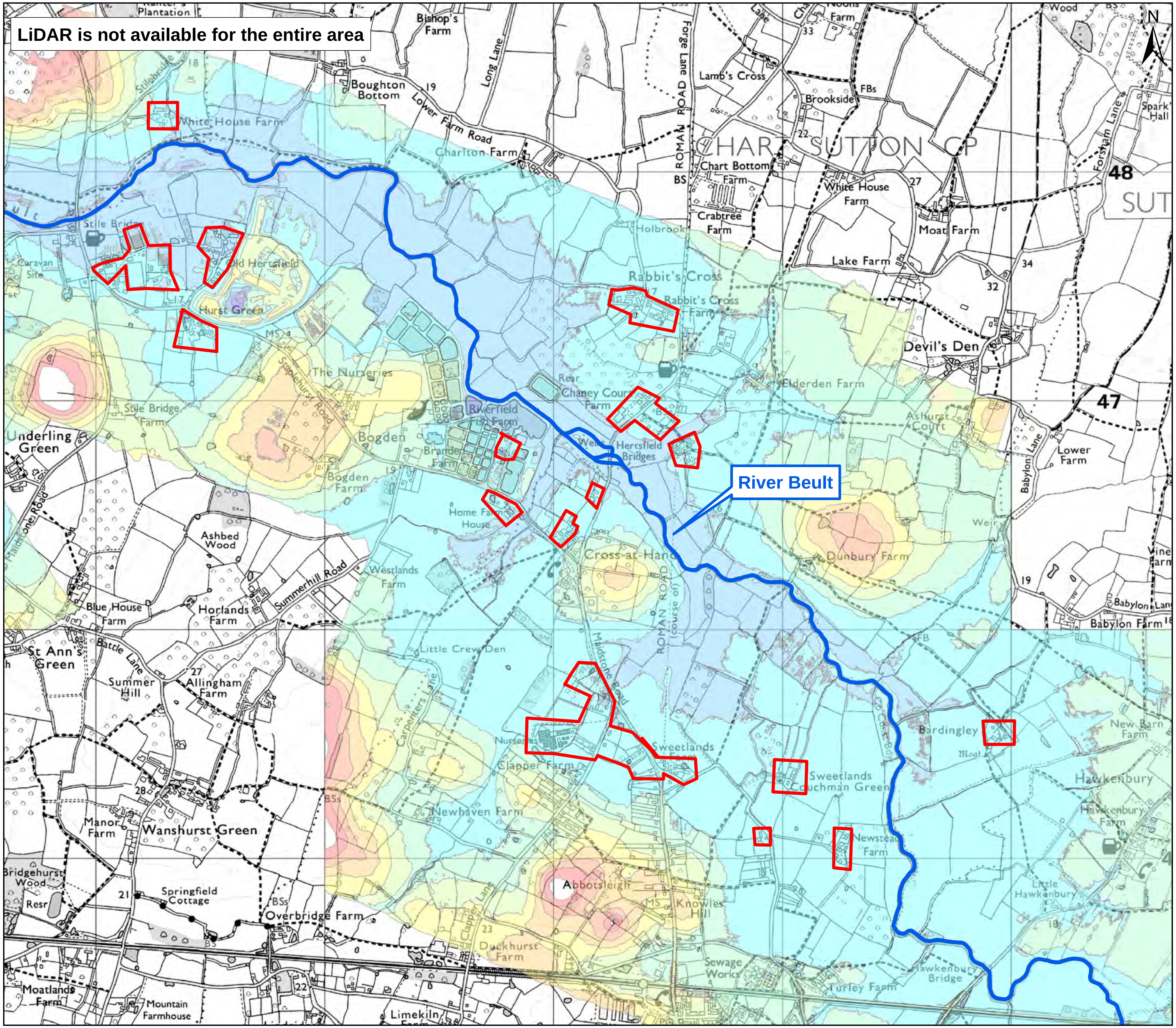


River Medway Flood Storage Areas Initial Assessment

Figure 5: Potential River Beult FSA Hawkenbury to Stilebridge

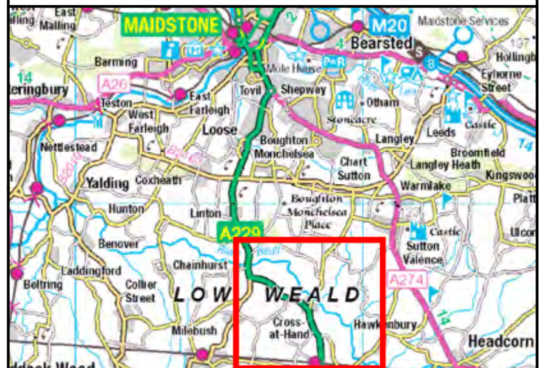
Key

Main River

Properties with ground levels 16-17m AOD

Ground Levels from LiDAR

- 8 - 10m AOD
- 11 - 12m AOD
- 13 - 14m AOD
- 15 - 16m AOD
- 17 - 18m AOD
- 19 - 20m AOD
- 21 - 22m AOD
- 23 - 24m AOD
- 25 - 26m AOD
- 27 - 28m AOD



Data sources: Environment Agency, Ordnance Survey

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Scale (at A3): 1:16,000

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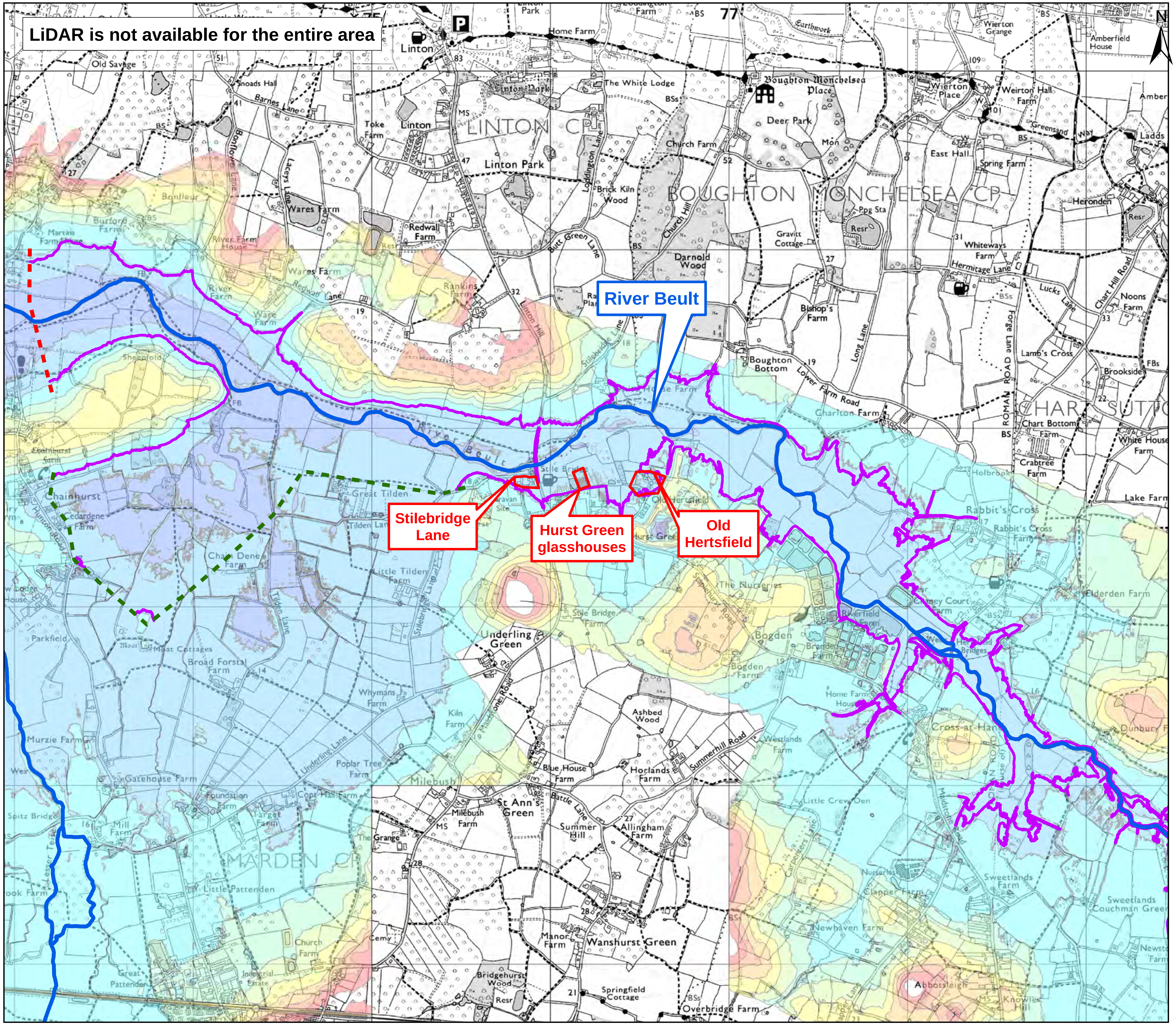


River Medway Flood Storage Areas Initial Assessment

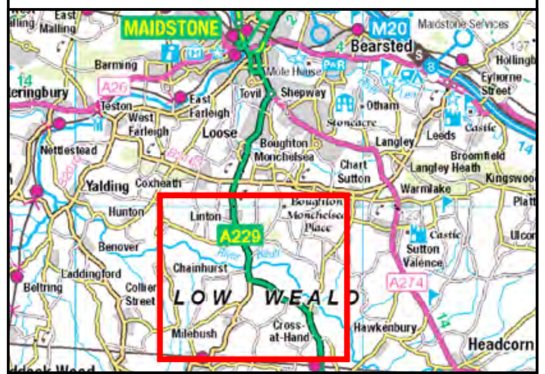
Figure 6: Potential River Beult FSA Chainhurst

Key

- Main River
- Proposed location for main FSA embankment
- Proposed location for side FSA embankment
- 15.75m AOD contour (recommended maximum storage level)
- Properties potentially at risk and requiring mitigation at a stored water level of 15.75mAOD

Lower

- 8 - 10m AOD
- 10 - 12m AOD
- 12 - 14m AOD
- 14 - 16m AOD
- 16 - 18m AOD
- 18 - 20m AOD
- 20 - 22m AOD
- 22 - 24m AOD
- 24 - 26m AOD
- 26 - 28m AOD



Data sources: Environment Agency, Ordnance Survey

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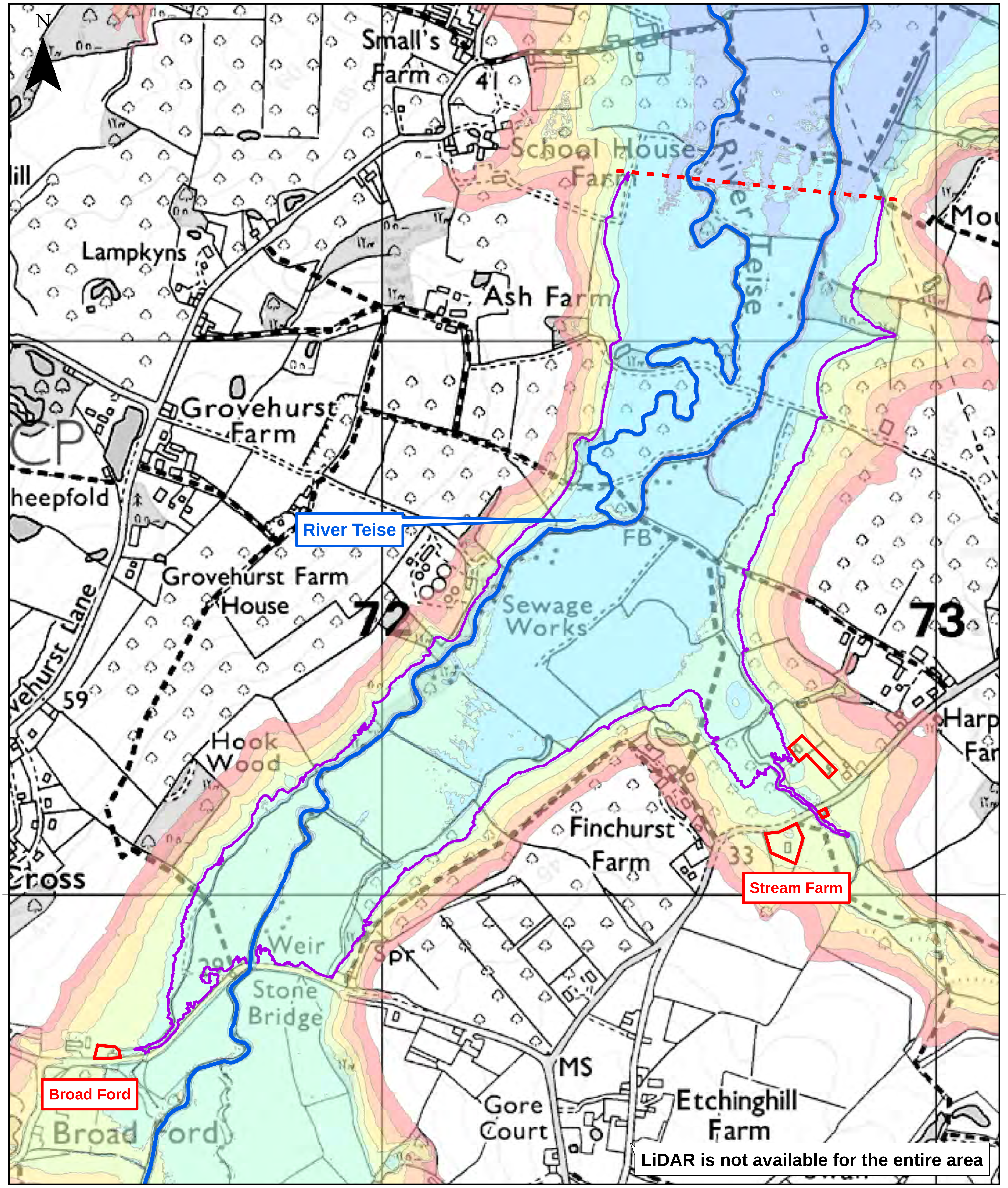

River Medway Flood Storage Areas Initial Assessment

Figure 7: Potential River Teise FSA Cottage Wood

Key

- Main River
- Proposed location for FSA embankment
- 27.5m AOD contour (recommended maximum storage level)
- Properties with ground levels of 28m AOD

Ground Levels from LiDAR

- 18 - 20m AOD
- 21 - 22m AOD
- 23 - 24m AOD
- 25 - 26m AOD
- 27 - 28m AOD
- 29 - 30m AOD
- 31 - 32m AOD
- 33 - 34m AOD

0 0.125 0.25 Km

Scale (at A3): 1:6,500

Data sources: Environment Agency, Ordnance Survey

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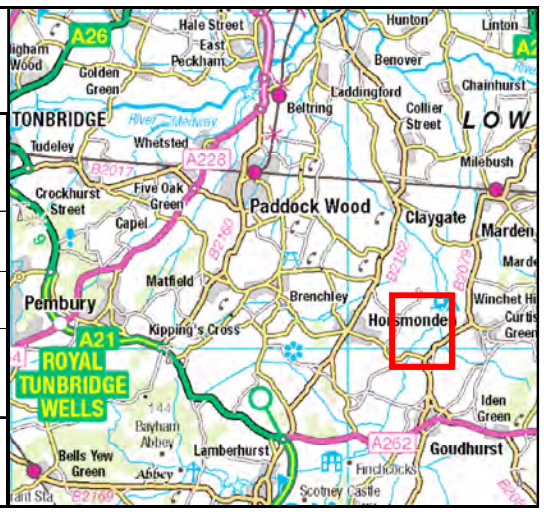

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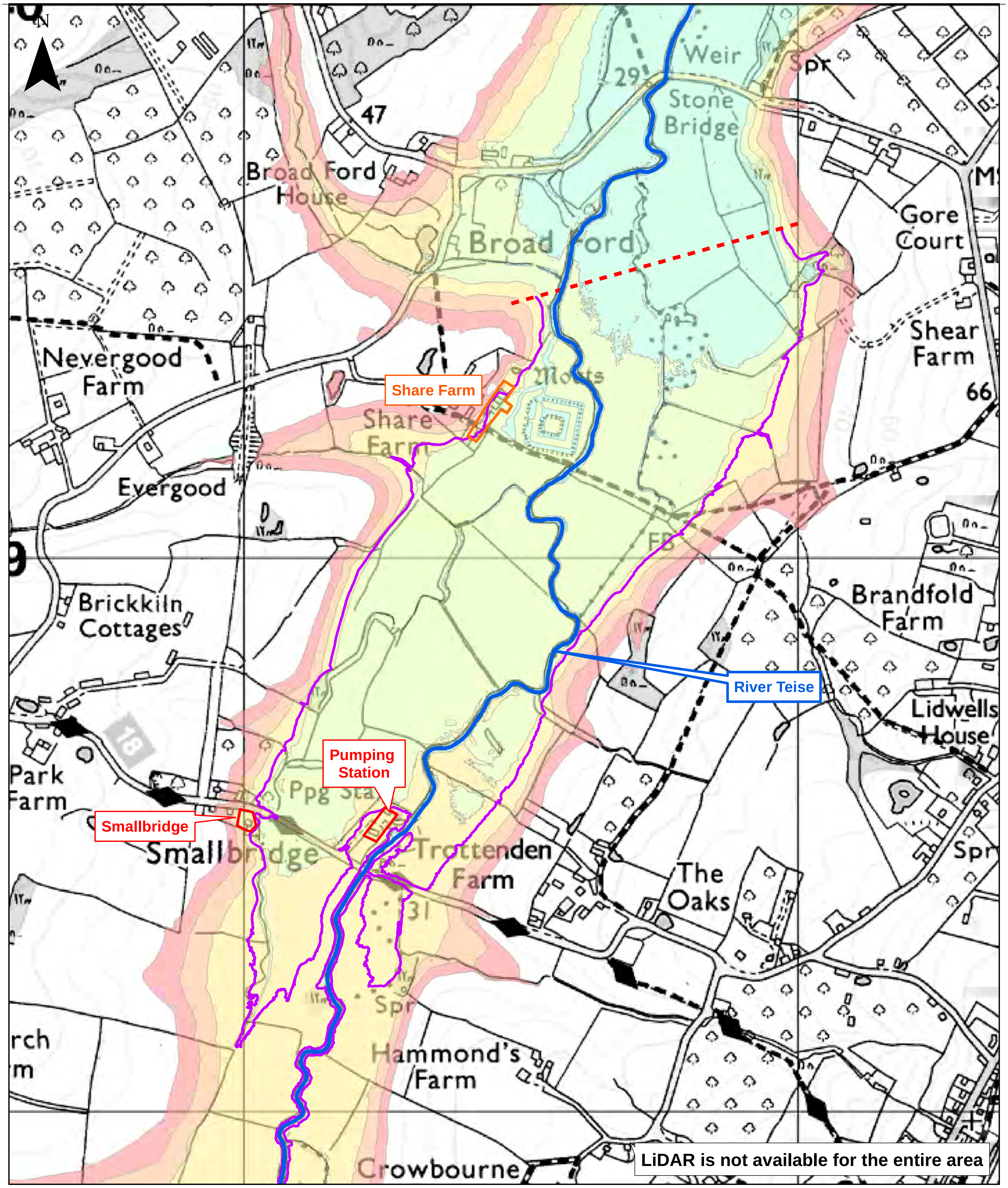
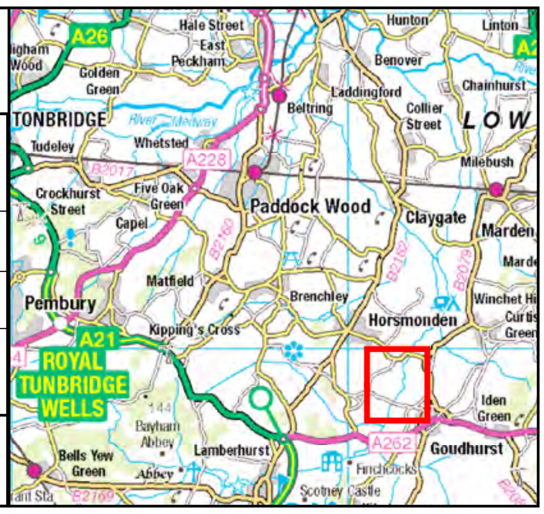


River Medway Flood Storage Areas Initial Assessment

Figure 8: Potential River Teise FSA Stonebridge



Key

- Main River
- Proposed location for FSA embankment
- 30.5m AOD contour (maximum recommended storage level)
- Properties at risk at 30.5m AOD
- Properties / assets with ground level 31 - 32m AOD

Ground Levels from LiDAR

- 18 - 20m AOD
- 20 - 22m AOD
- 22 - 24m AOD
- 24 - 26m AOD
- 26 - 28m AOD
- 28 - 30m AOD
- 30 - 32m AOD
- 32 - 34m AOD

0 — 0.125 — 0.25 Km

Scale (at A3): 1:6,500

Data sources: Environment Agency, Ordnance Survey

Reference: 5138683	Status: Final	Purpose of issue: For Report	Rev: v2	Model File Identifier: 62 / MG / 006

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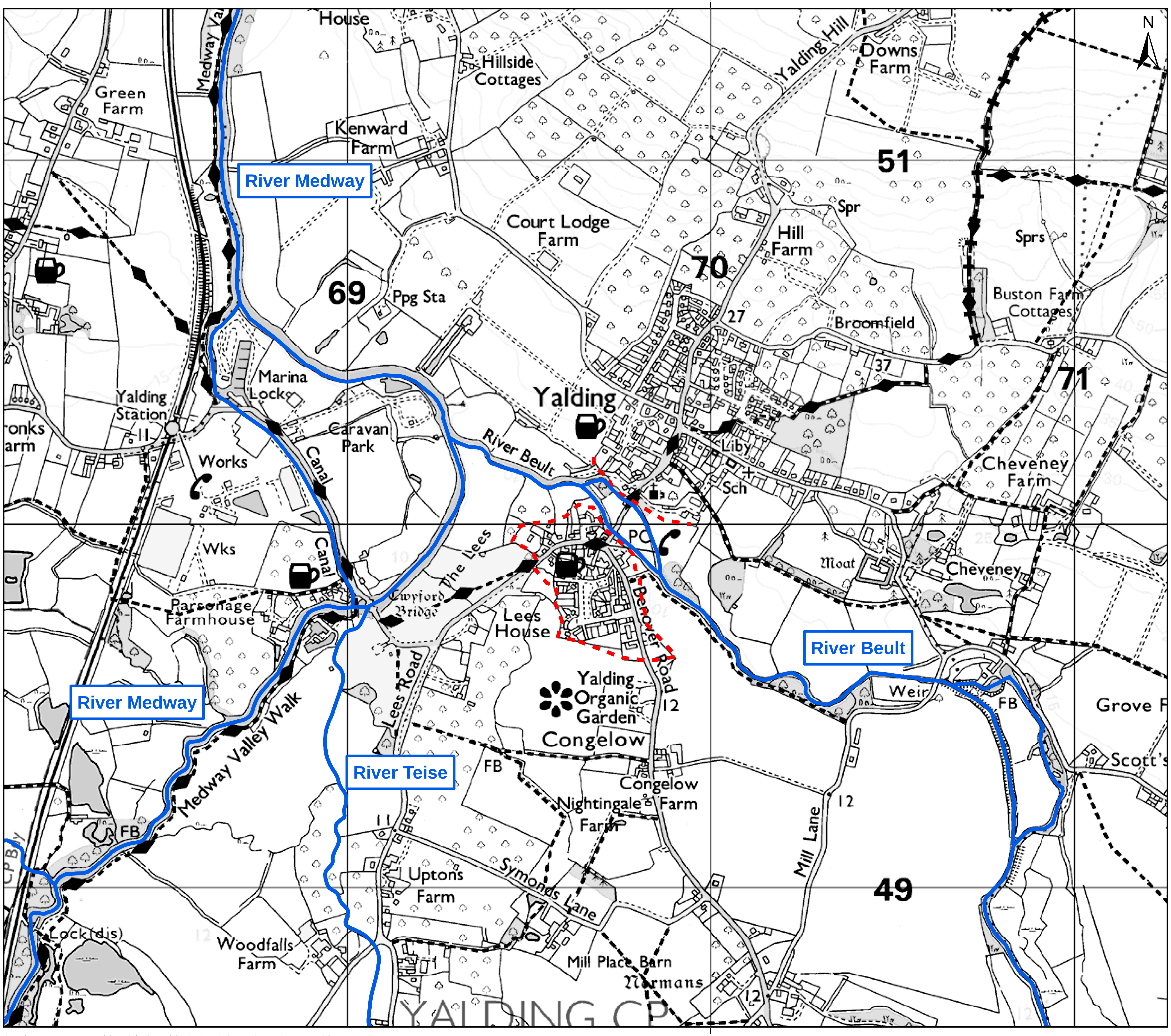
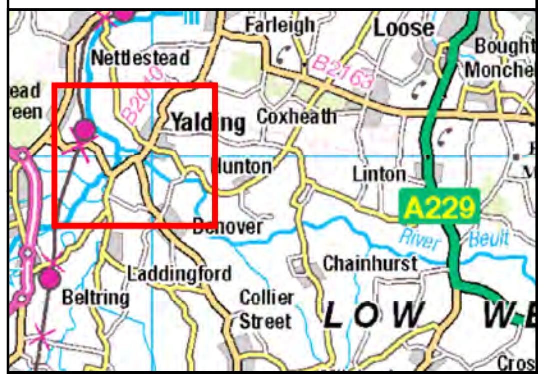


River Medway Flood Storage Areas Initial Assessment

Figure 9: Potential Yalding Local Defences

Key

- Main River
- Indicative location of proposed Yalding walls and embankments



Data sources: Environment Agency, Ordnance Survey

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Scale (at A3): 1:10,000

Environment Agency

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Appendix B Leigh FSA Additional Information

B.1 Summary of 2010 Spillway Investigation

In 2010 a project by Halcrow investigated the flow velocities and protection required on the downstream slopes of the embankments at Leigh FSA. This section provides a summary of the key conclusions of this investigation, as relevant for the River Medway FSA IA.

For the purposes of the investigation, the embankment was divided into three segments as follows:

- Northern embankment – from the northern end of the embankment to the railway line and incorporating the control structure;
- Middle embankment – from the railway line to the A21 viaduct; and
- Southern embankment – for the A21 viaduct to the southern end of the embankment in the vicinity of the Haysden cottages.

The key conclusions of the spillway review were as follows:

- All three segments of the embankment are modelled to overtop in the 1,000 year, 10,000 year and PMF events;
- Under current arrangements, the northern and middle embankment downstream slope protection was considered inadequate for the 10,000 year and PMF events;
- The southern embankment is protected by high tailwater levels in the 10,000 year and PMF events. The 1,000 year event is the critical event;
- Open mat reinforcement would be required to protect the southern embankment against damage in the 1,000 year event;
- A rough concrete block system would be required to protect the northern and middle embankments against damage in the PMF event;
- Application of Quantitative Risk Assessment (QRA) principles however showed that the costs per life saved for protecting the northern and middle embankments against the 10,000 year and PMF events were disproportionate;
- Two other engineering options were considered:
    - Raising the southern embankment; or
    - A 170m long concrete spillway.

  The capital costs of these schemes was greater than the embankment protection schemes and so these options were not taken forward.
- The Environment Agency suggest that the additional protection to the southern embankment for the 1,000 year event should be included in any works to increase the capacity of the storage area.
- Other incidental works were also recommended:
    - Provide additional reinforcement around the manholes on the northern embankment;
    - Reinforce the access paths on the south side of the railway line with Armorloc blocks; and
    - Reinforce the cycle track surface with Armorloc blocks.
- The hydraulic modelling of the reservoir area showed that there was a significant head drop across the Six Arches Bridge so that the water level in the southern and middle compartments were higher than in the northern compartment by the following amounts:
    - 1,000 and 10,000 year – 300mm; and
    - PMF – about 900mm.

The main consideration for this IA is thus the inclusion of the cost of protecting the downstream slope of the southern embankment. In 2010, the cost of this work was estimated at around £470k. A cost for the other incidental works was not provided but is likely to be small in comparison to the cost of protecting the southern embankment.

B.2 Leigh FSA Initial Overtopping Assessment

As part of this IA, an initial overtopping assessment has been undertaken for two locations: the cattle arch embankment, and the main embankment immediately south of the railway line. The cattle arch embankment was included because a breach here could result in an uncontrolled release of water which could flood the village of Leigh on the opposite side of the railway. The corner on the south side of the railway was an area which suffered some erosion from wave action shortly after completion of the scheme and was considered to be an appropriate location to assess the freeboard for the main embankment.

The measured fetch lengths are 2.7km and 1.25km for the cattle arch embankment and the main embankment respectively. The concurrent wind speed was taken as the 200 year wind, as recommended in the 3rd Edition of FRS. The mean overtopping discharge with the mean annual maximum wind speed was also calculated. The results for a static water level of 28.85m AOD (the proposed NMOWL under the improve option) and two different sets of embankment crest levels are provided in Table B-1.

Table B-1 Summary of overtopping assessment

Embankment Location	Fetch (km)	Static Water Level (m AOD)	Assumed Crest Level (m AOD)	Freeboard (m)	Wind Return Period (yrs)*	Mean Overtopping Discharge (l/s/m)
Main embankment (railway south side)	1.25	28.85	29.15 (existing)	0.3	200	19.8
					MAM	6.3
			29.45 (raised)	0.6	200	2.2
					MAM	0.3
Cattle arch	2.7		28.96 (existing)	0.11	200	216.8
					MAM	119.0
			29.45 (raised)	0.6	200	23.5
					MAM	6.3

* MAM is the Mean Annual Maximum wind return period.

The FRS (Defra, 2015) (Table 6.2) suggests an allowable mean wave overtopping discharge of 1 l/s/m for dam crests and downstream faces consisting of good grass-covered clay fill. Table B-1 shows that if the NMOWL is raised with no works to the embankments, the wave overtopping discharge will be unacceptably high. Even with works to provide a 0.6m freeboard, the FRS allowable discharge criterion is only met at the main embankment (corner location) when considering a mean annual maximum wind speed. Furthermore, the FRS gives a reduced mean wave overtopping discharge of 0.1 l/s/m where the area is used by pedestrians / members of the public. Neither the main embankment nor the cattle arch meets this criterion and would therefore be vulnerable to wave overtopping damage.

From this assessment it is concluded that increasing the NMOWL to 28.85m AOD would require remedial works at the cattle arch embankment and to the middle and southern parts of the main embankment to address the risk of wave overtopping. For the cattle arch this remedial work could include reinforcing the crest and downstream slope in conjunction with some crest raising. Works to the southern embankment to protect against overflow during the 1,000 year flood are proposed and it could be that these works would be sufficient for overtopping protection. This could be confirmed at the next design stage.

The fetch on the northern compartment is slightly less that than for the corner on the south side so it is likely that less robust protection against wave overtopping would be required to deal with overtopping with a raised NMOWL. This should be further investigated in the next stage of the project, alongside an assessment of wave overtopping of the railway embankment.

Appendix C River Beult and River Teise Potential Flood Storage Locations

C.1 River Beult

C.1.1. Required Storage Volume

Design event hydrographs from the Headcorn and the Stilebridge nodes from the hydraulic model have been used to calculate the volume of water which would need to be stored to reduce downstream flow in the River Beult during flood events. These hydrographs were selected based on maximum peak flow and it is noted that results would be different if maximum peak volume was the key criteria.

Volume calculations have been based on discharging a peak throttled flow (by using, for example, a hydrobrake). Three maximum outflows have been used – the peak flow in the 20% (1 in 5), 10% (1 in 10) and 5% (1 in 20) AEP event. The results are given for two locations (Headcorn and Stilebridge) in Table C-1.

Table C-1 River Beult storage volume requirement calculations

Maximum throttled flow		Volume of storage required (m^3) to store the specified design flood event			
Design event	**Flow (m^3/s)**	**10% (1 in 10)**	**5% (1 in 20)**	**2% (1 in 50)**	**1% (1 in 100)**
Headcorn					
20% (1 in 5)	30	230,000	710,000	1,460,000	3,870,000
10% (1 in 10)	37	-	300,000	890,000	2,860,000
5% (1 in 20)	47	-	-	320,000	1,620,000
Stilebridge					
20% (1 in 5)	52	880,000	2,080,000	7,150,000	10,480,000
10% (1 in 10)	68	-	640,000	4,150,000	6,290,000
5% (1 in 20)	83	-	-	2,000,000	3,580,000

C.1.2. Potential Storage Locations

Upstream of Headcorn (Figure 3, Appendix A)

A potential storage location on the Upper Beult was identified immediately upstream of Headcorn Aerodrome. The site is over 20km upstream of Yalding and encompasses approximately 30% of the total River Beult catchment. It is therefore unlikely that storage in this location would notably reduce flood risk in Yalding. It could however provide local benefits to the villages of Headcorn and Staplehurst, and isolated properties / small communities immediately downstream.

The village of Smarden is located about 2.5km upstream of the proposed storage area. The presence of properties both in Smarden and the surrounding area restricts the storage level which could be achieved without making property flooding worse. LiDAR, OS Mapping and the NRD was used to assess the maximum feasible storage level. Many upstream properties are located on ground levels between 22m and 23m AOD.

Storage to this level would increase the flood depth and flood frequency of properties currently at risk, and would flood properties not previously at risk. On this basis, the maximum feasible storage level at this location is estimated to be **21.75m AOD**. This would require a **600m length embankment up to 2.25m high**. At this storage level, local protection might be required to protect properties at Hadman Place (Bell Lane) and properties south of Town Bridge (Cage Lane, Smarden). The location of these properties and the potential location of the flood storage embankment is illustrated on Figure 3 in Appendix A.

Volumetric calculations have been undertaken using LiDAR to understand the potential storage that would be available to a level of 21.75m AOD in this location. This is relatively straightforward to calculate for a dry floodplain. If outflow from the FSA was however restricted to the 20% (1 in 5) AEP event, out-of-bank flow is already occurring, with water already naturally stored on the floodplain. This natural floodplain storage volume needs to be subtracted from the dry floodplain volume to calculate the additional storage capacity which would actually be provided. This process has been undertaken for each of the design events to which outflow could be throttled. The results are provided in Table C-2.

Table C-2 Volume of storage which could be provided in the Headcorn FSA

Proposed Storage Level	Volume of Storage (m^3) which could be provided			
	Dry floodplain	Less 20% (1 in 5) flood extent	Less 10% (1 in 10) flood extent	Less 5% (1 in 20) flood extent
21.75m AOD	800,000	580,000	480,000	350,000

It is noted that while confidence is held in the dry floodplain storage calculation, more uncertainty is associated with the natural floodplain storage volumes. This is because these have been calculated using generalised modelled flood water levels and superseded model extents (updated model results were not available at the time of these calculations).

The required storage volumes in Table C-1 were compared with the available volumes in Table C-2, the results of which are documented in Table C-3.

Table C-3 Ability to store design flood event volumes in the Headcorn FSA

Maximum Throttled Flow (Design Event)	Ability to store design flood event volume (% of required volume stored)			
	10% (1 in 10)	5% (1 in 20)	2% (1 in 50)	1% (1 in 100)
20% (1 in 5)	✓ (252%)	✕ (82%)	✕ (40%)	✕ (15%)
10% (1 in 10)	N/A	✓ (160%)	✕ (54%)	✕ (17%)
5% (1 in 20)	N/A	N/A	✓ (109%)	✕ (22%)

This analysis demonstrates that while some flood storage can be provided in this location it will not provide a high SoP. Furthermore, the site encompasses only approximately 30% of the total River Beult catchment and so is unlikely to provide any flood risk benefit to the downstream communities (including Yalding) which are the focus of this IA. For this reason, flood storage in this area was not taken forward for detailed analysis and appraisal.

Headcorn to Hawkenbury Bridge (Figure 4, Appendix A)

LiDAR, OS Mapping, the NRD and hydraulic model results were used to determine whether any potential flood storage locations are available between Biddenden Road, Headcorn and Hawkenbury Bridge. The natural floodplain is extensive in this area, with modelled 20% (1 in 5) AEP flood levels between 18m and 19m AOD. Stored water levels in any FSA would therefore have to be higher than 18.5m AOD to achieve any additional storage volume above that of the natural floodplain. There are several clusters of farm properties located in areas where ground levels are at, or below, 18.5m AOD and numerous farms and clusters of properties on ground around 19m AOD. There is also a railway line which runs on an embankment across the floodplain, crossing the River Beult in three locations.

The presence of all of the properties means that meaningful flood storage cannot be created in this area without significant adverse impacts which would be technically difficult and costly to mitigate. For this reason, flood storage in this area was not considered technically viable and was not be taken forward for further consideration.

Hawkenbury Bridge to Stilebridge (Figure 5, Appendix A)

LiDAR, OS Mapping, the NRD and hydraulic model results were used to determine whether any potential flood storage locations are available between Hawkenbury Bridge and Stilebridge. The natural floodplain is extensive in this area, with modelled 20% (1 in 5) AEP flood levels between 15m and 16m AOD. Stored water levels in any FSA would therefore have to be higher than this to achieve any additional storage volume above that of the natural floodplain. There are however numerous farms and clusters of properties on ground around 16m AOD. There is also a large fish farm complex located upstream of Stilebridge.

The presence of all of the properties means that meaningful flood storage cannot be created in this area without significant adverse impacts which would be technically difficult and costly to mitigate. For this reason, flood storage in this area was not considered technically viable and was not be taken forward for further consideration.

It is also noted that the very flat gradient on the River Beult means that a FSA created downstream at Chainhurst (see next section) will “back up” and store water in some of the area upstream of Stilebridge without the need to create a separate FSA upstream of Stilebridge.

Chainhurst (Figure 6, Appendix B)

A potential storage location on the Lower Beult at Chainhurst was identified as part of the MMS Review (Halcrow, 2010) and has been further investigated as part of this study. The site is less than 5km upstream of Yalding and encompasses over 85% of the total River Beult catchment.

The presence of properties in Chainhurst, Tilden and upstream of Stilebridge restricts the storage level which could be achieved without making property flooding worse. LiDAR, OS Mapping and the NRD has been used to assess the maximum feasible storage level. There are numerous farms and clusters of properties on ground around 16m AOD upstream of Stilebridge (see Figure 5, Appendix A). Storage above this level would increase the flood depth and flood frequency of properties currently at risk, and would flood properties not previously at risk. On this basis, the maximum feasible storage level at this location is **15.75m AOD**. This would still require a **720m length embankment up to 3m high** across the Beult valley upstream of Hunton Road / East Street.

Local mitigation might be needed to protect properties and a pub on the southern side, immediately downstream of Stilebridge. This could be achieved by raising the level of Tilden Lane in this location. There may also be an increased risk of flooding to properties at Old Hertsfield, agricultural glasshouses at Hurst Green and Riverfield Fish Farm for which mitigation could be provided if necessary.

Flooding in the area around Chainhurst is complex, with floodwater from the River Beult flowing southwards and inundating the Tilden area. This same area can also flood from the Lesser Teise located further to the south. Work by Halcrow as part of the MMS Review (Halcrow, 2010) suggested that construction of an embankment at Chainhurst would re-route floodwater from the River Beult, into the low-lying Tilden area and then into the Lesser Teise floodplain, from where it would re-join the River Beult upstream of Yalding. The embankment therefore effectively only partially reduced and delayed the peak flow in the Beult at Yalding while increasing the risk of flooding to numerous properties around Chainhurst and Tilden.

Preventing this re-routing of floodwater would require construction of around **3km of side embankments (1 – 2m high)** to the south of the River Beult, the proposed locations for which are illustrated on Figure 6 in Appendix A. These side embankments will also protect properties in this area and prevent any worsening of existing flood risk. An alternative configuration of shorter side embankments parallel to the River Beult was considered, but rejected because they significantly reduced the volume of storage available in the resulting FSA.

Volumetric calculations have been undertaken using LiDAR to understand the potential storage available up to a level of 15.75m AOD. As with the Headcorn site, calculations were done for a dry floodplain and also the additional storage capacity which could be provided over and above the natural floodplain storage volume. The results are provided in Table C-4.

Table C-4 Volume of storage which could be provided in the Chainhurst FSA

Proposed Storage Level	Volume of Storage (m^3) which could be provided			
	Dry floodplain	Less 20% (1 in 5) flood extent	Less 10% (1 in 10) flood extent	Less 5% (1 in 20) flood extent
15.75m AOD	5,100,000	3,800,000	3,400,000	2,100,000

The required storage volumes in Table C-1 were compared with the available volumes in Table C-4, the results of which are documented in Table C-5.

Table C-5 Ability to store design flood event volumes in the Chainhurst FSA

Maximum Throttled Flow (Design Event)	Ability to store design flood event volume (% of required volume stored)			
	10% (1 in 10)	5% (1 in 20)	2% (1 in 50)	1% (1 in 100)
20% (1 in 5)	✓ (432%)	✓ (183%)	✕ (53%)	✕ (36%)
10% (1 in 10)	N/A	✓ (531%)	✕ (82%)	✕ (54%)
5% (1 in 20)	N/A	N/A	✓ (105%)	✕ (59%)

C.2 River Teise

C.2.1. Required Storage Volumes

Design event hydrographs from the Stonebridge node in the hydraulic model have been used to calculate the volume of water which would need to be stored to reduce downstream flow in the River Teise during flood events. Volume calculations have been based on discharging a peak throttled flow (by using, for example, a hydrobrake). Three maximum outflows have been used – the peak flow in the 20% (1 in 5), 10% (1 in 10) and 5% (1 in 20) AEP event. The results are provided in Table C-6.

Table C-6 River Teise storage volume requirement calculations at Stonebridge

Maximum throttled flow		Volume of storage required (m^3) to store the specified design flood event			
Design event	**Flow (m3/s)**	**10% (1 in 10)**	**5% (1 in 20)**	**2% (1 in 50)**	**1% (1 in 100)**
20% (1 in 5)	49	200,000	700,000	1,610,000	2,930,000
10% (1 in 10)	63	-	290,000	1,020,000	1,930,000
5% (1 in 20)	83	-	-	420,000	1,080,000

C.2.2. Potential Storage Locations

Cottage Wood (Figure 7, Appendix A)

A potential storage location at Cottage Wood on the River Teise (about 2km downstream of Stonebridge) was identified as part of the MMS Review (Halcrow, 2010). This has been further investigated as part of this study. The site is upstream of the split into the Lower and Lesser Teise, about 4km upstream of Collier Street and 11km upstream of Yalding. It encompasses 78% of the total River Teise catchment. Locations further downstream are unsuitable for flood storage because of the significant increase in width of the floodplain and the presence of many low-lying properties.

The floodplain upstream of the proposed embankment location is rural with few properties at risk of flooding. There are however farm and residential buildings and to the north of Goudhurst Road, west of Stonebridge. Ground level around these buildings is 28m AOD. Goudhurst Road (minimum level 28m AOD) is slightly raised above the floodplain and acts to restrict downstream flows during more frequent flood events. Storage above 28m AOD would therefore increase the risk of both property and road flooding. The valley floor at Cottage Wood is at 24m AOD. A storage level of **27.5m AOD** would require a **470m long embankment up to 3.5m high** (see Figure 7, Appendix A)**.** This is considered a reasonable maximum embankment height appropriate for this location.

Volumetric calculations have been undertaken using LiDAR to understand the potential storage available up to a level of 27.5m AOD. As with the River Beult sites, calculations were undertaken for a dry floodplain and also the additional storage capacity which could be provided over and above the natural floodplain storage volume. The results are provided in Table C-7.

Table C-7 Volume of storage which could be provided in the Cottage Wood FSA

Proposed Storage Level	Volume of Storage (m^3) which could be provided			
	Dry floodplain	Less 20% (1 in 5) flood extent	Less 10% (1 in 10) flood extent	Less 5% (1 in 20) flood extent
27.5m AOD	1,210,000	1,110,000	1,020,000	880,000

The required storage volumes in Table C-6 were compared with the available volumes in Table C-7, the results of which are documented in Table C-8.

Table C-8 Ability to store design flood event volumes in the Cottage Wood FSA

Maximum Throttled Flow (Design Event)	Ability to store design flood event volume (% of required volume stored)			
	10% (1 in 10)	5% (1 in 20)	2% (1 in 50)	1% (1 in 100)
20% (1 in 5)	✓ (555%)	✓ (159%)	✕ (69%)	✕ (38%)
10% (1 in 10)	N/A	✓ (352%)	✓ (100%)	✕ (53%)
5% (1 in 20)	N/A	N/A	✓ (210%)	✕ (81%)

The analysis carried out has shown that flood storage on the River Teise could lower the level of flooding in downstream communities if a suitable site is identified. The only flood storage areas suitable on the River Teise have spatial and technical limitations that would need to be assessed and overcome. The flood event size and distribution in the downstream areas are dependent on the location and passage of the weather events experienced and this would need to be considered. There is potential for reduction of flows in Chainhurst from the Teise storage areas, however, this would require storage on the Beult to be implemented. Stonebridge (Figure 8, Appendix A)

Previous work has also investigated a storage location 500m upstream of Stonebridge. This is also a rural location, although there are low lying properties at Stonebridge (minimum ground level 29.5m AOD) and Smallbridge (minimum ground level 31m AOD), and a pumping station downstream of Smallbridge (minimum ground level 31.75m AOD). Taking into account upstream properties and assets, and maximum recommended embankment heights (the valley floor in this area is 27m AOD), the recommended storage level at this location is 30.5m AOD. This would require a 460m embankment up to 3.5m high across the Teise valley upstream of Stonebridge. Storage to this level would also require mitigation to prevent detrimental impact to nearby properties. The location of the proposed embankment and upstream properties / assets are illustrated on Figure 8 in Appendix A.

Volumetric calculations have been undertaken using LiDAR to understand the potential storage available up to a level of 30.5m AOD in this location. As with the other sites, calculations were done for a dry floodplain and also the additional storage capacity which could be provided over and above the natural floodplain storage volume. The results are provided in

Table C-9. This site alone does not provide sufficient storage volume to attenuate flows on the River Teise. It could however be considered in combination with the downstream Cottage Wood FSA.

Table C-9 Volume of storage which could be provided in the Stonebridge and Cottage Wood FSAs

Proposed Storage Location and Level	Volume of Storage (m^3) which could be provided			
	Dry floodplain	Less 20% (1 in 5) flood extent	Less 10% (1 in 10) flood extent	Less 5% (1 in 20) flood extent
Stonebridge 30.5m AOD	880,000	830,000	750,000	130,000
Stonebridge and Cottage Wood combined	2,090,000	1,940,000	1,770,000	1,010,000

Comparing the required volumes in Table C-6 with the available volumes in

Table C-9 demonstrates that the combined storage could provide a 2% (1 in 50) standard, but falls just short of a 1% (1 in 100) standard, as indicated in Table C-10.

Table C-10 Ability to store design flood event volumes in the two River Teise FSAs

Maximum Throttled Flow (Design Event)	Ability to store design flood event volume (% of required volume stored)			
	10% (1 in 10)	5% (1 in 20)	2% (1 in 50)	1% (1 in 100)
20% (1 in 5)	✓ (970%)	✓ (277%)	✓ (120%)	✕ (66%)
10% (1 in 10)	N/A	✓ (610%)	✓ (174%)	✕ (92%)
5% (1 in 20)	N/A	N/A	✓ (240%)	✕ (94%)

Appendix D Hydraulic Modelling

JBA Consulting File Note: River Medway Flood Storage Areas Options Modelling

NOTE TO FILE

JBA Project Code	2015s3166
Contract	River Medway Flood Storage Areas Options Modelling
Client	VBA Joint Venture Ltd
Date	January 2016
Author	Matthew Savill and Ben Gibson
Subject	Medway FSAs flood risk modelling assessment

1 Scope and objectives

JBA Consulting was commissioned by VBA Joint Venture Ltd (VBA) too conduct flood risk modelling to support their assessment into the viability of flood risk management options within the River Medway catchment downstream of Leigh FSA. Specifically, the main workstreams of the project were as follows:

- Increasing the Normal Maximum Operating Water Level (NMOWL) of Leigh FSA from 28.05m AOD to 28.85m AOD and assessing the influence this has on predicted flooding downstream.
- Testing the impact that three Flood Storage Areas (FSAs) located on the River Beult and River Teise catchments has on predicted flooding. The FSAs were named Chainhurst FSA (River Beult), Cottage Wood FSA (River Teise) and Stonebridge FSA (River Teise). The FSAs were tested as follows:
    - Chainhurst FSA tested in isolation
    - Chainhurst FSA and Cottage Wood FSA tested together
    - Chainhurst FSA, Cottage Wood FSA and Stonebridge FSA tested together
- Increased conveyance between Maidstone and the confluence of the River Medway and the River Beult. This was achieved through testing a 5m widening of the channel between the River Beult-River Medway confluence to Maidstone.
- Testing of the 3 no. FSAs in combination with the increased NMOWL of Leigh FSA to 28.85m AOD.

Each workstream involved simulated this changes through one or more of the hydraulic models developed for the Medway Catchment Mapping and Modelling Study, finalised in 2015. The models used in this study were Model 2, Model 3 and Model 4. The key features of each model are presented in Table 1-1. The main study reporting from the Medway Catchment Mapping and Modelling study[1], along with the Model Operation Manuals[2] for each model should be read to better understand the configuration of each hydraulic model. Furthermore, the hydrological reporting[3] for the study should be read to provide further background to the hydrological inputs to each hydraulic model.

For the purpose of this assessment, the model and outputs from the Medway Catchment Mapping and Modelling study represent the current flood risk condition of the River Medway catchment. Updates were made to the hydraulic models under each workstream to represent the flood risk management schemes. These changes are documented in sections 2, 3 and 4.

For the Leigh FSA NMOWL workstream, defended outputs were available for the six annual exceedance probability (AEP) events tested in Model 2 (20%, 5%, 2%, 1.33%, 1% and 0.4% AEP events). However, VBA also required undefended outputs for each of these AEP events. The Medway Catchment Mapping and Modelling study only simulated undefended 5% and 1% AEP events. Therefore as part of this study the remaining four AEP undefended case events were simulated through the Model 2 hydraulic model and model outputs (depth grids in ASCII format) supplied to VBA. The continuous simulation hydrology reporting from the previous study documents how these other undefended events can be extracted from the hydrological modelling.

1.1 Output zones

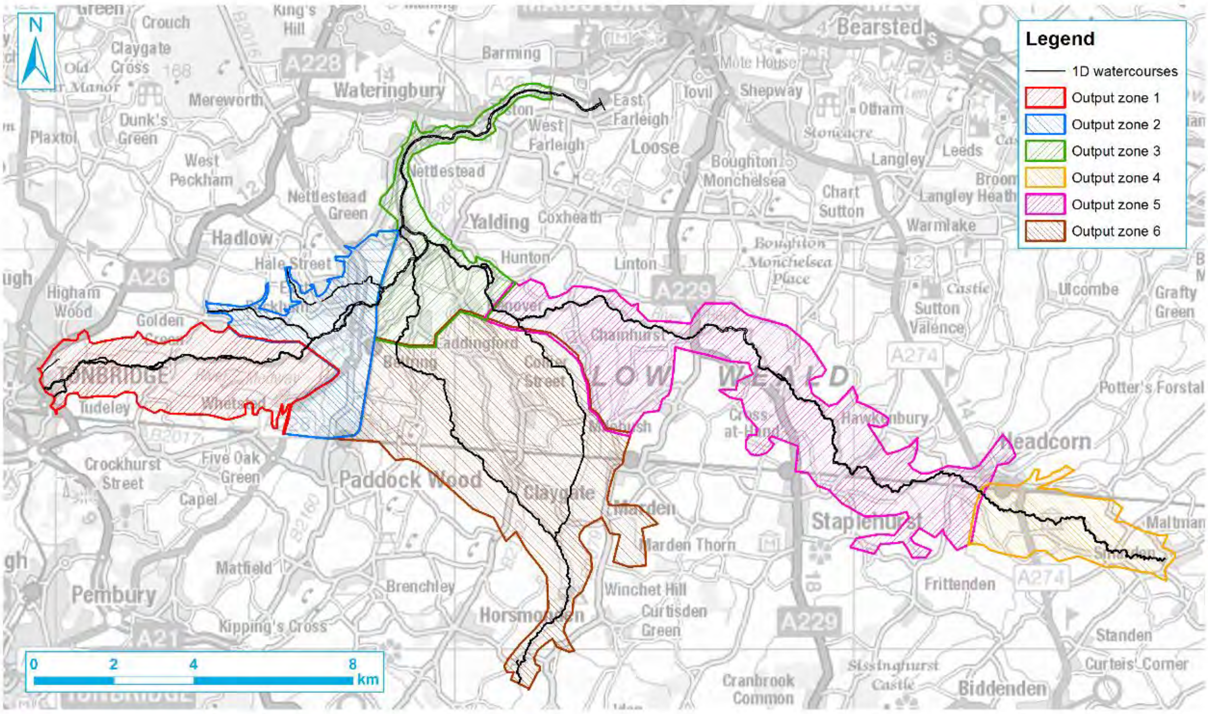
Within Model 3, further division of the model area takes place where a number of 'output zones' are assigned in which given hydrological inputs provide the design event hydrology for that reach of watercourse. Six outputs zones are present (Figure 1-1). Models 2 and 4 have only one output zone each (the full model extent). Within Model 3 the final study-wide outputs are therefore a composite of the design event hydrology and resulting flood risk mapping outputs in each output zone i.e. the 1% AEP event outputs are a combination of the six output zones. The model nodes that correspond within each output zone are provided within the previous study reporting.

[1] Medway Catchment Mapping and Modelling main study report, October 2015, JBA Consulting for Environment Agency.

[2] Medway Catchment Mapping and Modelling main study report Appendix B: Model Operation Manuals, October 2015, JBA Consulting for Environment Agency.

[3] Medway Catchment Mapping and Modelling main study report Appendix A: Hydrology Report, October 2015, JBA Consulting for Environment Agency.

Figure 1-1: Model 3 output zones



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For the purpose of modelling completed to meet the objectives of this study, the conveyance improvements testing only required simulation of output zone 3. The testing of the three FSAs (Chainhurst, Cottage Wood and Stonebridge) required simulation of outputs zones 3, 5 and 6. Output zones 1, 2 and 4 were not simulated as it was considered that impacts on flooding in these zones brought about by the FSAs would be very small or non-existent. For the modelling of the three FSAs tested in conjunction with the NMOWL adjustments at Leigh FSA, modelling was extended to include output zones 1 and 2 given the influence that the Leigh FSA adjustments have on flows from upstream.

NOTE TO FILE

JBA Project Code	2015s3166
Contract	River Medway Flood Storage Areas Options Modelling
Client	VBA Joint Venture Ltd
Date	January 2016
Author	Matthew Savill and Ben Gibson
Subject	Medway FSAs flood risk modelling assessment

Table 1-1: Details of the models developed for the Medway Catchment Mapping and Modelling Study used in this study

Model name	Subject watercourses	Extents	Output zones*	Workstreams in this study	Modelling approach
Model 2	River Medway Gas Works Stream Botany Stream	*River Medway (incl. Botany Stream and Gas Works Stream):* Downstream of Leigh FSA to Hartlake Bridge Upstream - (Easting: 556390, Northing: 146120) Downstream - (Easting: 562940, Northing: 147260) *Hilden Brook:* From upstream of London Road (Easting: 558740, Northing: 147730) *Hawden Stream:* From downstream of Leigh Road (Easting: 557080, Northing: 148130)	1	Leigh FSA NMOWL	ISIS-TUFLOW (1D-2D)
Model 3	River Medway River Teise Lesser Teise River Beult	*River Medway:* From Cannon Lane/Vale Road, Tonbridge to East Farleigh GS Upstream 1 - (Easting: 559700, Northing: 146520) Upstream 2 - (Easting: 559940, Northing: 146320) Downstream - (Easting: 573680, Northing: 153660) *River Teise:* From upstream of Stonebridge GS (Easting: 571580, Northing: 139160) *Lesser Teise:* Full watercourse extent *River Beult:* From Smarden (Easting: 587820, Northing: 142270) *River Bourne:* From Victoria Road, Golden Green (Easting: 563820, Northing: 148460)	6	River Beult and Teise FSAs Conveyance improvement testing	ISIS-TUFLOW (1D-2D)

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Model name	Subject watercourses	Extents	Output zones*	Workstreams in this study	Modelling approach
		Cault Stream: From East Peckham FSA (Easting: 565800, Northing: 149490)			
Model 4	River Medway	*River Medway:* From Teston to Allington Lock Upstream - (Easting: 570870, Northing: 153050) Downstream - (Easting: 574840, Northing: 158150) (continuing in 1D only modelling to Smurfit TL site) *River Len:* From Wat Tyler Way (Easting: 576500, Northing: 155620)	1	River Beult and Teise FSAs Conveyance improvement testing	ISIS-TUFLOW (1D-2D)

* Output zones are discussed in section 1.1.

2 Increased NMOWL at Leigh FSA from 28.05m AOD to 28.85m AOD

The Normal Maximum Operating Water Level (NMOWL) in Leigh FSA is currently 28.05m AOD, meaning operators store water up to a maximum permissible level of 28.05m AOD. The option tested increasing this permissible level from 28.05m AOD to 28.85m AOD.

Revised outflows from Leigh FSA, derived from adjustments to the continuous simulation hydrological reporting (refer to section 2.1) cascade into the Model 2 flood risk mapping model. Testing involved understanding the impacts on flood risk of this revised NMOWL for the 20%, 5%, 2%, 1.33%, 1% and 0.4% AEP defended case events. Data provided to VBA was ASCII format depth grids for each event derived directly from TUFLOW.

Data used as part of this assessment is summarised below. Readers should refer to the information supplied as part of the Medway Catchment Mapping and Modelling study for further information. Refer to section 1 for further information on documents from the previous study. Information presented here relates solely to adaption of models to provide outputs for the current study.

2.1 Data used

The hydrological modelling used information developed for the Medway Catchment Mapping and Modelling study as the basis for updates. The main input data is summarised below.

Table 2-1: Summary of data used in deriving Leigh FSA outflows with NMOWL of 28.85m AOD

Data	Use in updated hydrological modelling
Stochastic flow series (5,000-years of continuously simulated flow data)	Calculated by PDM rainfall runoff models from an hourly stochastic rainfall series. For discrete events, extracted hydrographs form the upstream boundaries to the LeighBarrier01.DAT ISIS model (see below).
Continuous simulation routing model (LeighBarrier01.DAT)	ISIS model is comprised of VPMC routing reaches, RIVER Sections and one RESERVOIR. Leigh FSA, and the operation of the three radial gates, is represented by the DAT and associated IED files. Model is run for all significant AMAX events in the 5,000-year inflow series (a total of 3,174). In normal operation, the model restricts outflow from the FSA to 80m^3/s. If there is insufficient storage to achieve this, different gate operation scenarios are simulated. The optimum gate operation for each flood event is then selected and used according to these simple rules: 1.) If water levels are below the NMOWL, then the optimum scenario is that with lowest outflows. 2.) If water levels rise above the NMOWL, then the optimum scenario is that which produces the lowest water levels.

2.2 Summary of adjustments to hydrological modelling and approach

2.2.1 Model adjustments

Logical rules controlling the central and (combined) north and south gates (in two IED files) were updated. In the original scenario, the gates open to pass forward the inflow at 28.05m AOD. This value was raised to 28.85m AOD. This was the only edit made to the model files.

2.2.2 Model run changes

The models were then run in the same way as described in the Medway Catchment Mapping and Modelling hydrology report. The NMOWL was increased in the software choosing the optimum model run, i.e.:

- Scenarios are rejected if water levels exceed 28.86m AOD (previously 28.06m AOD) in the FSA; BUT
- If all scenarios exceed 28.86m AOD then that which gives the lowest water level is chosen.

All other steps in deriving inflows to Model 2 were identical to the original study.

3 River Beult and River Teise Flood Storage Areas

Three Flood Storage Areas (FSAs) required schematising and testing through the flood risk mapping models 3 and 4 to produce flood risk mapping outputs that can be used to assess the benefits of developing FSAs in the catchment. The proposed FSAs are located on the River Beult and River Teise and are named according to the settlement they are located closest to: Chainhurst FSA (River Beult), Cottage Wood FSA (River Teise) and Stone Bridge FSA (River Teise).

The FSA scheme details were provided by VBA and are summarised within the sections below. Firstly, a summary is provided on the initial approach tested which was intended to provide revised hydrological inputs to the flood risk mapping models. These revised hydrological inputs were tested to better reflect the expected hydrological design events post-construction of the FSAs (e.g. due to the presence of the FSAs, return period events downstream of the FSAs will be expected to change due to storage within the FSAs. However, for reasons presented within section 3.1 this approach was not taken forward and the original hydrological inputs to the flood risk mapping models were retained.

Each set of FSAs tested were simulated for the 20%, 5%, 2%, 1.33%, 1% and 0.4% AEP events and maximum depth grids in ASCII format were supplied to VBA for each event.

3.1 Initial method: updating continuous simulation hydrological routing models (*approach not taken forward)*

With the presence of an embankment(s) and flow control(s), the nature of a given return period event may change downstream of each FSA. For instance, under increased storage behind an embankment, flood volumes may become more critical to determining peak water levels and flood extents, both upstream and downstream of the embankment.

To account for such changes it was intended that each FSA option would be schematised the Middle Medway routing model which is used as part of the process for deriving continuous simulation hydrological inputs. By schematising the FSAs within the routing models and re-simulating the 5,000-years of continuous simulation event information for each option, new peak flows estimates throughout the catchment could be derived based on updated flood frequency curves at each model node. The return period events extracted from the continuous simulation modelling could then be simulated through the flood risk mapping modelling (with FSAs) schematised to provide updated outputs on return periods flows under each scheme option.

To enable the FSAs to be implemented within the routing models, and to simplify the continuous simulation modelling to involve only one model, it was necessary to update the routing model. The following updates were made:

- Incorporation of the 'MidMedway.DAT' routing model (also used within the Medway Catchment Mapping and Modelling study) to represent the River Medway and River Bourne.
- Incorporation of the River Beult routing model ('Beult01.DAT' also used within the Medway Catchment Mapping and Modelling study) to represent the River Beult upstream of Stilebridge GS.
- Incorporation of parts of the Upper River Teise 1D flood risk mapping model ('UT-100yr_d.DAT', produced in the Upper Teise, Beult and Bourne 2007 flood risk mapping study) to represent the River Teise upstream of Stonebridge GS.
- Replacement of routing sections implemented along the River Beult (downstream of Stilebridge GS) and River Teise (downstream of Stonebridge GS) with modelled data from the Model 3 flood risk mapping model. The majority of structures were removed from the model and River Sections were extended into the floodplain with LIDAR data. ISIS Spill units were used to represent the transfer of flows between watercourses via the floodplain. This was particularly important to replicate the transfer of water between the River Beult and Lesser Teise upstream of the proposed Chainhurst FSA embankment.

However, on re-running the 5,000-years of continuously simulated data, checks on the flood frequency curve at East Farleigh GS indicated differences, typically slightly lower flows for a given return period event. Therefore, to understand the differences in terms of predicted flood risk it was decided to simulate the revised design events through the flood risk mapping model. Tests were completed with the 5-year, 20-year and 100-year defended case return period design events focused on output zone of Model 3. Reasonable differences in the predicted flood depths were noted, and to a lesser extent the predicted flood extents. Estimates of baseline damages using these outputs were completed by VBA and compared with the previous study outputs, which also showed differences.

Interrogation of the flows which contribute to design events was completed and focused on the contribution of flows from the River Medway, River Beult and River Teise on output zone 3. The assessment looked at the magnitude contribution of each watercourse to a given design in terms of return period estimate on each watercourse. It was found for output zone 3 (which is focused on the confluence of these watercourses) different watercourses were contributing a given return period event (e.g. some were Beult-dominated events, whilst others Teise or Medway dominated events). The watercourse contributing to a given design event (e.g. 100-year) also varied between the previous study hydrology and the hydrology derived from the updated 'MidMedway.DAT' routing model. This, in addition to the change in flood frequency curve resulting from routing model updates also contributed to the differences in flood risk modelling outputs reported above.

In order to fully understand the differences and complete a robust analysis using these updated continuous simulation outputs, it would be necessary to complete actions to make the results pre- and post-FSA testing model comparable, which could be achieve by:

- Ensuring the same watercourse are contributing to each design event (e.g. both the pre- and post-FSA events are Beult dominated events), or
- Simulating a number of events for a given return period (which cover dominance from each of the River Beult, River Teise and River Medway) and combine these to create worst-case flood depth mapping.

However, given pressures on project programme (meaning conducting a larger number of model simulations and/or in-depth analysis into the continuous simulation hydrology contribution was not possible), it was agreed to revert to testing the original flood risk mapping hydrology through the flood risk mapping models. To provide VBA with information regarding which watercourses are contributing largest flows within each design event, return period estimates for contributing watercourses, along with hydrograph shapes for these watercourses were supplied. This information is presented within section 5.

3.2 FSA scheme details

3.2.1 Chainhurst FSA

Embankment locations

The main embankment was implemented across the River Beult floodplain at Chainhurst upstream of Hunton Road/East Street. Three side embankments were also implemented in the model, these were located:

- South of the River Beult in the Tilden/Chainhurst area preventing flows from bypassing into the Lesser Teise valley.
- Protecting the properties along Tilden Lane, downstream of Stilebridge.
- Protecting the properties at Old Hertsfield.

These locations were indicated by the GIS file 'Chainhurst_FSA_embankments' provided with the project scope information.

Embankment elevations

The main embankment was assigned an elevation of 15.75m AOD. All three side embankments were assigned elevations of 16.50m AOD.

FSA outflows

Flows passing downstream through the main embankment were restricted to 75m^3/s.

3.2.2 Cottage Wood FSA

Embankment location

The single embankment was located across the River Teise floodplain downstream of Stonebridge GS. This location was indicated by the GIS file 'CottageWood_FSA_embankment' provided with the project scope information.

Embankment elevation

The embankment was assigned an elevation of 27.50m AOD.

FSA outflows

Flows passing downstream through the main embankment were restricted to 60m^3/s.

3.2.3 Stonebridge FSA

Embankment location

The single embankment was located across the River Teise floodplain upstream of Stonebridge GS. This location was indicated by the GIS file 'Stonebridge_FSA_embankment' provided with the project scope information.

Embankment elevation

The embankment was assigned an elevation of 30.50m AOD.

FSA outflows

Flows passing downstream through the main embankment were restricted to 60m^3/s.

3.3 Representation of FSAs in flood risk mapping model

The approach used to implement the proposed FSAs within the flood risk mapping models is discussed below.

3.3.1 Embankments

All embankments tested in the model were implemented using Z-Shapes. These raised the model grid cells to the elevation of the embankments noted above, meaning water cannot flow past this point across the floodplain until the embankment level is exceeded. No account of freeboard elevation was added and therefore the embankments were allowed to overtop at the elevations above. Any overtopping of the embankments was represented in the 2D TUFLOW domain whereby flow passes across the embankment crest implemented by the Z-Shape. At the channel/structure location within the ISIS 1D model a SPILL unit was implemented with the elevation of the embankment and width of the upstream channel section.

3.3.2 Flow control

The flow control structures implemented at the location of the channel/embankment intersection throttled flows passing through the channel/ to those recorded above. The flows controls were represented in the model using Flow-Head units (ISIS QHBDY units). A flow-head relationship was derived from the baseline flood risk mapping modelling. For a given flow passing through the QHBDY unit, a given water level is specified up to the design outflow flow. Above this flow, the outflow is fixed and water levels rise according to the available storage in the FSA.

3.4 Model Simulations

Four suites of model runs were simulated, each representing a different storage option. These were:

- Chainhurst FSA only
- Chainhurst and Cottage Wood FSAs
- Chainhurst, Cottage Wood and Stonebridge FSAs
- Chainhurst, Cottage Wood and Stonebridge FSAs tested in conjunction with the adjustments to Leigh FSA Normal Maximum Operating Water Level (NMOWL) recorded within section 2.

3.5 Model 4 hydrological inflows

Inflows to Model 4 are not predicted flows cascaded down from Model 3. Rather, they are inflows extracted from the continuous simulation hydrological modelling at the model node representing East Farleigh gauging station. Therefore the X-year design event upstream of East Farleigh GS at the downstream of Model 3 differs from the same X-year design event in Model 4.

Given the requirement to understand how the FSAs influence model predictions through Maidstone (Model 4) it was necessary to account for the reduction in flows predicted for design event. It was agreed that the peak flows predicted at East Farleigh GS for each of the design events within Model 3, output zone 3 between the as-is case (no FSAs) and the with FSAs case would be compared, and the percentage reduction in peak flows would be applied to the Medway flows implemented within Model 4 for the given design event. The scaling factors applied to the River Medway inflow to Model 4 (ISIS QTBDY: MED04) are presented in Table 3-1 for each of the FSA options tested. Of note is that the 5-year event is predicted to show a very slight increase in inflows. Because of a change in the timing of event.

Table 3-1: Scaling factors applied to the River Medway inflow (node MED04) within Model 4 to represent the influence of the River Beult and River Teise FSAs

Return period event	Scaling factor applied to MED04 (Model 4 inflow for River Medway)		
	Chainhurst FSA	Cottage Wood FSA	Stonebridge FSA
5	1.006	1.002	1.005
20	0.969	0.962	0.960
50	0.956	0.950	0.949
75	0.960	0.966	0.959
100	0.958	0.946	0.944
250	0.969	0.961	0.946

3.6 Testing of three FSAs in conjunction with the increase in Leigh FSA Normal Maximum Operating Water Level from 28.05m AOD to 28.85m AOD

In order to test the influence of the three Beult/Teise FSAs in conjunction with changes to the NMOWL at Leigh FSA from 28.05m AOD to 28.85m AOD, the hydrological input from Leigh FSA (ISIS QTBDY: OutflowLB), the ISIS Event Data files for Model 3 were updated with the revised 'OutflowLB' flows from the Leigh FSA NMOWL workstream (refer to section 2).

In addition to updating the hydrological inflows, this element of modelling required simulation of model output zones 1 and 2 (in addition to output zones 3, 5 and 6 simulated for just the FSA testing).

The same approach for testing the impact on flood risk within Model 4 was retained from the assessment into the three FSAs. The scaling factors applied to the River Medway inflow to Model 4 (ISIS QTBDY: MED04) are presented in Table 3-2 for the option testing the three FSAs and NMOWL adjustments in combination.

Table 3-2: Scaling factors applied to the River Medway inflow (node MED04) within Model 4 to represent the influence of the River Beult and River Teise FSAs, along with the adjustments to Leigh FSA NMOWL

Return period event	Scaling factor applied to MED04 (Model 4 inflow for River Medway)
	Chainhurst FSA
5	1.005
20	0.960
50	0.886
75	0.917
100	0.894
250	0.946

4 Improved conveyance option

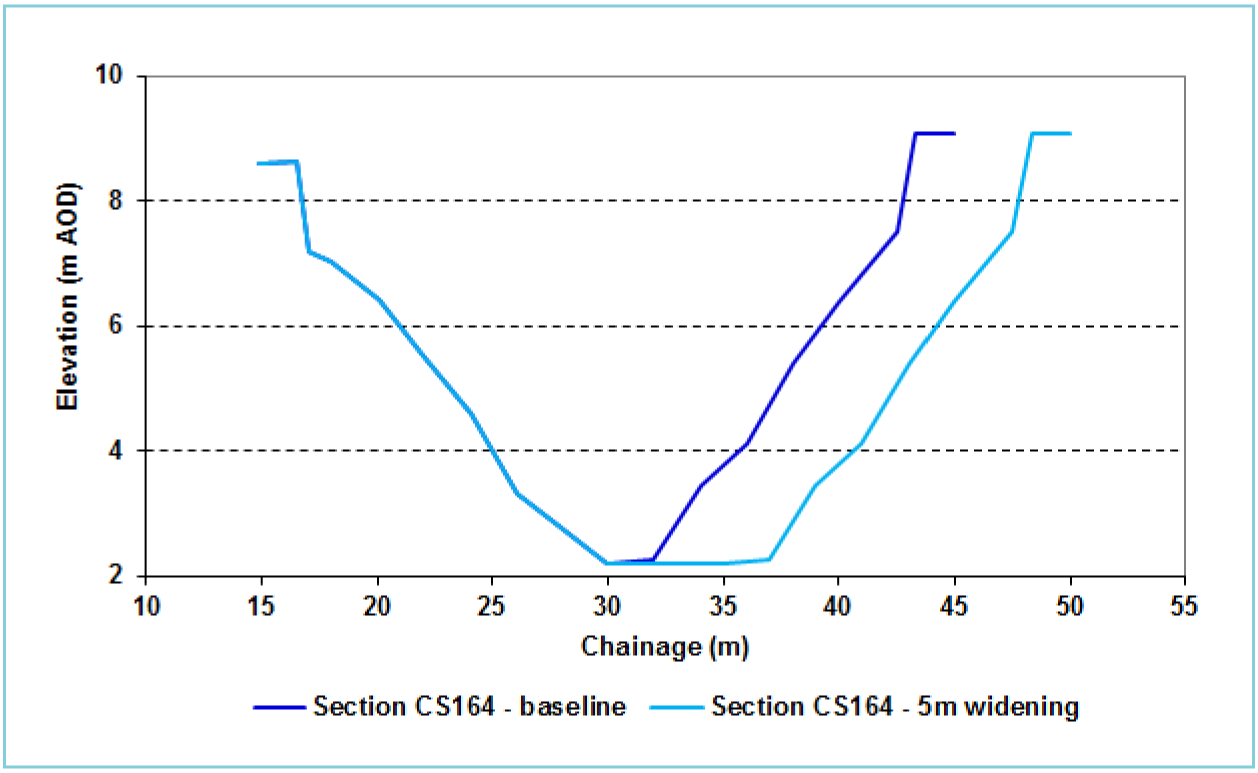
Increased conveyance between the confluence of the River Medway and River Beult and Maidstone (Lock Meadow Footbridge) was tested within Model 3 (output zone 3) and Model 4. The sections below document the manner in which the hydraulic model was adjusted. Following simulation of the 2% AEP defended case event and 25 December 2013 calibration event tested in the Medway Catchment Mapping and Modelling study maximum depths grids in ASCII format were issued to VBA for comparison against the current case outputs.

4.1 River channel

ISIS River Section units within the study area were widened by 5m at the lowest point in the channel bed. No adjustments were made to the shape of the channel bank and no changes were made to hydraulic roughness of the channels. The approach therefore represents a scenario where the channel is widened into the floodplain, but shape remains consistent. An example of an adjusted section is provided in Figure 4-1.

Any areas of 1D channel sections which extend beyond the bank top were not adjusted to replicate the loss of floodplain that would occur due to the channel widening. Additionally, the 1D-2D ISIS-TUFLOW bank connections (HX lines) were not widened at this stage to reflect the works. The modelled approach therefore replicates a case whereby actual benefits of widening may have been slightly overestimated. However, given that this investigation is at very initial stages, and the model grid size is 20m in Model 3 and 6m in Model 4, any overestimation was expected to be small.

Figure 4-1: Cross-section CS164 before and after 5m widening



4.2 Bridge structures

The degree of adjustment to the bridge structures on the reach was based on the headloss (difference in water levels between upstream and downstream faces) at the four bridge structures in the defended 2% AEP event and 25 December 2013 calibration event simulations completed as part of the Medway Catchment Mapping and Modelling study. These are presented in Table 4-1.

Table 4-1: Headloss at structures in 2% AEP (defended) design event and December 2013 calibration event

Bridge	Headloss 2% AEP event (m)	Headloss December 2013 event (m)
Bow Bridge Upstream node: S6u Downstream node: S6d	0.03	0.03
Teston Bridge Upstream node: CS176U Downstream node: CS178D	0.20	0.20
Barming Bridge Upstream node: CS182U Downstream node: CS184D	0.13	0.11
East Farleigh Bridge Upstream node: CS186U Downstream node: CS188BJD	0.33	0.40

Given the relatively small headloss predicted at Bow Bridge and Barming Bridge, no adjustments to these structures were implemented within the model. Given the larger headloss predicted as Teston Bridge and East Farleigh Bridge, adjustments to these structures were implemented. The flow area of each bridge (each modelled as a Bernoulli Loss unit) was increased by 15% to represent increased flow area through the bridges. No changes in the soffit levels of the bridge arches were undertaken, nor were adjustments made to the loss coefficients 'K' values, within these units). Each bridge is a listed structure and a Scheduled Ancient Monument so it was considered that more extreme testing (e.g. removal of these structures) would not be representative.

5 Timing and magnitude of peaks in design events

It is noted above that the contribution to flooding from the tributaries around the River Medway, River Beult and River Teise confluences can influence the predicted flooding in the area, even if for instance the cumulative flow downstream of their confluence is the same. This is particularly true for Yalding, situated at the confluence of these watercourses.

The contribution to flooding from each watercourse is important to understand given that FSA schemes are being tested on each watercourse. If for instance, under the Chainhurst FSA option (River Beult) the X-year return period flood at Yalding is derived from a much larger return period flood event on the River Teise (but a small event on the River Beult), then the FSA may not be shown to reduce flood risk. Whilst for this one design event simulation this is sensible, not all X-year flood events at Yalding are expected to result from River Teise dominated events – some will be from Beult and Medway dominated events. Therefore, focusing on just one scenario may adversely impact the cost:benefit predictions. Understanding of each design event allows the user to more fully understanding the resulting benefits predicted from the FSA schemes.

To assist with the understanding of predicted flooding within the hydraulic models and the influence that this may have on predicted flooding, the timing and magnitude of the peak flows flowing down each watercourse for each of the design flows in each output zone was extracted and is presented within the sections below. This allows the user to visualise which watercourse provided the largest proportion of flows in each event. The magnitude of flows is reported as a return period estimate for the main contributing watercourses, whilst flow hydrographs for the same locations indicate the timing of these inputs. Information for output zone 4 is not presented as this area, between Smarden and Headcorn was not simulated as part of the study. The locations that return period estimates and flow hydrographs were extracted are noted below:

- Node: OutflowLB – River Medway, downstream of Leigh FSA
- Node: Stonebridge – River Teise at Stonebridge GS
- Node: Stilebridge – River Beult at Stilebridge GS
- Node: CS156JD* – River Medway, downstream of Yalding Marina
- Node: CS189** – River Medway at East Farleigh GS

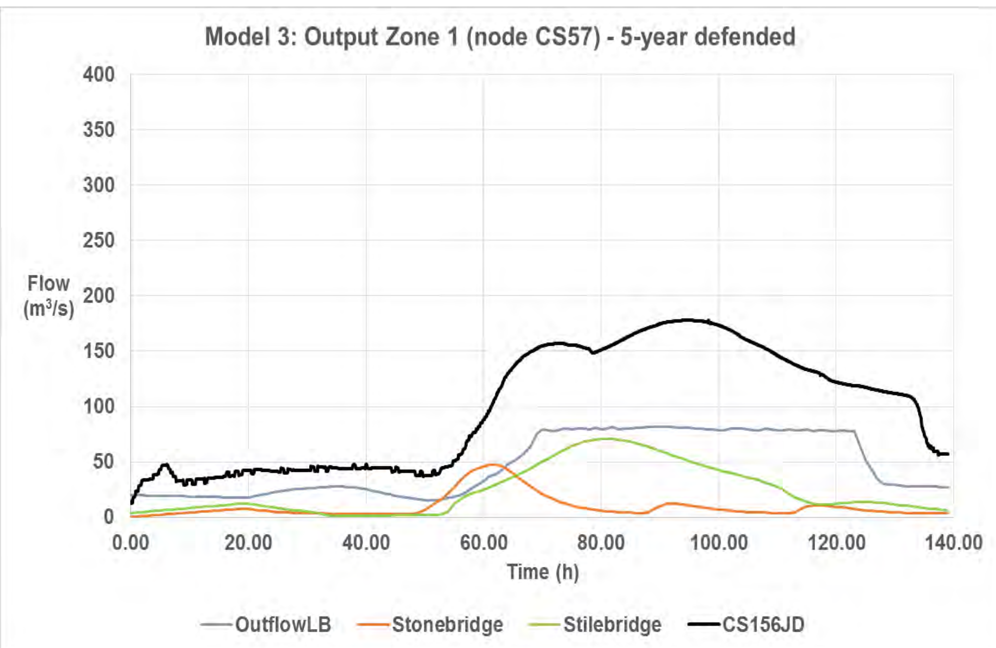
*Used for displaying flow hydrographs

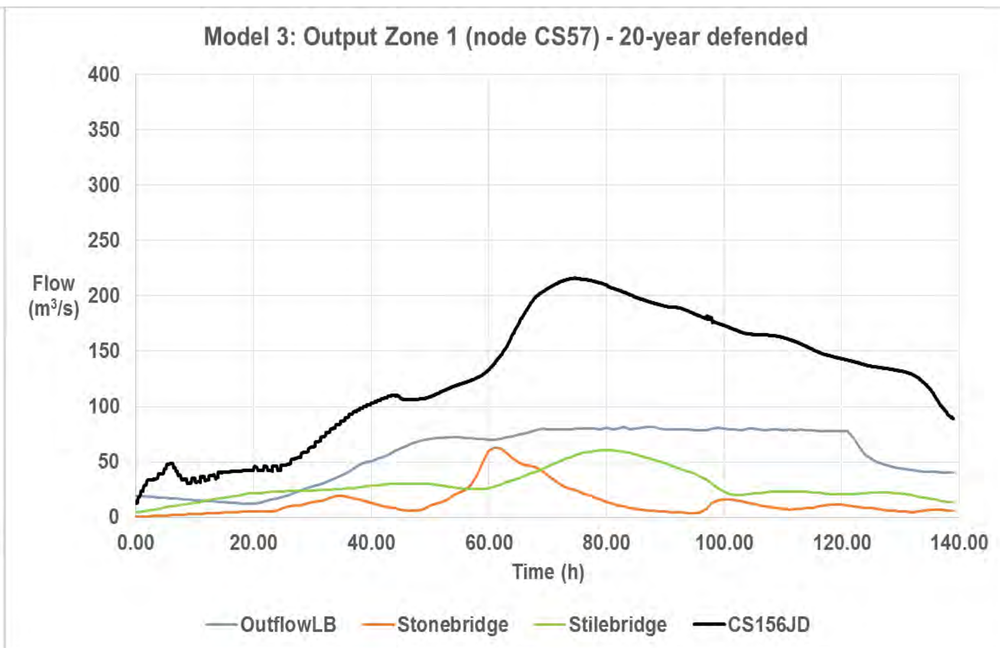
**Used for determine return period estimates

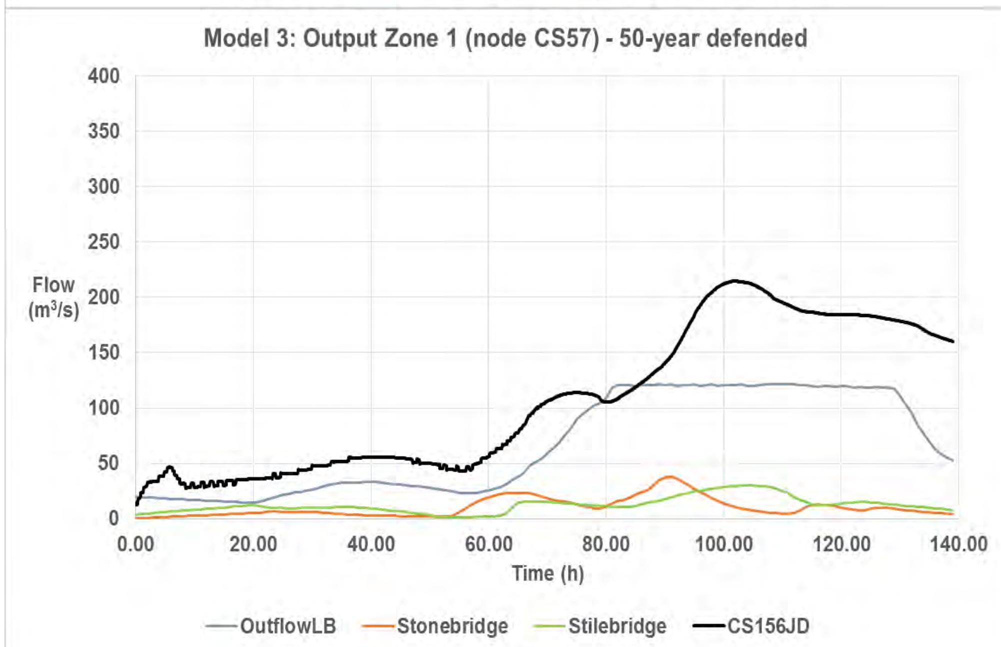
The return period estimates presented at each node are based on the peak flow at each of the contributing watercourses (more specifically the model nodes inspected on each watercourse). From the hydrograph plots presented in the following sections it is evident that watercourses respond at different times, therefore it is not simply the case that the peak flows/return period events reported for each watercourse contribute towards total flows. Moreover, although plots are presented for all return period and output zones tested, some watercourses do not influence predictions in certain areas. For instance, River Beult and Rive Teise flows do not influence the predictions in output zone 1, which is upstream of East Peckham and primarily influenced by River Medway flows.

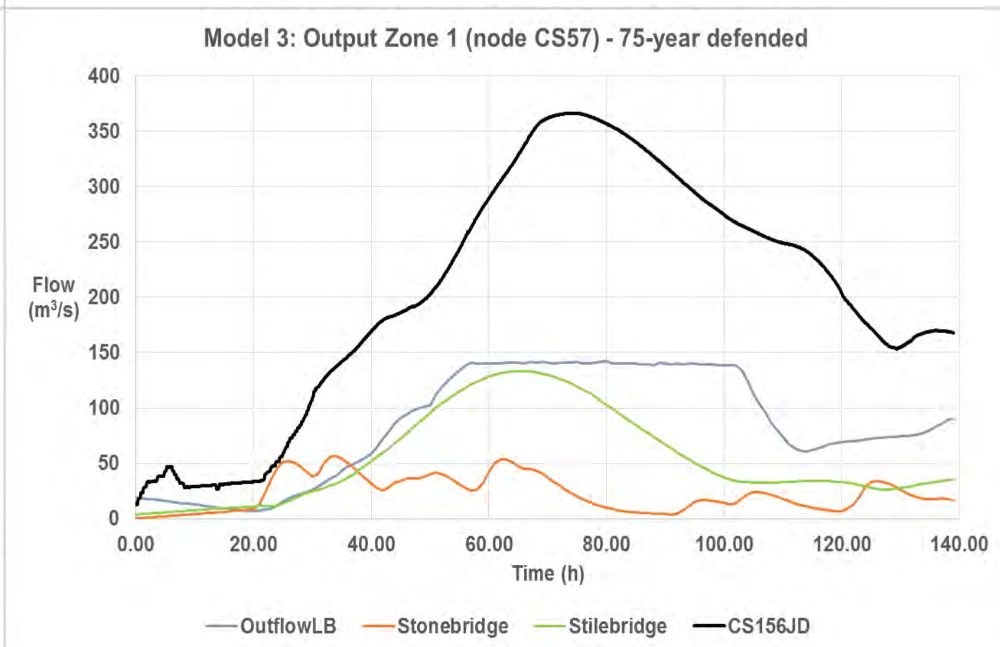
5.1 Output Zone 1

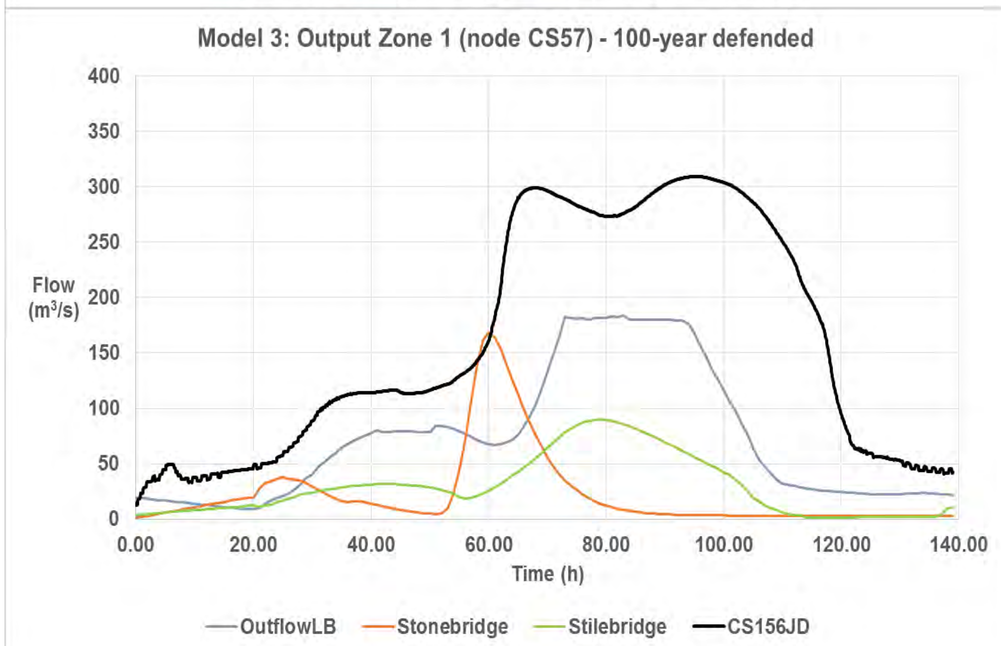
	Output Zone 1: Predicted return period for contributing flows at the following four locations			
Design event (return period)	**OutflowLB**	**Stonebridge**	**Stilebridge**	**CS189**
5	14	<5	11	7
20	18	9	7	12
50	50	<5	<5	12
75	75	7	115	145
100	110	225	27	68
250	275	195	<5	82

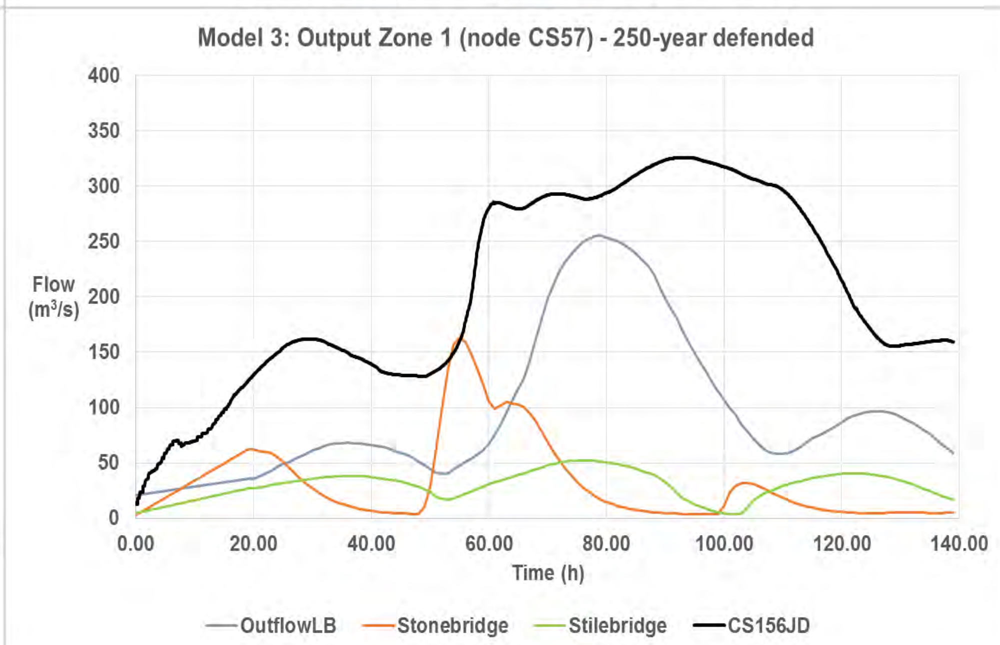






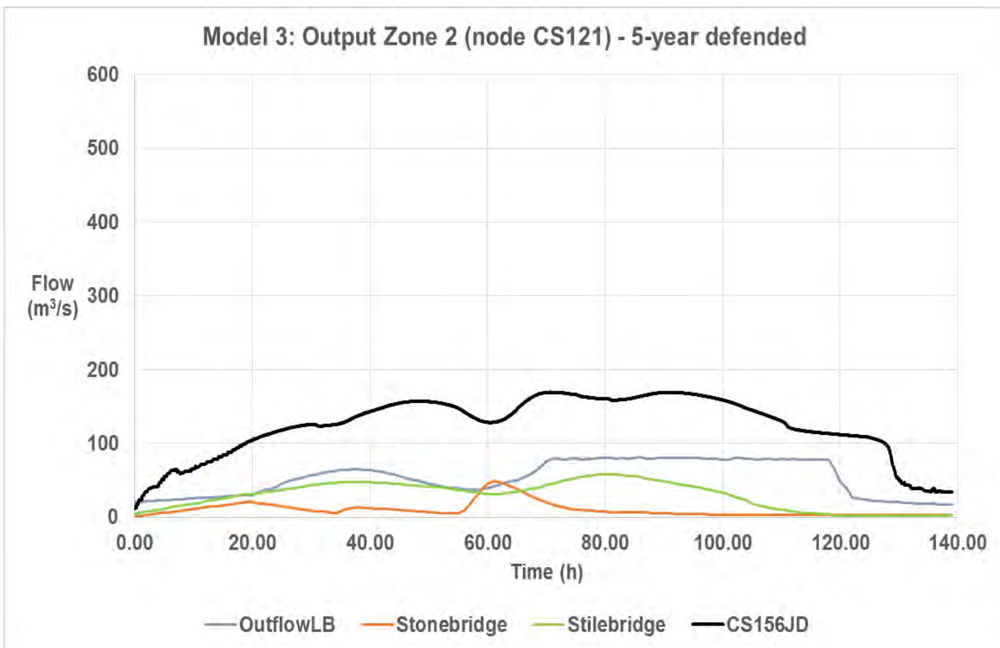


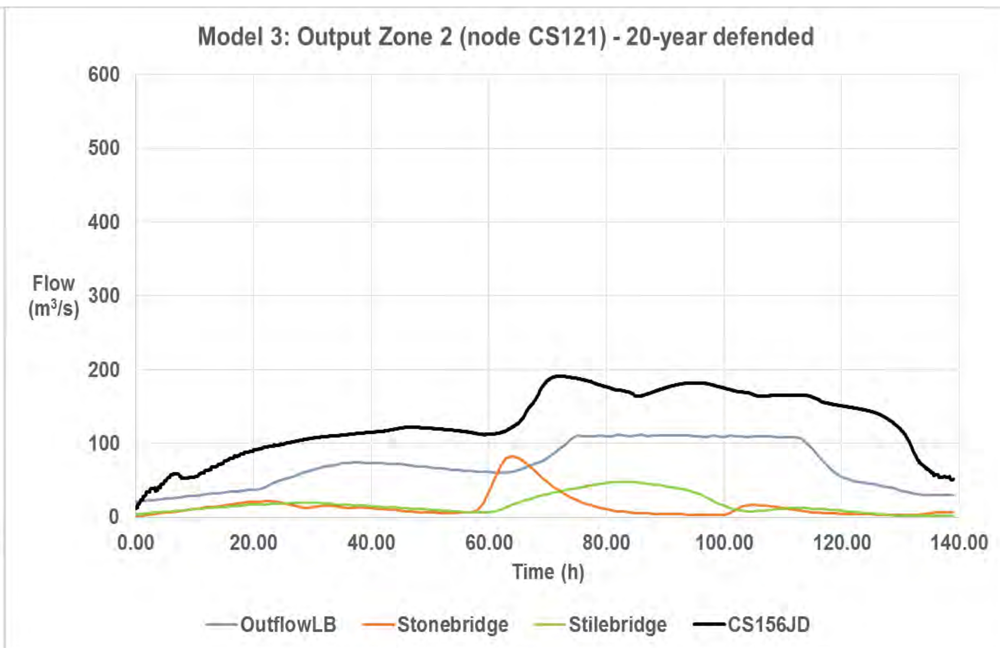


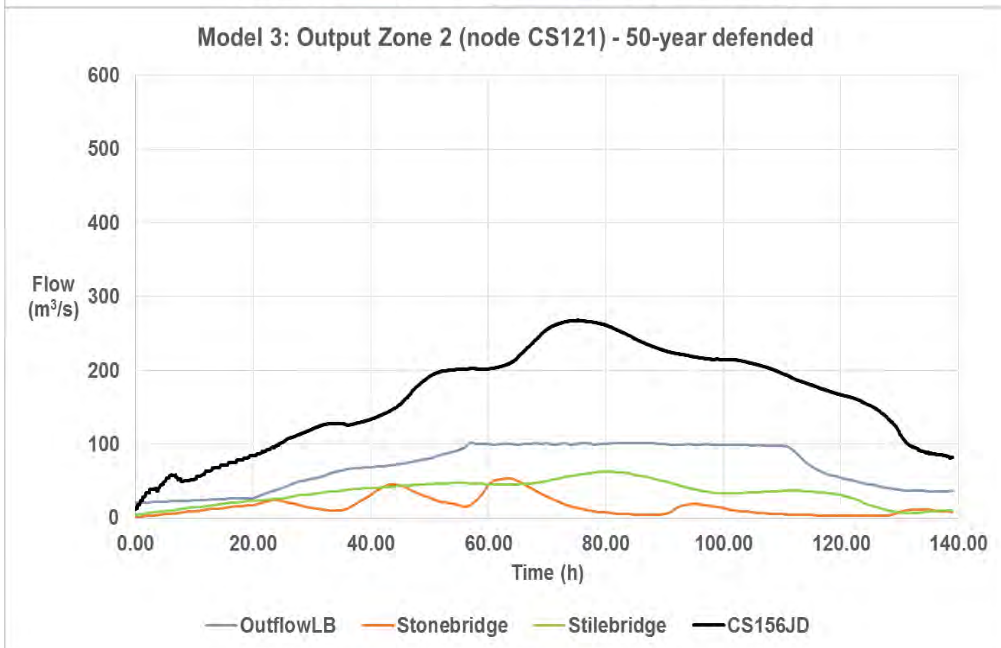


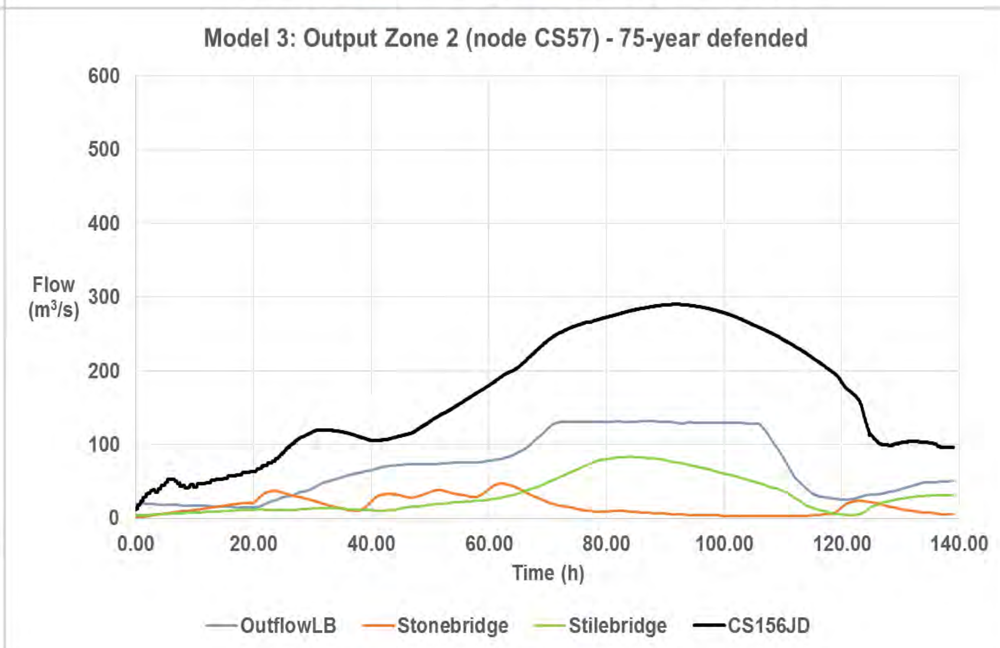
5.2 Output Zone 2

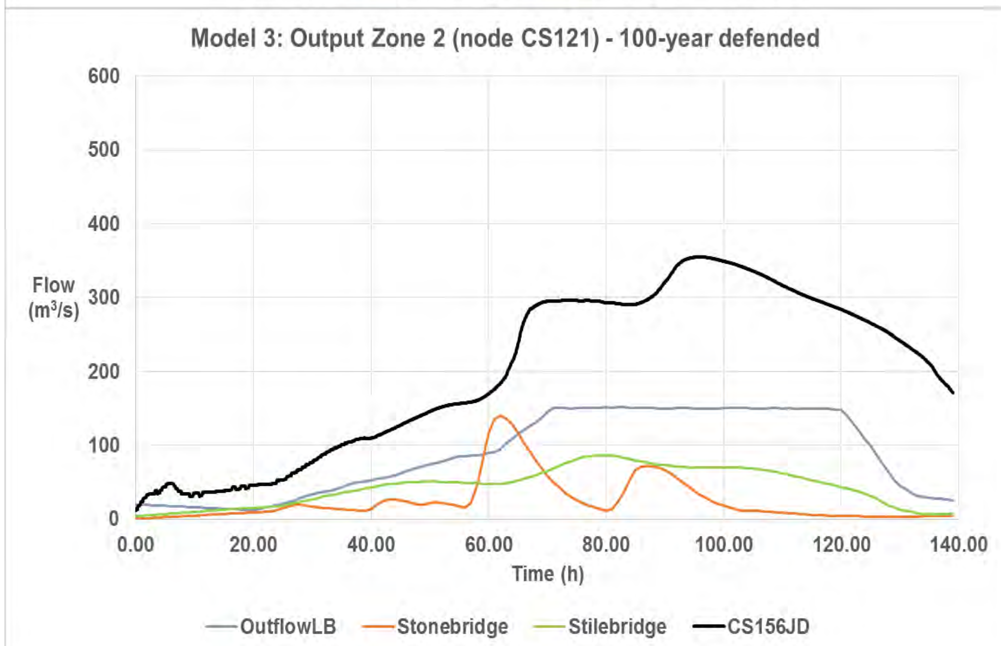
	Output Zone 2: Predicted return period for contributing flows at the following four locations			
Design event (return period)	**OutflowLB**	**Stonebridge**	**Stilebridge**	**CS189**
5	10	<5	6	5
20	43	19	<5	7
50	37	6	8	32
75	59	<5	20	51
100	82	100	23	110
250	155	15	>1000	>1000

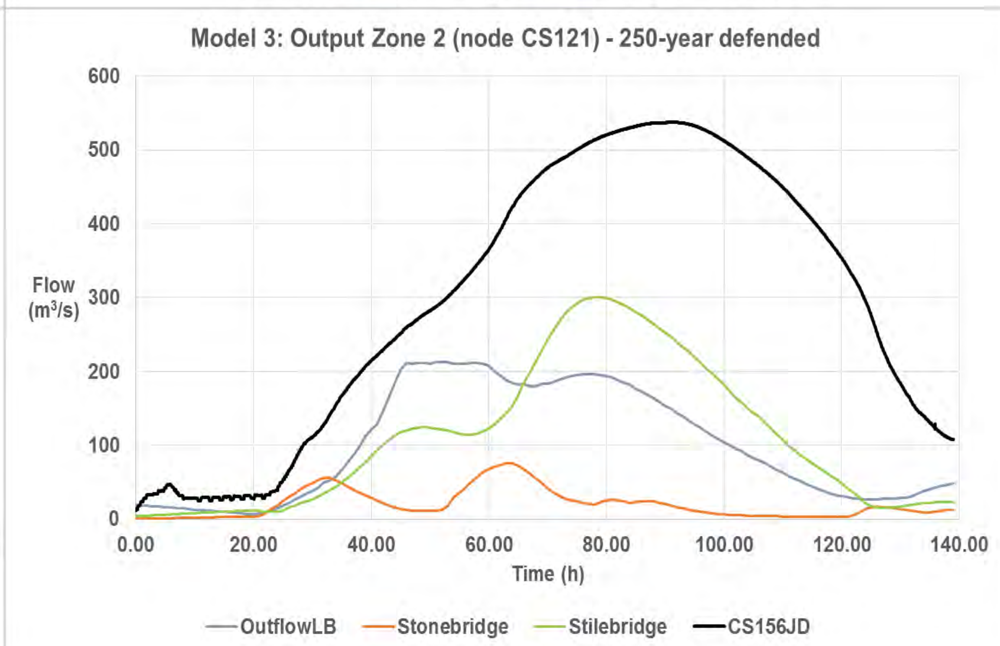






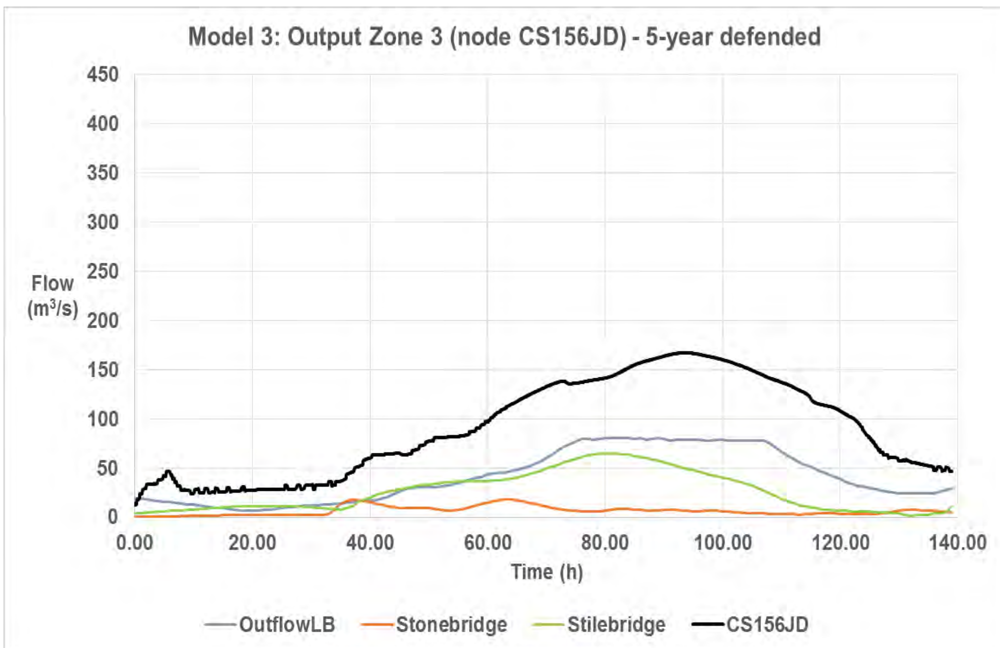


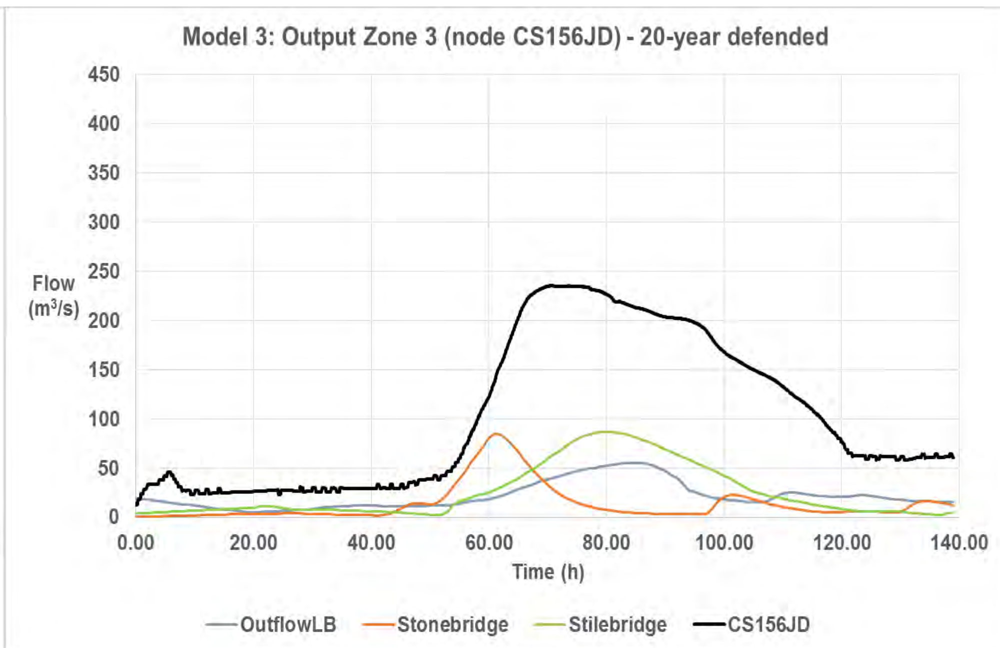


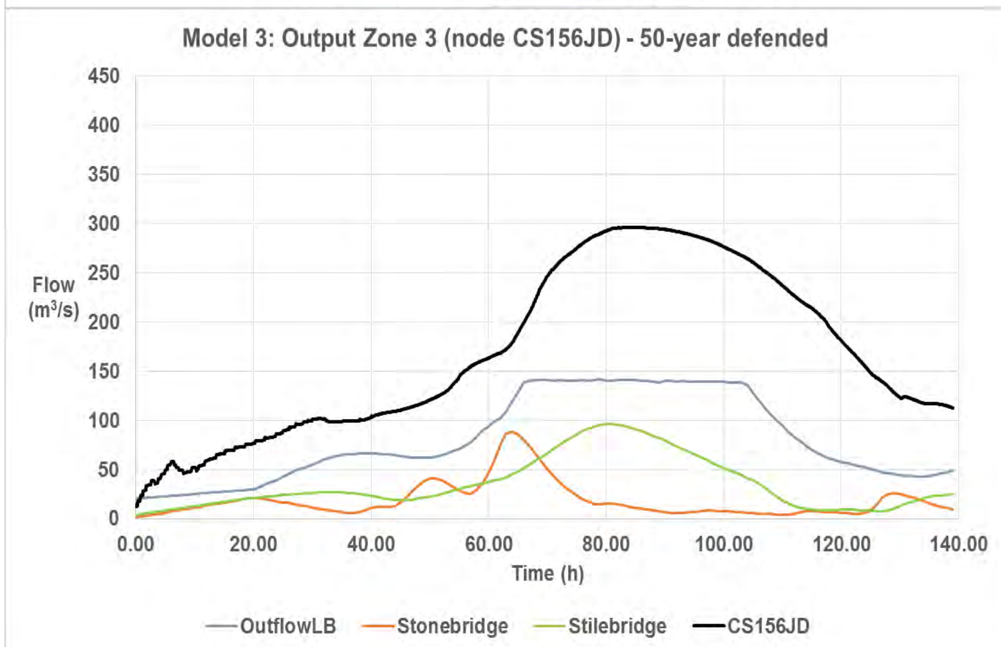


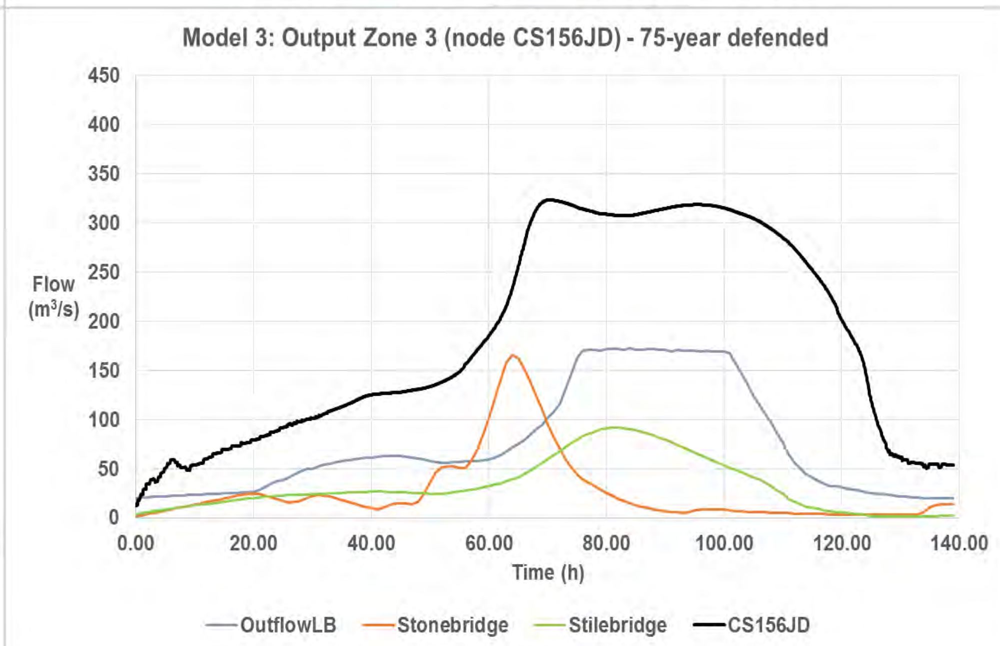
5.3 Output Zone 3

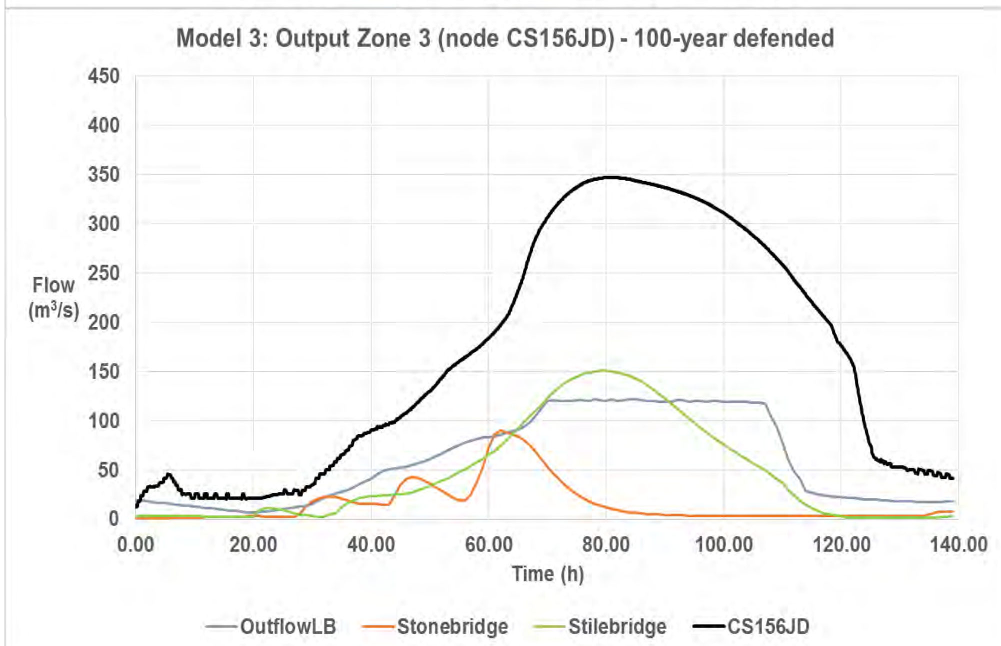
	Output Zone 3: Predicted return period for contributing flows at the following four locations			
Design event (return period)	**OutflowLB**	**Stonebridge**	**Stilebridge**	**CS189**
5	9	<5	8	5
20	<5	21	23	18
50	74	24	35	53
75	99	210	29	79
100	50	24	225	105
250	22	>1000	24	135

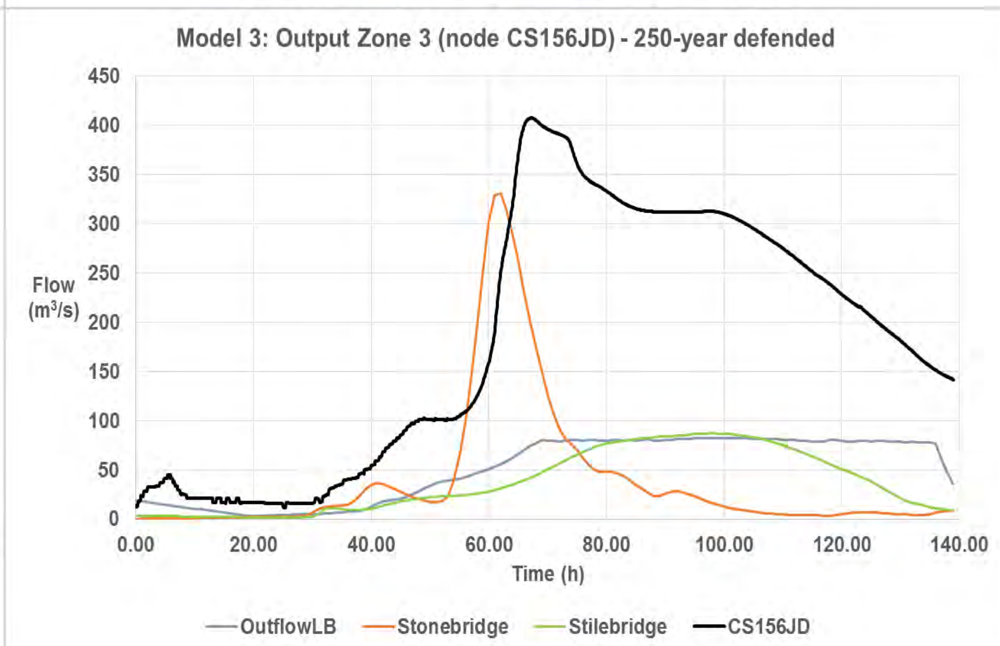






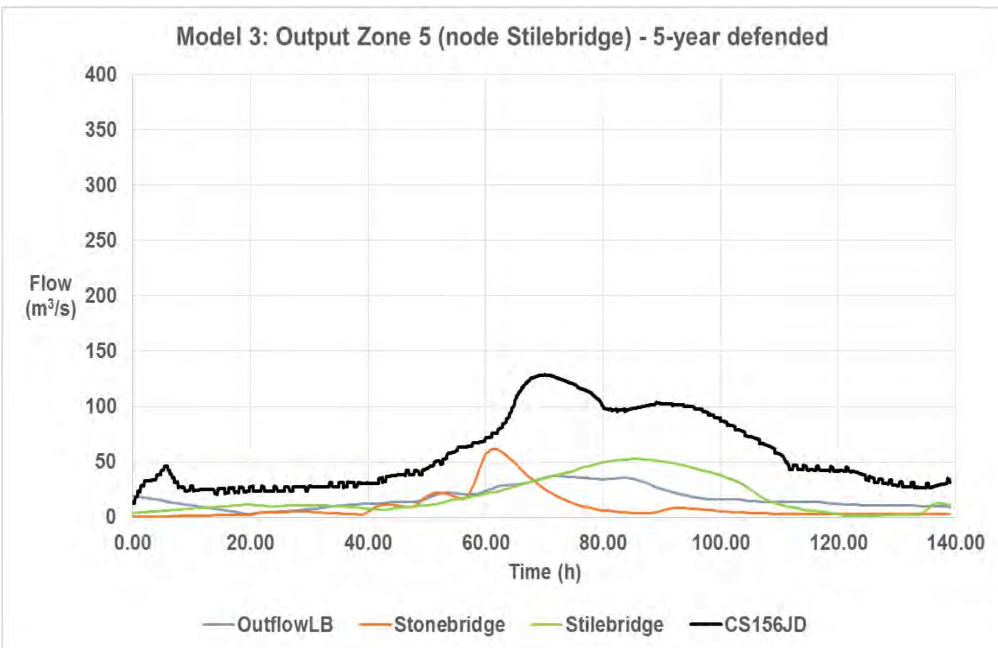


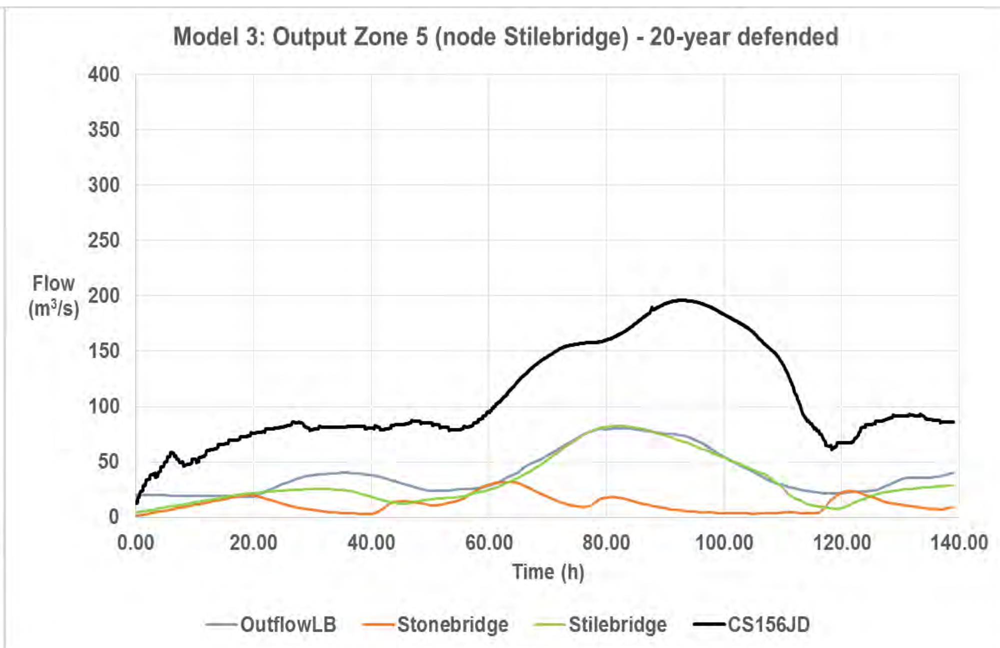


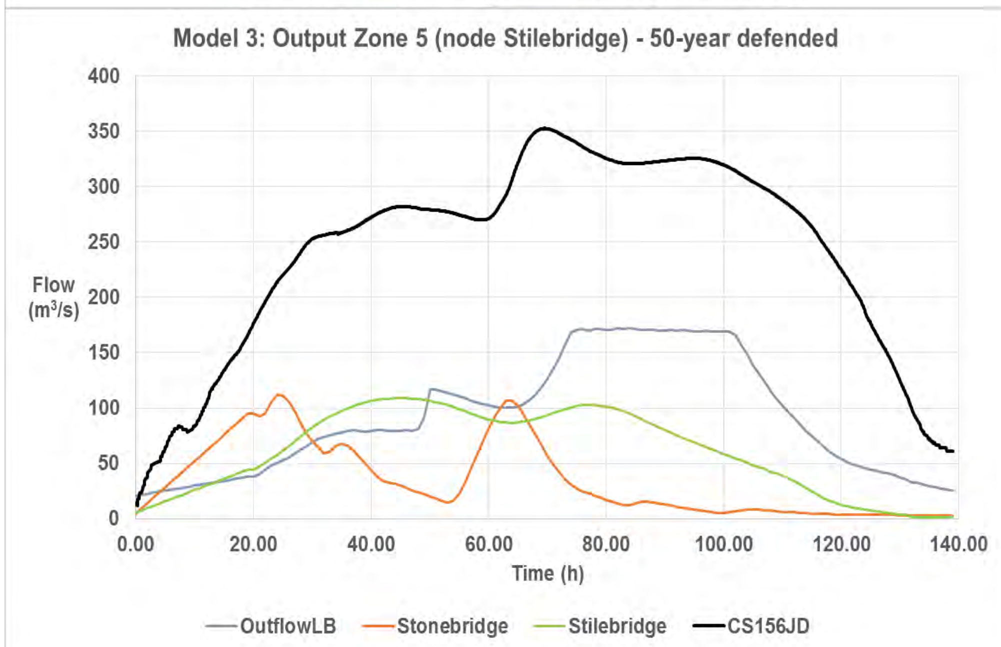


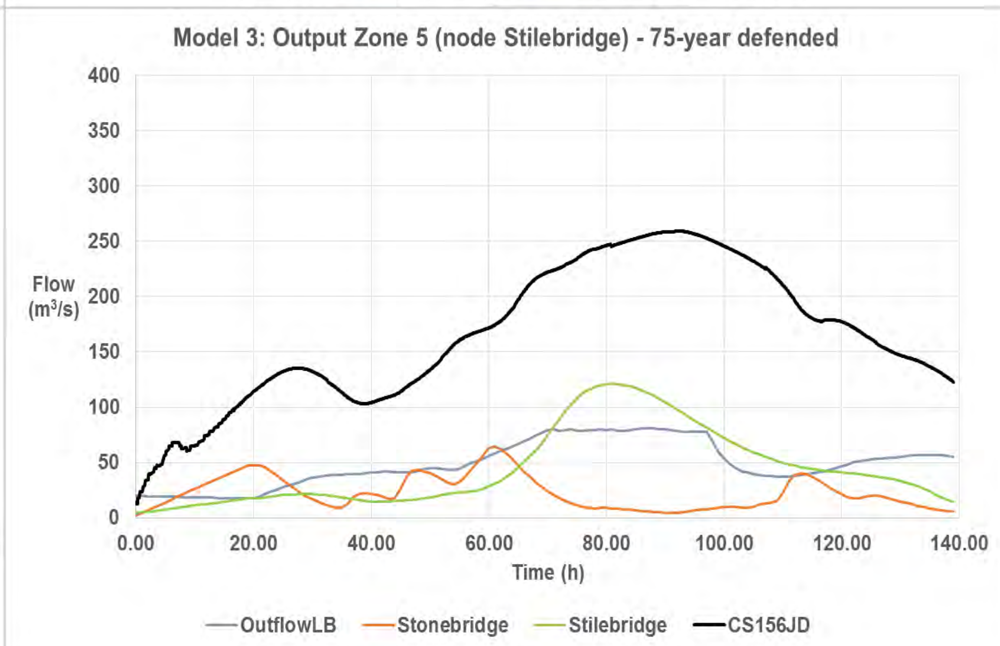
5.4 Output Zone 5

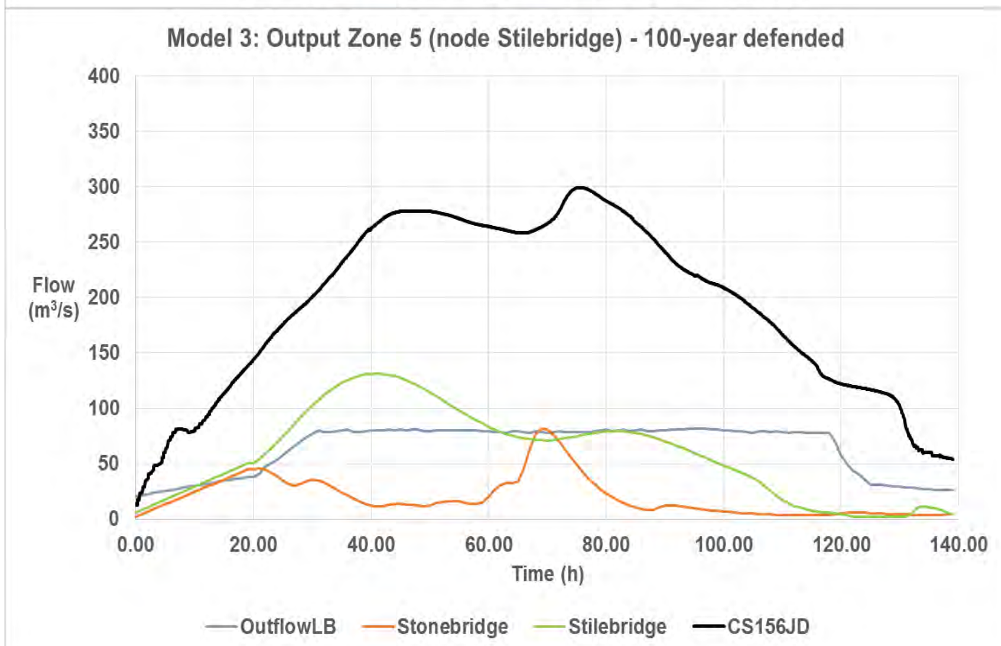
	Output Zone 5: Predicted return period for contributing flows at the following four locations			
Design event (return period)	OutflowLB	Stonebridge	Stilebridge	CS189
5	<5	9	<5	<5
20	8	<5	20	9
50	99	53	50	93
75	9	10	75	32
100	13	19	105	49
250	14	120	250	130

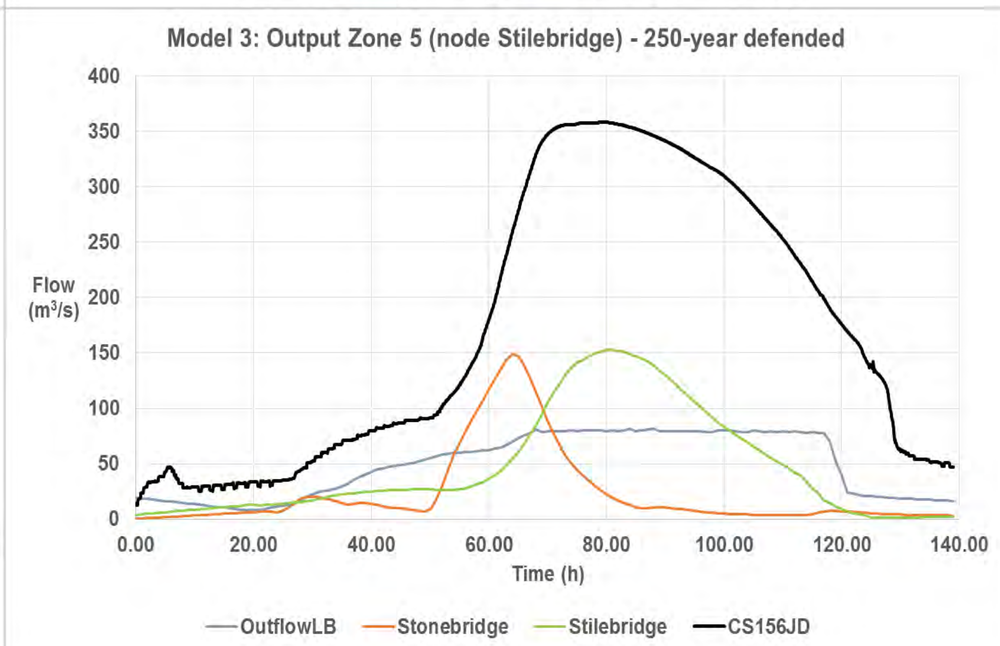






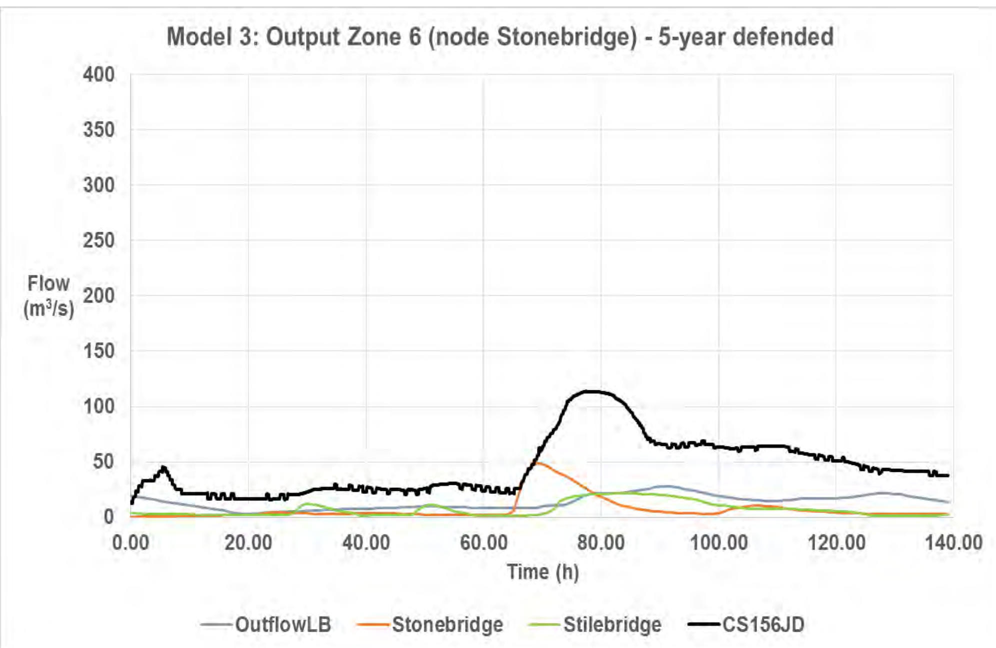


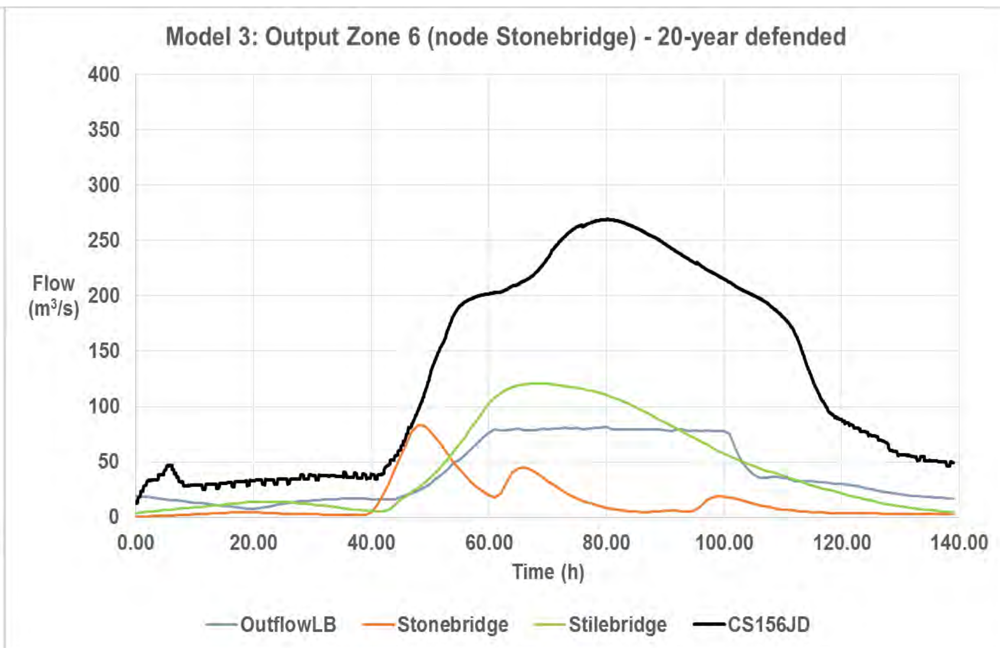


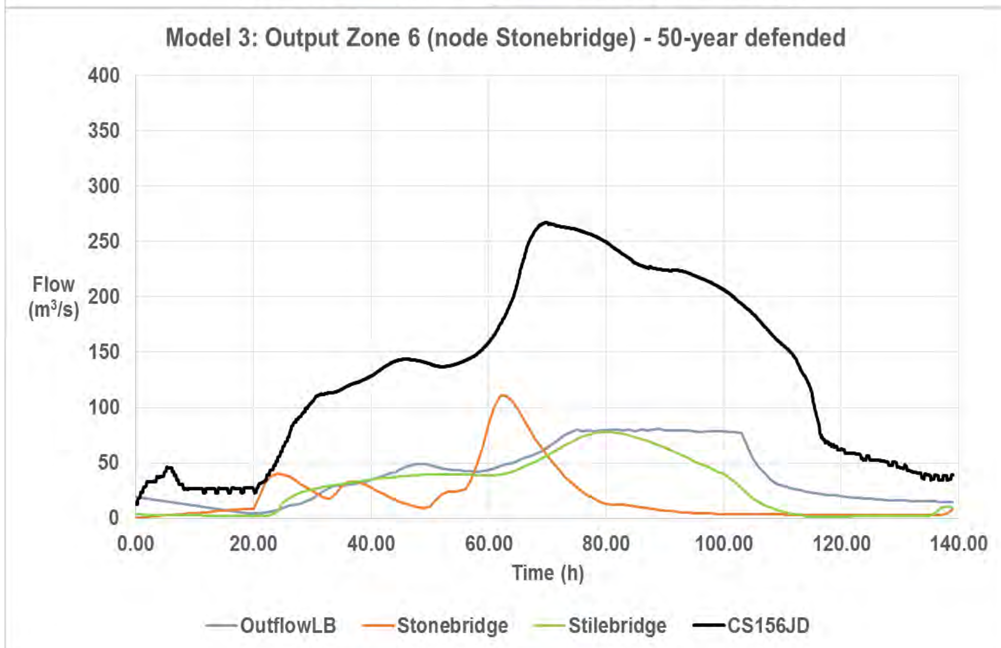


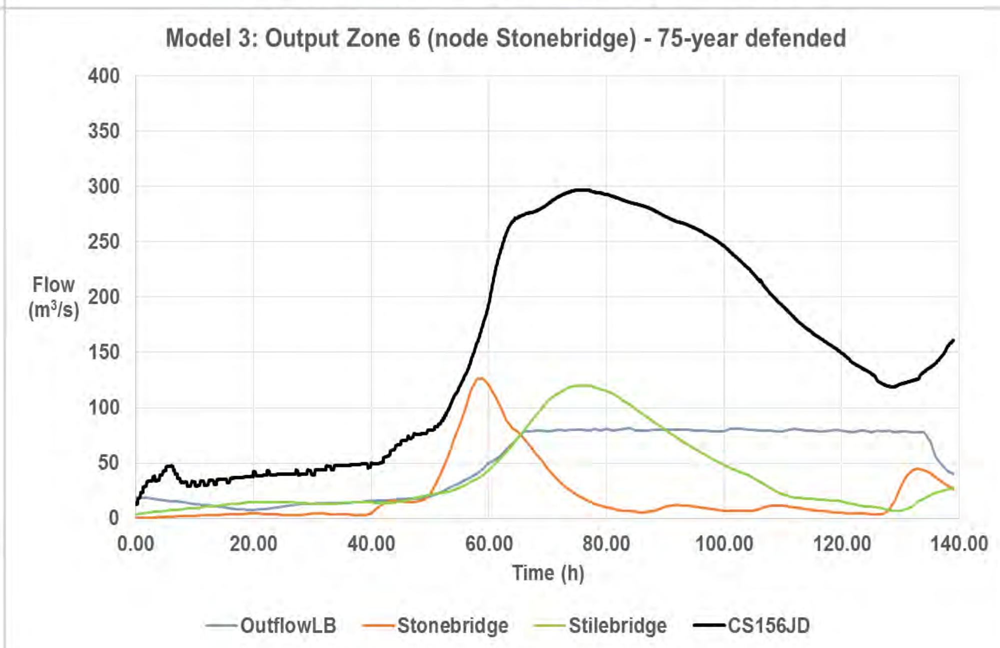
5.5 Output Zone 6

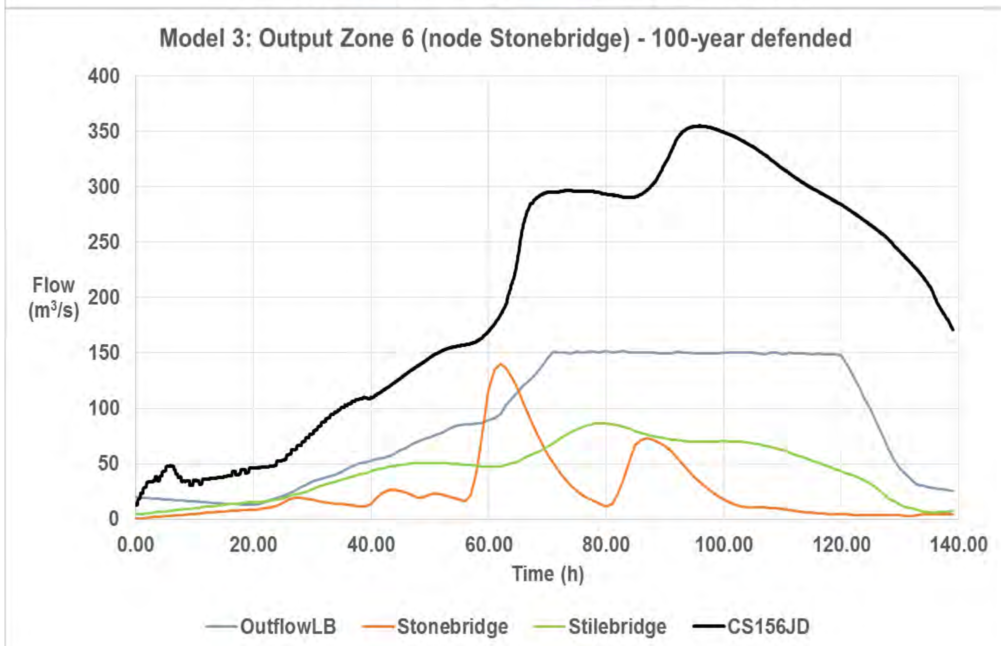
	Output Zone 6: Predicted return period for contributing flows at the following four locations			
Design event (return period)	**OutflowLB**	**Stonebridge**	**Stilebridge**	**CS189**
5	<5	5	<5	<5
20	13	20	74	34
50	9	49	16	29
75	16	75	72	51
100	82	100	23	110
250	8	250	71	38

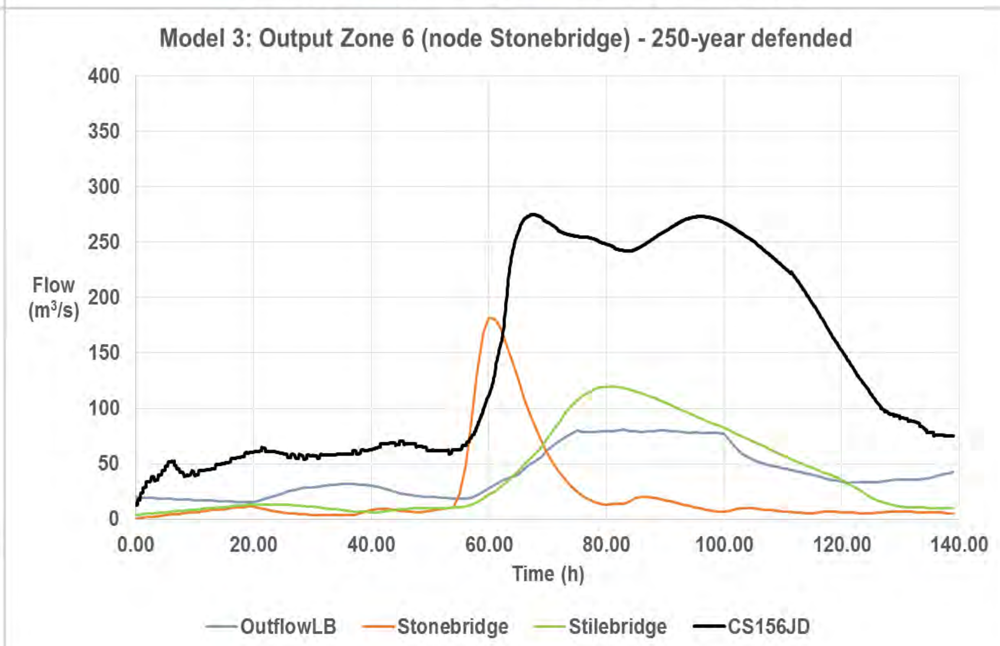












Appendix E Environmental Appraisal

Option Environmental Appraisal Summary Tables for:

1. Improve Leigh FSA
2. River Beult FSA at Chainhurst
3. River Teise FSA at Cottage Wood
4. River Teise FSA at Stonebridge
5. Yalding local defence scheme
6. River Medway conveyance improvements

Option: Leigh FSA
Summary Description: Increase the Normal Maximum Operating Water Level (NMOWL) from 28.05m AOD to 28.85m AOD at Leigh FSA on the River Medway, upstream of Tonbridge.

Environmental Receptor / Topic	Risks or Constraints to / from the receptor / option (consider construction and operation)	Potential Opportunities or Enhancements	Possible mitigation requirements or future action
Air and Climate • Air quality • Impact of climate change on the options • Resilience to future climate change • Increase or decrease in risks from natural disasters or flooding.	The proposed option is unlikely to have any effects on air quality beyond localised, temporary impacts during the construction stage. These are not considered to be a significant risk or constraint to the works. Flows on the River Medway into the Leigh FSA are expected to increase in the future as a result of climate change. The downstream Standard of Protection (SoP) through Tonbridge will therefore reduce over time.	The ability to include climate change projections in this option is limited because the maximum feasible storage level has been determined through consideration of the upstream assets, and has not explicitly been designed to accommodate climate change. Not-withstanding this, the option will help to mitigate climate change impacts, particularly in the short-term.	The potential impact of climate change should be fully incorporated at the detailed appraisal stage.
Archaeology and Cultural Heritage • Statutory: Scheduled Monuments, Listed Buildings, Registered Park and Gardens) • Non-statutory – Conservation Areas, potential for unknown archaeology.	There are no statutory heritage sites affected by the proposed option. The only listed structure within the FSA is Penshurst Bridge (grade II). This road does not currently flood, but a more detailed review is required to determine whether it would be at risk of flooding if the NMOWL was increased. The higher water level would result in a very minor increase in the encroachment of flood water into Penshurst Place; a Registered Park and Garden. This encroachment is not considered to be significant. It is also the location of a proposed localised mitigation measure (flood wall) to ensure no loss of access to Place Barn Farm and Well Place Farm. There are no other designated statutory or non-statutory historical assets within the FSA.	Most of the listed buildings in Tonbridge, including Tonbridge Castle remains are located to the north of the River Medway on higher ground, and are not at risk of flooding. Two listed buildings have been identified as benefiting from the Improve works: the oasthouse and granary to the south of Hawden and a high street shop (No. 73). Hydraulic model results indicate a reduction in flood risk to both buildings, with both shallower flood water and a reduced frequency of flooding. There may be some minor reductions in flood risk (shallower flood water) to listed buildings downstream of Tonbridge.	Archaeological desk based assessment and further investigations / impact assessment may be required prior to implementation of the scheme to manage risks to unknown or unrecorded archaeological remains either in the areas where construction works will be required or in newly-flooded areas. The scheme would require early consultation with the relevant historic environment bodies (statutory and non-statutory) to ensure that proposals and designs were effective and acceptable from a heritage perspective.
Biodiversity, flora and fauna • Protected sites – SPA/SAC/Ramsar, SSSI, County or Local designations • Specific opportunities for site improvement • Habitats of Principal Importance for Biodiversity (formerly BAP Priority) • Protected species potential.	There are no statutory nationally-designated nature conservation sites present within the FSA. The nearest sites are Polebrook Farm (SSSI), approximately 2km north west and Cowden Meadow (SSSI), 3km to the south west. The River Medway Site of Nature Conservation Importance (SNCI) is located both upstream and downstream of the Leigh FSA embankment, designated for its variety of habitats. This area is also part of the Haysden Country Park and additionally designated as a Local Nature Reserve and Special Landscape Area. There are several Habitats of Principal Importance present within the FSA, including areas of ancient woodland, deciduous forestry and good quality semi-improved grassland. Much of this lies within the existing FSA, but the proposed scheme will slightly increase the flood extent as well as the flood depth and duration. There are some small stands of woodland upstream of Penshurst that are likely to be newly affected by the higher impounded water level. It is likely that protected species are present within the scheme area, and appropriate studies would need to be undertaken to better identify risks and develop appropriate mitigation.	There may be opportunities to incorporate biodiversity enhancements within the design of the expanded FSA (e.g. improved floodplain connectivity or enhanced wetland habitats), although this is likely to be limited given that the option is for works to an existing flood risk management asset. Any opportunities to create and restore habitats will help to contribute to England's Biodiversity Strategy 2020 targets and funding Outcome Measure 4a.	Studies of the condition of the habitats within both the existing and enlarged FSA would be required, along with consideration of the likely effects of changes in the flood regime (flood depth and flood duration). Protected species surveys would be required at an appropriate stage of the scheme design, and mitigation strategies developed where these are likely to be affected.

Option: Leigh FSA
Summary Description: Increase the Normal Maximum Operating Water Level (NMOWL) from 28.05m AOD to 28.85m AOD at Leigh FSA on the River Medway, upstream of Tonbridge.

Environmental Receptor / Topic	Risks or Constraints to / from the receptor / option (consider construction and operation)	Potential Opportunities or Enhancements	Possible mitigation requirements or future action
Land quality, soils and geology • Agricultural land quality • Risks to and from contaminated land or landfills • Geological interests (geological SSSIs or RIGS)	According to the Agricultural Land Classification (ALC) database, the majority of the land is Grade 3 or 4 with some Grade 2 areas around Ensfield and north east of Penshurst. This option will entail only a minor loss of agricultural land associated with the required works to the main embankment and the local defence solutions provided for the upstream assets. The agricultural land within the FSA already floods naturally (with no impounding) and during impounding events. The increase in operating water level would increase flood extent, depth and duration, which could affect the longer term agricultural use of the area, although this is considered unlikely.	There would be a reduction in the extent of agricultural land flooded downstream of the FSA, which would have some slight benefits for agricultural productivity. The principle benefits of the option are however to properties in Hildenborough and Tonbridge.	Land contamination studies and risk assessments may be required.
Landscape and visual amenity • Designated landscapes (National Parks, AONB) • Landscape quality • Historic landscapes • Visual receptors (from roads, footpaths, recreational assets).	The National Character Area (NCA) is *High Weald* and 'encompasses the ridged and faulted sandstone core of the Kent and Sussex Weald. It is an area of ancient countryside and one of the best surviving medieval landscapes in northern Europe.' The FSA upstream of Ensfield Bridge lies within the *High Weald* Area of Natural Beauty (AONB). The land is almost entirely all Green Belt land. The increase in NMOWL is likely to require works to raise both the main embankment and existing berms / embankments which provide protection to upstream assets. The visual impact of this work will be relatively limited because the structures are already present in the landscape. Landscape and visual impacts on the AONB and from public rights of way around Haysden Water would still need to be considered.	There are likely to be limited opportunities for significant landscape enhancements as part of the scheme.	Careful landscaping and grading of slopes could reduce the visual impact of the option. Sympathetic designs for structures that blend in with the local environment would be required to mitigate identified impacts. Choices of materials and finishes, along with planting or other methods of screening could help to reduce visual impacts. A landscape and visual impact assessment would be required to determine the scale of the impact (particularly on the AONB) and potential effectiveness of mitigation measures.
Population and Human Health • Local residents, vulnerable people • Potential noise issues • Local businesses and economy • Recreation and access (incl. potential for improvement) • Risks to health from flooding, construction works etc.	There would be no additional recreational, commercial or residential assets lost through the works to increase the NMOWL. Flood depth and duration would however increase in the western part of Haysden Country Park. Any noise impacts on local residents would be limited to the construction stages and therefore temporary. This issue is unlikely to be significant. In the absence of any mitigation measures, the increase in impounded water level is likely to have some impacts to the following assets / infrastructure: • Tonbridge Town Sailing Club clubhouse • Railway line east of Leigh station • Cattle arch and south-east Leigh • Southern Water and Environment Agency Leigh Pumping Station • Properties in the south-western and south-eastern parts of Leigh • Access track for Place Barn Farm and Well Place Centre • Penshurst Sewage Treatment Work (STW) • Bridge House and The Yews, Penshurst.	Reduction in flood risk to properties in Tonbridge and Hildenborough, and to a lesser extent, East Peckham and further downstream would reduce risk to life and human health impacts including reduced stress and anxiety due to fears of flooding. Local economic benefits of reduced business disruption and increased future business certainty associated with reduced flood risk. Development restrictions in the area adjacent to the Leigh FSA could be implemented to prevent any future increases in NMOWL being restricted by the presence of upstream assets.	The Improve Leigh FSA option includes localised mitigation measures, as set out in Table 2-2 in the main report. These will ensure that flood risk is not made worse for upstream assets and infrastructure as a result of the increase in operating water level. Landowner compensation has already been paid for the existing FSA. Further compensation payments may need to be made to landowners affected by the enlarged FSA and / or the greater depth of flood water and longer flood duration.

Option: Leigh FSA
Summary Description: Increase the Normal Maximum Operating Water Level (NMOWL) from 28.05m AOD to 28.85m AOD at Leigh FSA on the River Medway, upstream of Tonbridge.

Environmental Receptor / Topic	Risks or Constraints to / from the receptor / option (consider construction and operation)	Potential Opportunities or Enhancements	Possible mitigation requirements or future action
Water (Rivers, estuaries, lakes and groundwater) • WFD compliance • Biological quality • Chemical quality • Flows and morphology • Abstractions • Groundwater quality and quantity. Please note surface water body status classifications are based on River Basin Management Plan 2014 cycle 2 data.	The Mid Medway from Eden Confluence to Yalding (GB106040018182) – *Moderate Potential Overall Status*, will be a direct receptor. Further upstream there are two waterbodies: the Mid Medway from Hartfield to Eden Confluence (GB106040018181) – *Moderate Overall Status* and Lower Eden (GB106040018160) – *Moderate Potential Overall Status*. Downstream there are three further waterbodies: Little Hawden Stream (GB106040018150) – *Moderate Overall Status*, Hilden Brook (GB106040018170) – *Poor Overall Status* and Somerhill Stream (GB106040018410) – *Poor Overall Status*. While the increase in NMOWL will increase flood extent, depth and duration along the River Medway upstream of the Leigh FSA embankment, the land affected is already subject to both “natural” flooding and inundation during impounding events. The River Medway channel is already heavily engineered around the existing control structure, therefore works under this option would have no further adverse impacts on channel form and function. The option would not prevent waterbody objectives from being met. A temporary site compound and material store will be required on site and temporary haul roads may need to be constructed to allow construction vehicles access to the site. Both temporary structures and haul roads mean an increase in impermeable area and increased potential surface water runoff. The site is partly within the *Kent Weald Western – Medway* Groundwater Body (GB40602G502300) is currently at Good Quantitative Quality and Poor Chemical Quality. The waterbody covers a very extensive area from East Grinstead in the west to Cranbrook in the east.	Currently all affected water bodies are at Poor or Moderate Overall Status, and there may be opportunities to contribute towards the WFD waterbody objectives. This should be further investigated at the next stage because delivery of the RBMP objectives is central to the Environment Agency’s implementation of the WFD. Creation of buffer strips or wetlands on the floodplain could restrict/trap fine sediment movements back into the channel.	A preliminary WFD compliance assessment was undertaken as part of the MMS review (Halcrow, 2010) and concluded that the option to increase the NMOWL at Leigh FSA is likely to be compliant, with no anticipated waterbody deterioration and no prevention of mitigation measures implementation. A full WFD assessment is recommended at the next stage to include more detailed examination of the potential impacts and opportunities, and liaison with the relevant internal functions of the Environment Agency. Appropriate mitigation and good practice during temporary works would be required to mitigate for any potential sediment runoff and water quality impacts during the works.

Option: River Beult FSA at Chainhurst
Summary Description: Provide flood storage on the River Beult in the Chainhurst area. A storage level of 15.75m AOD would require a 720m embankment up to 3m high across the River Beult valley upstream of Hunton Road / East Street and 3km of side embankments (1 – 2m high) to the south of the River Beult to prevent the re-routing of floodwater into the Lesser Teise floodplain.

Environmental Receptor / Topic	Risks or Constraints to / from the receptor / option (consider construction and operation)	Potential Opportunities or Enhancements	Possible mitigation requirements or future action
Air and Climate • Air quality • Impact of climate change on the options • Resilience to future climate change • Increase or decrease in risks from natural disasters or flooding.	The proposed option is unlikely to have any effects on air quality beyond localised, temporary impacts during the construction stage. These are not considered to be a significant risk or constraint to the works. Depending on the source of the material for the embankment there are potentially high carbon costs associated with the construction of the embankment and the requirement to source material for the structure and transport it to the site.	The ability to include climate change projections in this option is limited because of the maximum feasible storage level. It will therefore be difficult to design this option to accommodate likely future climate change.	In order to mitigate potential effects the feasibility of locally obtaining material would need to be determined. At this stage it is thought that a local source of material is available.
Archaeology and Cultural Heritage • Statutory: Scheduled Monuments, Listed Buildings, Registered Park and Gardens) • Non-statutory – Conservation Areas, potential for unknown archaeology.	There are two listed buildings in the proposed FSA, as defined by the 15.75m AOD contour: Old Hertsfield Farmhouse and the adjacent barn. If this option was taken forward, localised flood protection would need to be provided so that flood risk was not made worse to these listed buildings. There are also a number of listed buildings immediately downstream/adjacent to the proposed embankments which could be directly affected aesthetically by the scheme. These include: • The Grade II listed Great Tilden Farmhouse, Barn and former Granary, located on Tilden Lane, to the south of the proposed side embankment. • The Grade II listed former stables on Hunton Road, Chainhurst, also located adjacent to the side embankment. • A cluster of listed buildings to the north of the River Beult downstream of the proposed main embankment.	A number of listed buildings between Chainhurst and Yalding will benefit from the reduction in flood risk achieved by the River Beult FSA. These benefits are however limited to relatively few properties and the option generally reduces flood depth across a wide area instead of entirely preventing property flooding.	Archaeological desk based assessment and further investigations may be required prior to implementation of the scheme to manage risks to unknown or unrecorded archaeological remains within the footprint of the scheme. Localised flood protection measures may need to be considered to any listed buildings that fall within the footprint of the storage area. Careful and sympathetic designs that complement the historic environment could be used to mitigate some impacts. These would require early consultation with the relevant historic environment bodies (statutory and non-statutory) to ensure that designs were effective and acceptable from a heritage perspective.
Biodiversity, flora and fauna • Protected sites – SPA/SAC/Ramsar, SSSI, County or Local designations • Specific opportunities for site improvement • Habitats of Principal Importance for Biodiversity (formerly BAP Priority) • Protected species potential.	The River Beult is designated as a SSSI to the confluence with the River Medway. The SSSI is currently in unfavourable condition relating to a decline in water quality and change in habitat structure, caused for example by over-straightening of bank-side habitat. It is one of the few clay rivers in England which retains a characteristic flora and fauna. This type of river occurs predominantly in central England and has usually been canalised for land drainage purposes. The River Beult has a characteristically diverse clay-river flora, with many emergent (water edge) plant species and a smaller number of submerged or floating plants. The FSA may alter the functioning of these habitats during large events and will need to be investigated further and any solution should be combined with the River Beult Restoration Plan. The increase in flood extent upstream of the new embankment has the potential to increase the enrichment of the River with phosphate and nitrate from agricultural run-off. Options could be explored	There may be opportunities to incorporate biodiversity enhancements within the design of the FSA (for example, improved floodplain connectivity or enhanced wetland habitats). This can help to contribute to England's Biodiversity Strategy 2020 targets and funding Outcome Measure 4a. Opportunities to improve the condition of the River Beult locally should be sought as part of the design; for example, land management improvements within the FSA footprint, or improved management of the riparian corridor through the scheme area. These opportunities would need to be undertaken in partnership with local landowners and in combination with the River Beult Restoration Plan, seeking to improve the currently unfavourable status of the SSSI.	Studies of the condition of the habitats within the FSA would be required, along with consideration of the likely effects of changes in the flood regime. Protected species surveys would be required at an appropriate stage of the scheme design, and mitigation strategies developed where these species are likely to be affected.

Option: River Beult FSA at Chainhurst
Summary Description: Provide flood storage on the River Beult in the Chainhurst area. A storage level of 15.75m AOD would require a 720m embankment up to 3m high across the River Beult valley upstream of Hunton Road / East Street and 3km of side embankments (1 – 2m high) to the south of the River Beult to prevent the re-routing of floodwater into the Lesser Teise floodplain.

Environmental Receptor / Topic	Risks or Constraints to / from the receptor / option (consider construction and operation)	Potential Opportunities or Enhancements	Possible mitigation requirements or future action
	with how to best manage the land as part of this scheme to reduce this impact on the SSSI. There are areas of ancient woodland upstream of the embankment east of Chainhurst, as well as several other Habitats of Principal Importance present within the FSA, including areas of deciduous forestry and good quality semi-improved grassland. These habitats may be adversely affected by the increased flood extent, depth and duration, although a majority of this area is already part of the "natural floodplain" and so subject to occasional inundation. Downstream of the proposed FSA, to the north-east of Benover are lowland fens. These are unlikely to be affected by the option because 'normal' flows in the River Beult will be unaffected, with only the highest flood flows throttled by the new control structure. It is likely that protected species are present within the scheme area, and appropriate studies would need to be undertaken to better identify risks and develop appropriate mitigation.		
Land quality, soils and geology • Agricultural land quality • Risks to and from contaminated land or landfills • Geological interests (geological SSSIs or RIGS)	According to the Agricultural Land Classification (ALC) database, the majority of the land is Grade 2 or 3. There would be some direct loss of land required to construct the embankments. The agricultural land within the proposed scheme area is already prone to flooding, the scheme would result in an increase in the extent and time land is inundated for. This could affect the longer term agricultural use of the site.	There would be a reduction in the extent of agricultural land flooded downstream of the FSA embankment, which would have some slight benefits for agricultural productivity.	Land contamination studies and risk assessments may be required.
Landscape and visual amenity • Designated landscapes (National Parks, AONB) • Landscape quality • Historic landscapes • Visual receptors (from roads, footpaths, recreational assets)	The National Character Area (NCA) is *Low Weald* and is a 'broad, low-lying clay vale which largely wraps around the northern, western and southern edges of the High Weald'. The area is not designated as Green Belt. The proposed embankments cut through a number of fields and run parallel to a number of villages, including Chainhurst, Great Tilden and Hunton. Aesthetically the embankments will be standing at between 1 to 3m depending on their location and therefore will be easily visible from roads and properties. Although the option location is not subject to any statutory landscape designations, the extensive nature of the required flood embankments would have a significant impact on the local landscape and visual environment.	There are likely to be very limited opportunities to positively contribute to the local landscape and visual environment through this scheme.	Sympathetic designs for structures that blend in with the local environment would be required to mitigate identified impacts. Careful landscaping and grading of slopes could reduce the visual impact of the option, although such measures could be constrained by space or land use considerations. Choices of materials and finishes, along with planting or other methods of screening could help to reduce visual impacts. A landscape and visual impact assessment would be required to determine the scale of the impact and potential effectiveness of mitigation measures.

Option: River Beult FSA at Chainhurst
Summary Description: Provide flood storage on the River Beult in the Chainhurst area. A storage level of 15.75m AOD would require a 720m embankment up to 3m high across the River Beult valley upstream of Hunton Road / East Street and 3km of side embankments (1 – 2m high) to the south of the River Beult to prevent the re-routing of floodwater into the Lesser Teise floodplain.

Environmental Receptor / Topic	Risks or Constraints to / from the receptor / option (consider construction and operation)	Potential Opportunities or Enhancements	Possible mitigation requirements or future action
Population and Human Health • Local residents, vulnerable people • Potential noise issues • Local businesses and economy • Recreation and access (incl. potential for improvement) • Risks to health from flooding, construction works etc.	Any noise impacts on local residents would be limited to the construction stages and therefore temporary. This issue is unlikely to be significant. There would be no direct loss of recreational assets, however the proposed embankments would bisect several Public Rights of Way, which may require temporary or permanent diversion. The increase in water levels upstream are likely to have some impacts to the following: • Properties and pub at Stilebridge Lane • Hurst Green glasshouses • Properties at Old Hertsfield	The reduction in downstream flood risk would reduce risk to life and human health impacts including reduced stress and anxiety due to fears of flooding. These benefits are however limited to relatively few properties and the option generally reduces flood depth across a wide area instead of entirely preventing property flooding.	Local mitigation might be needed to protect properties and the pub immediately downstream of Stilebridge. This could potentially be achieved by raising the level of Tilden Lane in this location. Local defences may also be required to protect properties at Old Hertsfield, agricultural glasshouses at Hurst Green and Riverfield Fish Farm. Compensation may be required for local landowners for both the permanent loss of land associated with the embankment footprints and the temporary loss of land associated with inundation of the FSA.
Water (Rivers, estuaries, lakes and groundwater) • WFD compliance • Biological quality • Chemical quality • Flows and morphology • Abstractions • Groundwater quality and quantity Please note surface water body status classifications are based on River Basin Management Plan 2014 cycle 2 data.	There are a number of waterbodies either within or close to the proposed FSA including: Beult (GB106040018270) – *Moderate Potential Overall Status*, Beult at Yalding (GB106040018140) – *Moderate Potential Overall Status*, Teise and Lesser Teise (GB106040018260) – *Moderate Potential Overall Status* and Marden Mill Stream (GB106040018310) – *Moderate Potential Overall Status*. The flood extent along the River Beult upstream of the proposed main embankment will increase as a result of the proposed scheme, with the potential to alter flow dynamics and sediment deposition. Channel form or function will not be directly affected and so it is considered unlikely that the option will prevent waterbody objectives from being met. Furthermore, out-of-bank flows and floodplain inundation already regularly occurs in this area and 'normal' flows in the River Beult will be unaffected, with only the highest flood flows throttled by the new control structure. The River Beult flows directly through the proposed FSA and new embankment, and a new in-channel control structure will be required. This will result in a loss of the natural river channel in this area, albeit over a very short distance relative to the overall waterbody length. In-channel works will be required to construct the proposed embankment and associated control structure. A temporary site compound and material store will be required on site and temporary haul roads may need to be constructed to allow construction vehicles access to the site. Both temporary structures and haul roads mean an increase in impermeable area and increased potential surface water runoff. There are no groundwater bodies along the site. The Greensand Middle is approximately 1.5km north.	Currently all nearby water bodies are at Moderate Overall Status, and there may be opportunities to contribute towards the WFD waterbody objectives. This should be further investigated at the next stage because delivery of the RBMP objectives is central to the Environment Agency's implementation of the WFD. Works to increase connectivity with the floodplain may lead to a natural enhancement in soil fertility, mitigate any potential diffuse agricultural pollution by re-depositing silt which was likely of agricultural origin and reduce the overall fine sediment loading downstream. These benefits are however unlikely to be significant because out-of-bank flows and floodplain inundation already regularly occurs in this area. Creation of buffer strips or wetlands on the floodplain could restrict / trap fine sediment movements back into the channel, subject to landowner agreement.	A preliminary WFD compliance assessment should be undertaken to closely examine the potential impacts and opportunities, and liaise with the Environment Agency's internal specialists at the earliest opportunity. Confirmation that in principle the option is compliant with the WFD would be required before proceeding. Should the option be taken forward, a full WFD assessment is recommended at the next stage. Appropriate mitigation and good practice during temporary works would be required to mitigate for any potential sediment runoff and water quality impacts during the works.

<table>
<tr><td colspan="4">Option: River Teise FSA at Cottage Wood
Summary Description: Provide flood storage on the River Teise in the Horsmonden area, downstream of Stonebridge. A storage level of 27.5m AOD would require a 470m embankment up to 3.5m high across the River Teise valley.</td></tr>
<tr><th>Environmental Receptor / Topic</th><th>Risks or Constraints to / from the receptor / option (consider construction and operation)</th><th>Potential Opportunities or Enhancements</th><th>Possible mitigation requirements or future action</th></tr>
<tr><td>Air and Climate
• Air quality
• Impact of climate change on the options
• Resilience to future climate change
• Increase or decrease in risks from natural disasters or flooding.</td><td>The proposed option is unlikely to have any effects on air quality beyond localised, temporary impacts during the construction stage. These are not considered to be a significant risk or constraint to the works. Depending on the source of the material for the embankment there are potentially high carbon costs associated with the construction of the embankment and the requirement to source material for the structure and transport it to the site.</td><td>The ability to include climate change projections in this option is limited because of the maximum feasible storage level. It will therefore be difficult to design this option to accommodate likely future climate change.</td><td>In order to mitigate potential effects the feasibility of locally obtaining material would need to be determined.</td></tr>
<tr><td>Archaeology and Cultural Heritage
• Statutory: Scheduled Monuments, Listed Buildings, Registered Park and Gardens)
• Non-statutory – Conservation Areas, potential for unknown archaeology.</td><td>There are no statutory or non-statutory designated sites of archaeological or cultural significance within the footprint of the proposed FSA. There are a number of listed buildings in the vicinity of the FSA, but these are unlikely to be directly impacted.</td><td>A number of listed buildings between Horsmonden and the confluences with the River Medway will benefit from the reduction in flood risk achieved by the River Teise FSA. These benefits are however limited to relatively few properties and the option generally reduces flood depth across a wide area instead of entirely preventing property flooding.</td><td>Archaeological desk based assessment and further investigations may be required prior to implementation of the scheme to manage risks to unknown or unrecorded archaeological remains within the footprint of the scheme.

If there are heritage assets located close to, or with sight-lines to and from the new embankment, further assessment would be required to ensure that the settings of these were not adversely affected by the new structure or inundation area.

Careful and sympathetic designs that complement the historic environment could be used to mitigate some impacts. These would require early consultation with the relevant historic environment bodies (statutory and non-statutory) to ensure that designs were effective and acceptable from a heritage perspective.</td></tr>
<tr><td>Biodiversity, flora and fauna
• Protected sites – SPA/SAC/Ramsar, SSSI, County or Local designations
• Specific opportunities for site improvement
• Habitats of Principal Importance for Biodiversity (formerly BAP Priority)
• Protected species potential.</td><td>There are a number of SSSI's within 4km of the site, but none within the proposed FSA. The High Weald AONB is present downstream of Stonebridge, but is located outside of the 27.5mAOD contour (proposed storage level).

No other statutory or non-statutory sites are directly affected by the proposed embankment or FSA.

There are a number of Habitats of Principal Importance present, including traditional orchard, deciduous woodland and ancient woodland which border the channel upstream of the embankment. The embankment is proposed through and immediately adjacent to deciduous woodland and a stand of ancient woodland. These habitats may be adversely affected by the increased flood extent, depth and duration, although a majority of this area is already part of the "natural floodplain" and so subject to occasional inundation.

The increase in flood extent upstream of the new embankment has the potential to increase the enrichment of the River with phosphate and nitrate from agricultural run-off. Options could be explored</td><td>There may be opportunities to incorporate biodiversity enhancements within the design of the FSA (e.g. improved floodplain connectivity or enhanced wetland habitats).</td><td>Studies of the condition of the habitats within the proposed FSA would be required, along with consideration of the likely effects of changes in the flood regime.

Protected species surveys would be required at an appropriate stage of the scheme design, and mitigation strategies developed where these species are likely to be affected.</td></tr>
</table>

Option: River Teise FSA at Cottage Wood
Summary Description: Provide flood storage on the River Teise in the Horsmonden area, downstream of Stonebridge. A storage level of 27.5m AOD would require a 470m embankment up to 3.5m high across the River Teise valley.

Environmental Receptor / Topic	Risks or Constraints to / from the receptor / option (consider construction and operation)	Potential Opportunities or Enhancements	Possible mitigation requirements or future action
	with how to best manage the land as part of this scheme to reduce this impact on the river and its habitats. It is likely that protected species are present within the scheme area, and appropriate studies would need to be undertaken to better identify risks and develop appropriate mitigation.		
Land quality, soils and geology • Agricultural land quality • Risks to and from contaminated land or landfills • Geological interests (geological SSSIs or RIGS).	According to the Agricultural Land Classification (ALC) database, all of the land within the FSA is Grade 3. There would be some direct loss of land required to construct the embankment. The agricultural land within the proposed scheme area is already prone to flooding, but the scheme would result in an increase in the extent and time land is inundated for. This could affect the longer term agricultural use of the site.	There would be a reduction in the extent of agricultural land flooded downstream of the FSA, which would have some slight benefits for agricultural productivity.	Land contamination studies and risk assessments may be required.
Landscape and visual amenity • Designated landscapes (National Parks, AONB) • Landscape quality • Historic landscapes • Visual receptors (from roads, footpaths, recreational assets).	The National Character Area (NCA) is *High Weald* and 'encompasses the ridged and faulted sandstone core of the Kent and Sussex Weald. It is an area of ancient countryside and one of the best surviving medieval landscapes in northern Europe.' The land is almost entirely Green Belt land. The existing landscape does not feature man-made embankments. However there are few receptors nearby which could be affected except for those properties at School House Farm and Ash Farm. A Public Right of Way is currently situated 50-70m to the north and parallel to the proposed embankment. Users of this path would be visually affected by the new embankment. It is thus concluded that although the option location is not subject to any statutory landscape designations, the new flood embankment could have a significant impact on the local landscape and visual environment.	There are likely to be very limited opportunities to positively contribute to the local landscape and visual environment through this scheme.	Sympathetic designs for structures that blend in with the local environment would be required to mitigate identified impacts. Careful landscaping and grading of slopes could reduce the visual impact of the option, although such measures could be constrained by space or land use considerations. Choices of materials and finishes, along with planting or other methods of screening could help to reduce visual impacts. A landscape and visual impact assessment would be required to determine the scale of the impact and potential effectiveness of mitigation measures.
Population and Human Health • Local residents, vulnerable people • Potential noise issues • Local businesses and economy • Recreation and access (incl. potential for improvement) • Risks to health from flooding, construction works etc.	Any noise impacts on local residents would be limited to the construction stages and therefore temporary. This issue is unlikely to be a significant constraint. The floodplain upstream of the proposed embankment location is rural with few properties at risk of flooding. There are however farm and residential buildings at Stream Farm on Summer Hill and to the north of Goudhurst Road, west of Stonebridge. The ground level around these buildings is 28m AOD. Goudhurst Road (minimum level 28m AOD) is slightly raised above the floodplain and acts to restrict downstream flows during more frequent flood events. The proposed storage level of 27.5m AOD was selected to ensure that flood risk to these properties and the road is not increased by the scheme.	The reduction in downstream flood risk would reduce risk to life and human health impacts including reduced stress and anxiety due to fears of flooding. Analysis suggests there are potential benefits to Collier Street and wider communities along the Lower and Lesser Teise. If a storm were to occur over the Teise catchment and not over the Beult catchment, upstream storage on the Teise could also potentially reduce flood risk in Yalding by reducing the inflow into the River Beult from the Lesser Teise. Lower flows in the Lesser Teise will also reduce flows in the Chainhurst area, of particular significance if the Cottage Wood FSA is combined with the Chainhurst FSA scheme. These benefits are however limited to relatively few properties and the option generally reduces flood depth across a wide area instead of entirely preventing property flooding.	Further review of the assets located around the 28m AOD ground level is required, and if necessary, the option can include mitigation measures such as improved flood resilience or localised flood protection measures for these assets. Compensation may be required for local landowners for both the permanent loss of land associated with the embankment footprints and the temporary loss of land associated with inundation of the FSA. If flood storage on the River Teise is taken forward to the OBC stage, a detailed consideration of the risk of coincident flood peaks and worsening of flood risk will be required. If this is found to be an issue, the River Teise FSA may require an active control structure instead of a passive one, significantly improving

Option: River Teise FSA at Cottage Wood
Summary Description: Provide flood storage on the River Teise in the Horsmonden area, downstream of Stonebridge. A storage level of 27.5m AOD would require a 470m embankment up to 3.5m high across the River Teise valley.

Environmental Receptor / Topic	Risks or Constraints to / from the receptor / option (consider construction and operation)	Potential Opportunities or Enhancements	Possible mitigation requirements or future action
	There are two footpaths which cross the floodplain within the FSA, one downstream of the sewage works and one immediately upstream of Stonebridge. Although these are already at risk of flooding, construction of the FSA would increase the depth and duration of flooding affecting these footpaths. The River Teise typically responds quicker to rainfall than either the River Beult or the River Medway. There is a risk that flood storage on the River Teise with a passive control structure will act to delay the flood peak on the River Teise such that it would then coincide with one or both peaks on the Beult and / or Medway, worsening flood risk for some areas downstream. The chance of this occurring is dependent on the amount and spatial pattern of rainfall received, antecedent conditions, operation of Leigh FSA and resulting flows on each of the rivers for any given event.		operational flexibility, but also significantly increasing capital, maintenance and operational costs.
Water (Rivers, estuaries, lakes and groundwater) • WFD compliance • Biological quality • Chemical quality • Flows and morphology • Abstractions • Groundwater quality and quantity. Please note surface water body status classifications are based on River Basin Management Plan 2014 cycle 2 data.	The proposed works will directly affect the Teise and Lesser Teise waterbody (GB106040018260) which is currently at *Moderate Potential overall status*. Other nearby waterbodies include the Beult at Yalding (GBGB106040018140) – *Moderate Potential Overall Status* downstream; Teise at Lamberhurst (GB106040018520) – *Poor Potential Overall Status* and Tributary of Teise (GB106040018510) – *Moderate Overall Status* upstream. The flood extent along the River Teise upstream of the proposed main embankment will increase as a result of the proposed scheme, with the potential to alter flow dynamics and sediment deposition. Channel form or function will not be directly affected and so it is considered unlikely that the option will prevent waterbody objectives from being met. Furthermore, out-of-bank flows and floodplain inundation already regularly occurs in this area and 'normal' flows in the River Teise will be unaffected, with only the highest flood flows throttled by the new control structure. The River Teise flows directly through the proposed FSA and new embankment, and a new in-channel control structure will be required. This will result in a loss of the natural river channel in this area, albeit over a very short distance relative to the overall waterbody length. In-channel works will be required to construct the proposed embankment and associated control structure. A temporary site compound and material store will be required on site and temporary haul roads may need to be constructed to allow construction vehicles access to the site. Both	Currently all affected waterbodies are at Poor or Moderate Overall Status, and there may be opportunities to contribute towards the WFD waterbody objectives. This should be further investigated at the next stage because delivery of the RBMP objectives is central to the Environment Agency's implementation of the WFD. Works to increase connectivity with the floodplain may lead to a natural enhancement in soil fertility, mitigate any potential diffuse agricultural pollution by re-depositing silt which was likely of agricultural origin and reduce the overall fine sediment loading downstream. These benefits are however unlikely to be significant because out-of-bank flows and floodplain inundation already regularly occurs in this area. Creation of buffer strips or wetlands on the floodplain could restrict/trap fine sediment movements back into the channel.	A preliminary WFD compliance assessment should be undertaken to closely examine the potential impacts and opportunities, and liaise with the relevant internal functions of the Environment Agency at the earliest opportunity. Confirmation that in principle the option is compliant with the WFD would be required before proceeding. Should the option be taken forward, a full WFD assessment is recommended at the next stage. Appropriate mitigation and good practice during temporary works would be required to mitigate for any potential sediment runoff and water quality impacts during the works.

Option: River Teise FSA at Cottage Wood
Summary Description: Provide flood storage on the River Teise in the Horsmonden area, downstream of Stonebridge. A storage level of 27.5m AOD would require a 470m embankment up to 3.5m high across the River Teise valley.

Environmental Receptor / Topic	Risks or Constraints to / from the receptor / option (consider construction and operation)	Potential Opportunities or Enhancements	Possible mitigation requirements or future action
	temporary structures and haul roads mean an increase in impermeable area and increased potential surface water runoff. The site is partly within the *Kent Weald Western – Medway* Groundwater Body (GB40602G502300) is currently at Good Quantitative Quality and Poor Chemical Quality. The waterbody covers a very extensive area from East Grinstead in the west to Cranbrook in the east.		

Option: River Teise FSA at Stonebridge
Summary Description: Provide flood storage on the River Teise in the Horsmonden area, upstream of Stonebridge. A storage level of 30.5m AOD would require a 460m embankment up to 3.5m high across the River Teise valley.

Environmental Receptor / Topic	Risks or Constraints to / from the receptor/option (consider construction and operation)	Potential Opportunities or Enhancements	Possible mitigation requirements or future action
Air and Climate • Air quality • Impact of climate change on the options • Resilience to future climate change • Increase or decrease in risks from natural disasters or flooding.	The proposed option is unlikely to have any effects on air quality beyond localised, temporary impacts during the construction stage. These are not considered to be a significant risk or constraint to the works. Depending on the source of the material for the embankment there are potentially high carbon costs associated with the construction of the embankment and the requirement to source material for the structure and transport it to the site.	The ability to include climate change projections in this option is limited because of the maximum feasible storage level. It will therefore be difficult to design this option to accommodate likely future climate change.	In order to mitigate potential effects the feasibility of locally obtaining material would need to be determined.
Archaeology and Cultural Heritage • Statutory: Scheduled Monuments, Listed Buildings, Registered Park and Gardens) • Non-statutory – Conservation Areas, potential for unknown archaeology.	The *Medieval moated site at Share Farm*, a Scheduled Monument is situated approximately 100m upstream of the proposed embankment. The *Share Farm* Grade II listed building is also located approximately 250m upstream of the embankment. These would be indirectly affected by the construction of the new embankment within their valley setting, and directly affected by an increase in the depth and duration of flooding due to impoundment within the FSA. This could pose a significant constraint to the progression of the option and would require early consultation with the relevant heritage consultees. There are no other statutory or non-statutory designated sites of archaeological or cultural significance within the FSA. Although a number of other listed buildings are located nearby, these are unlikely to be affected.	A number of listed buildings between Horsmonden and the confluences with the River Medway will benefit from the reduction in flood risk achieved by the River Teise FSA. These benefits are however limited to relatively few properties and the option generally reduces flood depth across a wide area instead of entirely preventing property flooding.	Archaeological desk based assessment and further investigations may be required prior to implementation of the scheme to manage risks to unknown or unrecorded archaeological remains within the footprint of the scheme. Careful and sympathetic designs that complement the historic environment could be used to mitigate some impacts, but may not adequately address the changes that would result from the new FSA. Localised flood protection measures could be considered to any heritage assets that fall within the footprint of the FSA, however these could also adversely affect the designations and may not be an appropriate solution. This option would require early consultation and engagement with the relevant historic environment bodies (statutory and non-statutory) to ensure that the option was acceptable from a heritage perspective.
Biodiversity, flora and fauna • Protected sites – SPA/SAC/Ramsar, SSSI, County or Local designations • Specific opportunities for site improvement • Habitats of Principal Importance for Biodiversity (formerly BAP Priority) • Protected species potential.	There are a number of SSSI's within 4km of the site and a NVZ is situated less than a kilometre to the west of the site. No other statutory or non-statutory sites are directly affected by the proposed embankment or FSA. There are few priority habitats in this area. The current proposed footprint of the embankment would affect a stand of orchard to the east; otherwise there are only limited potential impacts to occasional stands of deciduous woodland along Small Bridge Road and west of Brandfold Farm. It is likely that protected species are present within the scheme area, and appropriate studies would need to be undertaken to better identify risks and develop appropriate mitigation.	There may be opportunities to incorporate biodiversity enhancements within the design of FSA (for example improved floodplain connectivity or enhanced wetland habitats).	Studies of the condition of the habitats within the proposed FSA would be required, along with consideration of the likely effects of changes in the flood regime. Protected species surveys would be required at an appropriate stage of the scheme design, and mitigation strategies developed where these species are likely to be affected.
Land quality, soils and geology • Agricultural land quality • Risks to and from contaminated land or landfills • Geological interests (geological SSSIs or RIGS).	According to the Agricultural Land Classification (ALC) database, all of the land within the FSA is Grade 3. There would be some direct loss of land as a result of embankment construction. The agricultural land within the proposed FSA is already prone to flooding, but the scheme would result in an increase in the extent and	There would be a reduction in the extent of agricultural land flooded downstream of the FSA, which would have some slight benefits for agricultural productivity.	Land contamination studies and risk assessments may be required.

Option: River Teise FSA at Stonebridge
Summary Description: Provide flood storage on the River Teise in the Horsmonden area, upstream of Stonebridge. A storage level of 30.5m AOD would require a 460m embankment up to 3.5m high across the River Teise valley.

Environmental Receptor / Topic	Risks or Constraints to / from the receptor/option (consider construction and operation)	Potential Opportunities or Enhancements	Possible mitigation requirements or future action
	time land is inundated for. This could affect the longer term agricultural use of the site.		
Landscape and visual amenity • Designated landscapes (National Parks, AONB) • Landscape quality • Historic landscapes • Visual receptors (from roads, footpaths, recreational assets).	The proposed site is entirely within the *High Weald* Area of Natural Beauty (AONB). The National Character Area (NCA) is *High Weald* and 'encompasses the ridged and faulted sandstone core of the Kent and Sussex Weald. It is an area of ancient countryside and one of the best surviving medieval landscapes in northern Europe.' The land is almost entirely all green belt land. The proposed embankment is likely to have a significant impact on the AONB and the historic landscape as viewed from Share Farm and the adjacent Scheduled Monument. It is also likely that the embankment would be visible from Goudhurst Road (including Stonebridge). These landscape impacts could pose significant constraints to the progression of a flood storage option in this location.	Opportunities to enhance or positively contribute to the landscape and visual environment as part of this option are likely to be limited.	Sympathetic designs for structures that blend in with the local environment would be required to mitigate identified impacts. Careful landscaping and grading of slopes could reduce the visual impact of the option, although such measures could be constrained by space or land use considerations. Choices of materials and finishes, along with planting or other methods of screening could help to reduce visual impacts. A landscape and visual impact assessment would be required to determine the scale of the impact and potential effectiveness of mitigation measures.
Population and Human Health • Local residents, vulnerable people • Potential noise issues • Local businesses and economy • Recreation and access (incl. potential for improvement) • Risks to health from flooding, construction works etc.	Any noise impacts on local residents would be limited to the construction stages and therefore temporary. This issue is unlikely to be significant. This is also a rural location, although there are low-lying properties at Share Farm and Smallbridge, and a pumping station downstream of Smallbridge. Key operational impacts are likely to be associated with flooding of agricultural land. A public right of way runs parallel to the proposed embankment from Share Farm across the floodplain and is likely to be affected when the FSA is in operation. The River Teise typically responds quicker to rainfall than either the River Beult or the River Medway. There is a risk that flood storage on the River Teise with a passive control structure will act to delay the flood peak on the River Teise such that it would then coincide with one or both peaks on the Beult and / or Medway, worsening flood risk for some areas downstream. The chance of this occurring is dependent on the amount and spatial pattern of rainfall received, antecedent conditions, operation of Leigh FSA and resulting flows on each of the rivers for any given event.	The reduction in downstream flood risk would reduce risk to life and human health impacts including reduced stress and anxiety due to fears of flooding. Analysis suggests there are potential benefits to Collier Street and wider communities along the Lower and Lesser Teise. These benefits are however limited to relatively few properties and the option generally reduces flood depth across a wide area instead of entirely preventing property flooding.	Localised protection measures are likely to be required for assets within the FSA, namely Share Farm. Compensation may be required for local landowners for both the permanent loss of land associated with the embankment footprints and the temporary loss of land associated with inundation of the FSA. If flood storage on the River Teise is taken forward to the OBC stage, a detailed consideration of the risk of coincident flood peaks and worsening of flood risk will be required. If this is found to be an issue, the River Teise FSA may require an active control structure instead of a passive one, significantly improving operational flexibility, but also significantly increasing capital, maintenance and operational costs.
Water (Rivers, estuaries, lakes and groundwater) • WFD compliance • Biological quality • Chemical quality	The proposed works will directly affect the Teise and Lesser Teise waterbody (GB106040018260) which is currently at Moderate Potential overall status.	Currently all affected water bodies are at Poor or Moderate Overall Potential, and there may be opportunities to contribute towards the WFD waterbody objectives. This should be further investigated at the next stage because delivery of the	A preliminary WFD compliance assessment should be undertaken to closely examine the potential impacts and opportunities, and liaise with the relevant internal functions of the Environment Agency at the earliest opportunity. Confirmation that in principle the

Option: River Teise FSA at Stonebridge
Summary Description: Provide flood storage on the River Teise in the Horsmonden area, upstream of Stonebridge. A storage level of 30.5m AOD would require a 460m embankment up to 3.5m high across the River Teise valley.

Environmental Receptor / Topic	Risks or Constraints to / from the receptor/option (consider construction and operation)	Potential Opportunities or Enhancements	Possible mitigation requirements or future action
• Flows and morphology • Abstractions • Groundwater quality and quantity. Please note surface water body status classifications are based on River Basin Management Plan 2014 cycle 2 data.	Other nearby waterbodies include the Beult at Yalding (GBGB106040018140) – *Moderate Potential Overall Status*, the Teise at Lamberhurst (GB106040018520) – *Poor Potential Overall Status* and Tributary of Teise (GB106040018510) – *Moderate Overall Status*. The flood extent along the River Teise upstream of the proposed main embankment will increase as a result of the proposed scheme, with the potential to alter flow dynamics and sediment deposition. Channel form or function will not be directly affected and so it is considered unlikely that the option will prevent waterbody objectives from being met. Furthermore, out-of-bank flows and floodplain inundation already regularly occurs in this area and 'normal' flows in the River Teise will be unaffected, with only the highest flood flows throttled by the new control structure. The River Teise flows directly through the proposed FSA and new embankment, and a new in-channel control structure will be required. This will result in a loss of the natural river channel in this area, albeit over a very short distance relative to the overall waterbody length. In-channel works will be required to construct the proposed embankment and associated control structure. A temporary site compound and material store will be required on site and temporary haul roads may need to be constructed to allow construction vehicles access to the site. Both temporary structures and haul roads mean an increase in impermeable area and increased potential surface water runoff. The site is partly within the *Kent Weald Western – Medway* Groundwater Body (GB40602G502300) is currently at Good Quantitative Quality and Poor Chemical Quality. The waterbody covers a very extensive area from East Grinstead in the west to Cranbrook in the east.	RBMP objectives is central to the Environment Agency's implementation of the WFD. Works to increase connectivity with the floodplain may lead to a natural enhancement in soil fertility, mitigate any potential diffuse agricultural pollution by re-depositing silt which was likely of agricultural origin and reduce the overall fine sediment loading downstream. These benefits are however unlikely to be significant because out-of-bank flows and floodplain inundation already regularly occurs in this area. Creation of buffer strips or wetlands on the floodplain could restrict/trap fine sediment movements back into the channel.	option is compliant with the WFD would be required before proceeding. Should the option be taken forward, a full WFD assessment is recommended at the next stage. Appropriate mitigation and good practice during temporary works would be required to mitigate for any potential sediment runoff and water quality impacts during the works.

Option: Yalding Local Defence Scheme
Summary Description: Build linear defences (combination of walls and embankments) to protect properties on both the west and east sides of the River Beult through Yalding.

Environmental Receptor / Topic	Risks or Constraints to / from the receptor / option (consider construction and operation)	Potential Opportunities or Enhancements	Possible mitigation requirements or future action
Air and Climate • Air quality • Impact of climate change on the options • Resilience to future climate change • Increase or decrease in risks from natural disasters or flooding.	The proposed option is unlikely to have any effects on air quality beyond localised, temporary impacts during the construction stage. These are not considered to be a significant risk or constraint to the works. If this option is taken forward, consideration should be made of the carbon costs associated with sourcing and transporting the construction materials.	The desired Standard of Protection can be achieved through varying the defence height, taking current climate change projections into account. It is therefore possible to design the option to accommodate future climate change and / or to allow future adaptation to manage the realised impacts of climate change.	
Archaeology and Cultural Heritage • Statutory: Scheduled Monuments, Listed Buildings, Registered Park and Gardens) • Non-statutory – Conservation Areas, potential for unknown archaeology.	There are a number of Listed Buildings in Yalding, many on the B2162 (Hampstead Lane) and Benover Road. Town Bridge in Yalding is a 15th century ragstone causeway and is designated as a Scheduled Monument. While the walls would not directly physically impact any cultural heritage assets, there may be impacts on the setting of these assets depending on the location, height and construction type of the proposed defence.	The local defence scheme has the potential to significantly reduce the risk of flooding to many Listed Buildings in Yalding.	Archaeological desk based assessment and further investigations may be required prior to implementation of the scheme to manage risks to unknown or unrecorded archaeological remains within the affected area. Careful and sympathetic designs that complement the historic environment could be used to mitigate some impacts. These would require early consultation with the relevant historic environment bodies (statutory and non-statutory) to ensure that designs were effective and acceptable from a heritage perspective.
Biodiversity, flora and fauna • Protected sites – SPA/SAC/Ramsar, SSSI, County or Local designations • Specific opportunities for site improvement • Habitats of Principal Importance for Biodiversity (formerly BAP Priority) • Protected species potential.	The River Beult is designated as a SSSI to the confluence with the River Medway. The SSSI is currently in unfavourable condition relating to a decline in water quality and change in habitat structure, caused for example by over-straightening of bank-side habitat. The new flood defences are unlikely to have a direct impact on the river, although there is a risk of water pollution and sediment runoff during the construction phase. There are no other statutory or non-statutory designations. Yalding is located outside of two Nitrate Vulnerable Zones, located approximately 200m and 600m to the north and south respectively. There are no Habitats of Principal Importance along the indicative route of the walls, however there are some stands of deciduous woodland and traditional orchard to the west and south west of Yalding. Protected species are likely to be present within the scheme area, and appropriate studies would need to be undertaken to better identify risks and develop appropriate mitigation.	The local defence scheme option offers limited opportunities for biodiversity enhancements, although this should be further investigated if this option is taken forward, particularly in relation to works to restore the condition of the River Beult SSSI.	Protected species and habitat surveys would be required at an appropriate stage of the scheme design, and mitigation strategies developed where these species are likely to be affected.
Land quality, soils and geology • Agricultural land quality • Risks to and from contaminated land or landfills • Geological interests (geological SSSIs or RIGS).	According to the Agricultural Land Classification (ALC) database, the majority of the land is Grade 2 or 3. There will be some direct loss of agricultural land due to the footprint of the new defences, but this loss will be limited because the proposed defence alignment is on the boundary of the urban area. There is a risk that the loss of floodplain storage in the urban area of Yalding will increase flood risk to neighbouring areas, increasing the extent and depth of flooding on adjacent agricultural land. The location of the proposed option means that there is a risk of encountering existing localised	This option is designed to protect an urban area, with no land quality or soils opportunities.	Land contamination studies and risk assessments may be required.

Option: Yalding Local Defence Scheme
Summary Description: Build linear defences (combination of walls and embankments) to protect properties on both the west and east sides of the River Beult through Yalding.

Environmental Receptor / Topic	Risks or Constraints to / from the receptor / option (consider construction and operation)	Potential Opportunities or Enhancements	Possible mitigation requirements or future action
	contamination, however this can be managed through appropriate desk study/investigation and construction practices.		
Landscape and visual amenity • Designated landscapes (National Parks, AONB) • Landscape quality • Historic landscapes • Visual receptors (from roads, footpaths, recreational assets).	The historic village of Yalding has a high landscape quality and the introduction of new flood walls and embankments has the potential to detract from this. A high visual impact is anticipated for residents and visitors / recreational users. Space is limited through the private land along the River Beult, with careful design and landowner consultation required.	There are likely to be very limited opportunities to positively contribute to the local landscape and visual environment through this scheme.	Sympathetic designs for structures that blend in with the local environment would be required to mitigate identified impacts. Choices of materials and finishes, along with planting or other methods of screening could help to reduce visual impacts. A landscape and visual impact assessment would be required to determine the scale of the impact and potential effectiveness of mitigation measures.
Population and Human Health • Local residents, vulnerable people • Potential noise issues • Local businesses and economy • Recreation and access (incl. potential for improvement) • Risks to health from flooding, construction works etc.	Any noise impacts on local residents would be limited to the construction stages and therefore temporary. This issue is unlikely to be significant. The Medway Valley Walk public right of way runs along the northern boundary of Yalding along Hampstead Lane and over Yalding Bridge. There are other public rights of way along the River Beult but these are unlikely to be affected by the works.	The local defence scheme has the potential to significantly reduce the risk of flooding to many properties in Yalding. This reduction in flood risk could reduce risk to life and human health impacts associated with reduced stress and anxiety due to fears of flooding.	The proposed defence alignment crosses several roads, at which it is assumed that temporary defences will be required, utilised during a flood event. The ring-fence style of the alignment also means that pumps are likely to be needed to remove flood water should the defences be overtopped during an event which exceeds the design standard. Compensation may be required for local landowners for both permanent loss of land associated with the defence footprint.
Water (Rivers, estuaries, lakes and groundwater) • WFD compliance • Biological quality • Chemical quality • Flows and morphology • Abstractions • Groundwater quality and quantity. Please note surface water body status classifications are based on River Basin Management Plan 2014 cycle 2 data.	The proposed defences are unlikely to have a direct, physical effect on waterbodies in the area. Yalding is situated at the confluence of two water bodies: the Beult at Yalding (GB106040018140) – *Moderate Potential Overall Status* and the Mid Medway from Eden Catchment to Yalding (GB106040018182) – *Moderate Potential Overall Status*. Downstream is the Medway at Maidstone water body (GB106040018440) – *Moderate Potential Overall Status*. Whilst there are no physical impacts likely on the water bodies, there may be alterations in the flow and sediment dynamics as flood waters are routed elsewhere, or to locations they do not currently flood. A temporary site compound and material store will be required on site and temporary haul roads may need to be constructed to allow construction vehicles access to the site. Both temporary structures and haul roads mean an increase in impermeable area and increased potential surface water runoff. The Kent Greensand Middle groundwater body is situated north of Yalding, currently at Poor status for both quantitative statuses. This groundwater body is unlikely to be affected by any local defence scheme.	Currently all affected water bodies are at Moderate Potential Overall Status, and there may be opportunities to contribute towards the WFD waterbody objectives. This should be further investigated at the next stage because delivery of the RBMP objectives is central to the Environment Agency’s implementation of the WFD.	A preliminary WFD compliance assessment was undertaken as part of the MMS review (Halcrow, 2010) and concluded that the option to increase the NMOWL at Leigh FSA is likely to be compliant, with no anticipated waterbody deterioration and no prevention of mitigation measures implementation. A full WFD assessment is recommended at the next stage to include more detailed examination of the potential impacts and opportunities, and liaison with the relevant internal functions of the Environment Agency. Appropriate mitigation and good practice during temporary works would be required to mitigate for any potential sediment runoff and water quality impacts during the works.

Option: Conveyance Improvements
Summary Description: Improve conveyance between Yalding and Maidstone by widening the channel of the River Medway (by ~ 5m), with necessary works to the bridges along this reach of the river.

Environmental Receptor / Topic	Risks or Constraints to / from the receptor / option (consider construction and operation)	Potential Opportunities or Enhancements	Possible mitigation requirements or future action
Air and Climate • Air quality • Impact of climate change on the options • Resilience to future climate change • Increase or decrease in risks from natural disasters or flooding.	The proposed option is unlikely to have any effects on air quality beyond localised, temporary impacts during the construction stage. This is not considered to be a significant risk or constraint to the works. The widening of the channel would generate large quantities of waste material which would either have to be reused on site (if possible) or disposed of at an off-site facility. The latter would increase the carbon 'cost' of the option and reduce its sustainability relative to other options.	Conveyance improvements can reduce water levels during flood events but would not be specifically designed to accommodate future climate change.	Identification of opportunities for local material re-use.
Archaeology and Cultural Heritage • Statutory: Scheduled Monuments, Listed Buildings, Registered Park and Gardens) • Non-statutory – Conservation Areas, potential for unknown archaeology.	The most significant constraint to the proposals would be the required works to the Medway bridges at Teston and East Farleigh, both of which are designated as Scheduled Monuments and therefore require consent to undertake any works. Without major alterations to these bridges the intended increase in conveyance is unlikely to be achieved, but the required alterations are unlikely to be acceptable from a heritage perspective. There are also numerous Listed Buildings close to the River Medway, most of which are slightly set back from the river, but many of which are likely to be indirectly affected by conveyance improvement works, particularly in Wateringbury and East Farleigh. The channel widening would have an initial high impact on the historic setting of these buildings, and as there are numerous buildings involved this is likely to present a considerable constraint to the works.	Some listed buildings, particularly those in Yalding are likely to benefit from the reduction in flood depths which could occur following implementation of this option.	This option would require an extensive programme of archaeological study, investigation and evaluation throughout the scheme area. Careful and sympathetic designs that complement the historic environment could be used to mitigate some impacts, but it is unlikely that these could adequately address the impacts. Early consultation with the relevant historic environment bodies (statutory and non-statutory) to discuss the viability of this option would be required before deciding whether it was feasible to progress it.
Biodiversity, flora and fauna • Protected sites – SPA/SAC/Ramsar, SSSI, County or Local designations • Specific opportunities for site improvement • Habitats of Principal Importance for Biodiversity (formerly BAP Priority) • Protected species potential.	The River Beult is designated as a SSSI to the confluence with the River Medway. The SSSI is currently in unfavourable condition relating to a decline in water quality and change in habitat structure, caused for example by over-straightening of bank-side habitat. As the works will take place downstream of the SSSI on the River Medway, it is considered unlikely that this site would be affected. Potential impacts on the Medway and Swale SSSI/SPA/Ramsar and the Holborough to Burham Marshes SSSI downstream of the works would need to be considered to ensure no adverse impacts. These sites are downstream of the River Medway tidal boundary and so adverse impacts are considered to be unlikely. Along the channel there are a few stands of deciduous woodland and ancient woodland extending up to the bank edge, and numerous other trees and vegetation. It is highly likely that protected species are present within the scheme area, and appropriate studies would need to be undertaken to better identify risks and develop appropriate mitigation. The linear nature of the option means that impacts are likely to	There may be potential opportunities to improve the habitat diversity along the riverbanks or contribute towards the Habitats of Principal Importance for Biodiversity. Other opportunities could include the possibility of creating enhanced floodplain / washland habitats, subject to landowner agreement.	Studies of the condition of the habitats within the proposed scheme area would be required, along with consideration of the impacts of any losses. Once the impacts have been established, an option-wide mitigation plan would need to be developed setting out how impacts would be addressed, and where this could be achieved. It could be possible to improve or enhance biodiversity but this would require careful planning and integration from the outset of the scheme. Protected species surveys would be required at an appropriate stage of the scheme design, and mitigation strategies developed where these species are likely to be affected.

Option: Conveyance Improvements
Summary Description: Improve conveyance between Yalding and Maidstone by widening the channel of the River Medway (by ~ 5m), with necessary works to the bridges along this reach of the river.

Environmental Receptor / Topic	Risks or Constraints to / from the receptor / option (consider construction and operation)	Potential Opportunities or Enhancements	Possible mitigation requirements or future action
	be high, requiring tree removal, loss of established bankside vegetation, disturbance to bankside habitats, disturbance to fish migration and significant changes to existing instream habitats. Flow alterations could result in longer term changes to instream habitats post-construction.		
Land quality, soils and geology • Agricultural land quality • Risks to and from contaminated land or landfills • Geological interests (geological SSSIs or RIGS).	According to the Agricultural Land Classification (ALC) database, the majority of the land adjacent to the river channel is classified as Grade 3, with some limited Grade 2 areas and some Grade 1 to the east (right bank) of the Medway around Farleigh, with a smaller area of Grade 1 to the north around Pizien Well. The widening of the river channel could result in a minor loss of adjacent agricultural land. The widening work and associated excavation presents a risk of encountering contamination along the route. This risk would need to be accounted for in planning for any material re-use or disposal.	This option could provide very marginal benefits in terms of the reduction in flood risk to surrounding agricultural land.	Land contamination studies and risk assessments would be required to determine the risks that existing land contamination could pose.
Landscape and visual amenity • Designated landscapes (National Parks, AONB) • Landscape quality • Historic landscapes • Visual receptors (from roads, footpaths, recreational assets).	The site is split across two National Character Areas (NCA): *Low Weald* and *Wealden Greensand*. Land to the west (left bank) at Nettlestead is designated as Green Belt. Although there are no statutory landscape designations, the extensive nature of the works, changes to established mature vegetation patterns and changes to the channel and historic structures would create a highly significant change to the landscape and visual environment of the river.	There could be opportunities for enhancement of the local landscape; this would need to be determined via a scheme-wide appraisal of existing landscape quality. However the current setting of the Medway is largely rural and undeveloped; and opportunities for significant improvement over and above the current landscape quality are likely to be limited.	There would be significant landscape and visual impacts associated with the option. An option-wide mitigation strategy would be required in order to ensure that the short term and longer term impacts were managed and addressed.
Population and Human Health • Local residents, vulnerable people • Potential noise issues • Local businesses and economy • Recreation and access (incl. potential for improvement) • Risks to health from flooding, construction works etc.	The few residential properties adjacent to the river would experience temporary impacts from construction noise and disturbance, and permanent land take could be required from private gardens. There are likely to be services (utilities, electricity etc.) which would require diversion prior to the works. The option would have significant adverse effects on recreational users of the Medway, including walkers, cyclists, anglers and users of the Medway Navigation. The implications of the channel widening on locks and marinas throughout the option area would need to be carefully considered. Impacts on moorings and boating facilities and the economic impacts of these would also be a key consideration. The Medway Valley Walk follows the River Medway along the left bank with a variety of public rights of way spurring off. It is difficult to accurately assess the impact to the footpaths without understanding the exact nature and location of the proposed widening. However it is likely that some of these footpaths will require a diversion or closure during the construction and potential permanent diversion away from the river bank edge.	Reduction in flood risk would reduce risk to life and human health impacts from, reduced stress and anxiety due to fears of flooding. This is particularly true in Yalding, where a majority of the benefits are achieved.	Works could be phased to reduce impacts, although this would delay the realisation of flood risk benefits. This option would require early and close consultation with the public, riparian landowners and local businesses. There is considered to be a high risk of objection to this option from river users.

<table>
<tr><td colspan="4">Option: Conveyance Improvements
Summary Description: Improve conveyance between Yalding and Maidstone by widening the channel of the River Medway (by ~ 5m), with necessary works to the bridges along this reach of the river.</td></tr>
<tr><th>Environmental Receptor / Topic</th><th>Risks or Constraints to / from the receptor / option (consider construction and operation)</th><th>Potential Opportunities or Enhancements</th><th>Possible mitigation requirements or future action</th></tr>
<tr><td>Water (Rivers, estuaries, lakes and groundwater)
• WFD compliance
• Biological quality
• Chemical quality
• Flows and morphology
• Abstractions
• Groundwater quality and quantity.

Please note surface water body status classifications are based on River Basin Management Plan 2014 cycle 2 data.</td><td>The land on the right bank of the River Medway is designated as a groundwater Nitrate Vulnerable Zone. For the most part this is more than 5-10m away, however immediately upstream of Maidstone it is much closer to the bank edge.

The proposed works will have a direct, physical impact on the Medway at Maidstone water body (GB106040018440) – Moderate Potential Overall Status. Upstream of this is the Beult at Yalding (GB106040018140) – Moderate Potential Overall Status and the Mid Medway from Eden Catchment to Yalding (GB106040018182) – Moderate Potential Overall Status. Further downstream of Medway at Maidstone is the Medway transitional water body (GB530604002300), which is currently at Moderate Potential Overall Status.

Increasing the conveyance capacity of the River Medway between Yalding and Maidstone will allow more water to flow through the channel in the short-term. Over time however, channel capacity is expected to reduce as sediment is transported into, and stored within the channel and / or as vegetation establishes at the channel margins. This option is therefore likely to require long-term maintenance to maintain the additional capacity gained from the initial capital expenditure.

This option also conflicts with the mitigation measures listed within the 2009 RBMPs, including:
• Preserve and where possible enhance ecological value of marginal aquatic habitat, banks and riparian zone;
• Avoid the need to dredge (e.g. minimise under-keel clearance; use fluid mud navigation; flow manipulation or training works);
• Reduce impact of dredging;
• Retain marginal aquatic and riparian habitats (channel alteration); and
• Increase in-channel morphological diversity.

There is therefore considered to be a high risk of non-compliance with the requirements of the Water Framework Directive, which presents a significant constraint to the progression of this option.</td><td>Currently all affected water bodies are at Moderate Potential Overall Status, and there may be opportunities to contribute towards the WFD waterbody objectives. This should be further investigated at the next stage because delivery of the RBMP objectives is central to the Environment Agency's implementation of the WFD.

An alternative opportunity would to be to construct a two-stage channel profile and maintain the natural low flow dynamics, whilst creating an artificial low level floodplain to provide additional conveyance capacity.</td><td>A preliminary WFD compliance assessment should be undertaken to closely examine the potential impacts and opportunities, and liaise with the Environment Agency's internal specialists at the earliest opportunity before deciding whether to progress the option further. At this stage it is considered that there is a high risk of non-compliance with the requirements of the WFD.

Appropriate mitigation and good practice during temporary works would be required to mitigate for any potential sediment runoff and water quality impacts during the works.</td></tr>
</table>

Appendix F Economic Appraisal Methodology

F.1 Options Costs Methodology

Option cost summaries were provided in Sections 2 and 3. Table F-2 and Table F-3 provide more information on the methodology for calculating the cash costs for capital works. The costs listed are prior to inclusion of Optimism Bias.

Table F-1 Leigh FSA Cash Costs for Capital Works

Item	Cash Cost (£k)	Calculation Methodology
Appraisal, design & management (Maintain Leigh FSA)	848	High-level estimate: appraisal costed at 8% and design and management costed at 10% of the cash cost for initial capital works.
Southern embankment downstream slope protection	620	Halcrow 2010 report cost of £470k, with 20% added for incidental items and 10% added for price inflation.
Control structure mechanical improvements	4,090	November 2012 mechanical improvements costing of £4,416k. Design and construction management and risk removed (added as separate item on all works), reducing cost to £3,090k. Further £1,000k added for general upgrade works identified as necessary by the Environment Agency.
10-yearly works	500	Assumed cost for refurbishment works, required in additional to the annual maintenance works.
Major replacement year 40 and year 80	10,000	Assumed cost for control structure replacement and works to embankments.
Appraisal, design & management (additional for Improve option)	424	High-level estimate: appraisal costed at 8% and design and management costed at 10% of the cash cost for the additional initial capital works required under the Improve option.
Raised crest or new wave wall	650	Assume 300mm of raising or wave wall height (to provide 600mm freeboard) at £500/m run over the 1,300m length.
Railway line protection	500	Original 2006 estimate was £1.8M. Need for berm raising with a NMOWL of 28.85m AOD reviewed and considered unnecessary west of the Six Arches Bridge. Scale of raising to the east could also be reduced. Revised estimate of £500k but risk that this cost could be significantly higher.
Cattle arch protection, works in south-west Leigh	78	Cost of £780/m run determined from calculated fill volumes and applied over a 100m embankment length.
EA pumping station protection	65	Cost of £1,190/m run determined from calculated fill volumes and applied over a 55m embankment length.
SW pumping station protection	96	Cost of £870/m run determined from calculated fill volumes and applied over a 110m embankment length.
Works to pumping station access track	156	Cost of £1,946/m run determined from calculated fill volumes with an allowance for drainage works and applied over an 80m embankment length.
Well Place Farm access	113	Assume 0.5m wall height at £750/m run over the 150m length.

Item	Cash Cost (£k)	Calculation Methodology
Penshurst STW protection	300	Assume embankment raising or new wall at £1,000/m run over the 250m length, with an additional £50k allowance for works to the access track.
Bridge House	400	High level cost estimate of wall / bund solution or allowance for property purchase.

Table F-2 River Beult & River Teise FSAs Cash Costs for Capital Works

Item	Cash Cost (£k)	Calculation Methodology
River Beult: Chainhurst FSA		
Appraisal, design & management	993	High-level estimate: appraisal costed at 8% and design and management costed at 12% of the cash cost for FSA construction.
Estates purchase and landowner compensation	500	Assumed value using engineering judgement.
FSA construction	4,965	Calculated using SPONS (AECOM, 2015) from 125,000m^3 of fill material required at a cost of £20/m^3 (assumes local source), with additional costs for excavation, main outfall construction (£240k) and drainage works in the side embankment (£100k). Cost also includes allowances for unmeasured items (5%), site establishment, head office costs and profit (£700k) and Preliminary and General activities (£850k).
10-yearly works	263	High-level estimate costed at 5% of the cash cost for FSA construction.
River Teise: Cottage Wood FSA		
Appraisal, design & management	421	High-level estimate: appraisal costed at 5% and design and management costed at 12% of the cash cost for FSA construction.
Estates purchase and landowner compensation	200	Assumed value using engineering judgement.
FSA construction	2,479	Calculated using SPONS (AECOM, 2015) from 35,800m^3 of fill material required at a cost of £35/m^3 (assumes semi-local source), with additional costs for excavation and main outfall construction (£328k). Cost also includes allowances for unmeasured items (5%), site establishment, head office costs and profit (£353k) and Preliminary and General activities (£425k).
10-yearly works	131	High-level estimate costed at 5% of the cash cost for FSA construction.
River Teise: Stonebridge FSA		
Appraisal, design & management	283	High-level estimate: appraisal costed at 3% (only proposed in conjunction with Cottage Wood FSA) and design and management costed at 12% of the cash cost for FSA construction.

Item	Cash Cost (£k)	Calculation Methodology
Estates purchase and landowner compensation	200	Assumed value using engineering judgement.
FSA construction	1,886	Calculated using SPONS (AECOM, 2015) from 26,800m^3 of fill material required at a cost of £35/m^3 (assumes semi-local source), with additional costs for excavation and main outfall construction (£252k). Cost also includes allowances for unmeasured items (5%), site establishment, head office costs and profit (£276k) and Preliminary and General activities (£322k).
10-yearly works	100	High-level estimate costed at 5% of the cash cost for FSA construction.

Table F-3 Yalding Local Defence Scheme Cash Costs for Capital Works

Item	Cash Cost (£k)
Site investigation (including bore hole and trial pit)	36
Defence construction (walls and embankments)	1,586
Riverside pilling	510
Road raising and services diversion	210
Compensation costs	70
Environmental enhancements and landscaping	100
Road closure, diversion costs and signage	50
Design, supervision, CDM, cost management and EA costs	240
Site set up and demobilisation	60
Total cash cost (no Optimism Bias)	**2,862**

Note that these costs were provided by the Environment Agency. At this stage there has been no inclusion of costs of mitigation measures which may be required to compensate for the loss of floodplain storage and the impact of changing floodplain flow conveyance. The need for such measures will be further evaluated and costed if this option is taken forward.

F.2 Economic Flood Damages Methodology

F.2.1. Appraisal Areas

The River Medway FSA study area was divided into six appraisal areas consistent with the output zones used by JBA to produce the hydraulic model results (as described in Section 4.2 and Appendix D). These areas were as follows:

• Tonbridge & Hildenborough	JBA Model 2
• East Peckham area	JBA Model 3, Output Zone 1 & 2
• River Teise including Collier Street	JBA Model 3, Output Zone 6
• River Beult upstream of Yalding	JBA Model 3, Output Zone 5
• Yalding and Laddingford	JBA Model 3, Output Zone 3
• Maidstone	JBA Model 4

While the method applied to each appraisal area was the same, in some cases, different data was used. An example of this are the market values used for the capping of damages. These were calculated separately for each appraisal area using appropriate local data.

F.2.2. Property Damages

Property damages were assessed by using the MCM methodology and depth damage curves (as updated in 2015). The property dataset for the assessment was derived from the NRD (version 4, 2014), combined with Mastermap building outlines, and trimmed to the maximum modelled flood outline. Only properties located within the River Medway FSA IA study area were included in the economic appraisal.

F.2.3. Property Thresholds

Some property threshold surveys have been undertaken for the Environment Agency, and where available, individually-surveyed property thresholds were applied in the economic appraisal. Properties with significantly raised internal floor levels, for example where the ground floor is used for car parking only, were identified during site visits and an appropriate threshold applied. For all other buildings, residential properties were assumed to have an internal floor level that is 150mm above ground level, and non-residential properties were assumed to have an internal floor level that is 50mm above ground level.

F.2.4. Flood Depths

The flood depths for the assessment were taken from the model results provided by JBA. The model outputs were a series of flood depth grids for a range of fluvial flood events (20%, 5%, 2%, 1.3%, 1% and 0.4% AEP). Using GIS techniques the maximum modelled flood depth at each property location was extracted. It is assumed that no property flooding occurs in the 50% AEP flood event. Property flooding therefore first starts in events with an annual chance of less than 50%.

As described in Section 4.1.1, model results for all options were not available at the time the economic appraisal was undertaken. Property damages for the two River Teise FSAs combined with Improve Leigh FSA option (Improve 5) were instead calculated by subtraction, as follows:

Improve 5 damages = Improve 6 damages – Improve 2 damages + Improve 1 damages

Where: Improve 1 is Leigh FSA improve (no new FSAs), Improve 2 is River Beult FSA (with Leigh FSA maintained) and Improve 6 is all River Beult and River Teise FSAs with Leigh FSA improved.

A separate IA is being prepared for the Hildenborough flood alleviation scheme and this will include option modelling and economic appraisal. Model results were not however available at the time of this assessment. The proposed defence alignment was therefore used to identify the properties in Hildenborough that would benefit from the scheme and flood depths from the Leigh FSA Improve option model run set to zero (for all modelled flood events) for these properties. Flood depths in other locations were left unchanged. It is noted that this approach could slightly overestimate the benefits of this option because it does not take into account any downstream increase in flood depths arising from the loss of floodplain storage in Hildenborough. This can be taken into account if the option is taken forward for detailed appraisal.

A similar approach was taken for the Yalding local defence scheme option. Flood depths at properties which would benefit from the new defences were set to zero for modelled flood events up to and including the 1.3% (1 in 75) AEP event. For lower probability events exceeding the proposed SoP of the defence, the modelled flood depths were (conservatively) retained.

This approach was proportionate to the IA level of appraisal. If any of these options are taken forward to OBC stage, further modelling can be undertaken to refine the calculation of flood damages.

F.2.5. Capping of Damages

For the purpose of the economic assessment the Present Value (PV) damages of a property cannot exceed the current capital value.

Residential properties were capped at current market value, by property type. The market value prices are provided in Table F-4 and are based on 3-month moving average house prices, taken from data on property sales prices in the study area in September 2015 (Home.co.uk, 2015). These property prices were then uplifted by the Distributional Impact (DI) Factor, calculated from social class data for the relevant Local Authority Area (Nomis, 2015). Table F-5 and Table F-6 detail these calculations. The final set of residential capping values are provided in Table F-7.

Table F-4 Typical residential property prices within the study area

Appraisal Area	Price search area	Average property price for the search area			
		Detached	Semi-Detached	Terraced	Flat
Tonbridge & Hildenborough	Tonbridge	£532,417	£342,328	£293,850	£245,425
East Peckham area River Teise including Collier Street River Beult upstream of Yalding	TN12 postcode area	£460,178	£300,200	£290,850	£199,750
Yalding and Laddingford	ME18 postcode area	£518,800	£929,000	£245,000	£149,000
Maidstone	Maidstone	£394,806	£283,354	£223,282	£143,531

Table F-5 Calculation of the Distributional Impact Factor for Local Authority Areas

Social Class	Factor	Tonbridge & Malling BC			Tunbridge Wells BC			Maidstone BC		
		Count	%	Weighted Factor	Count	%	Weighted Factor	Count	%	Weighted Factor
AB	0.74	9,724	28%	0.21	11,316	33%	0.24	11,291	24%	0.18
C1	1.12	11,411	33%	0.37	10,896	31%	0.35	15,532	33%	0.37
C2	1.22	7,448	21%	0.26	6,447	19%	0.23	10,107	22%	0.26
DE	1.64	6,390	18%	0.30	6,081	18%	0.29	9,636	21%	0.34
Sum		**34,973**		**1.13**	**34,740**		**1.11**	**46,566**		**1.16**

Table F-6 Calculation of the Distributional Impact Factor for each appraisal area

Appraisal Area	Local Authority	Distributional Impact Factor
Tonbridge & Hildenborough	Tonbridge & Malling BC	1.13
East Peckham area	Tonbridge & Malling BC and Tunbridge Wells BC	1.12
River Teise including Collier Street	Maidstone BC and Tunbridge Wells BC	1.14
River Beult upstream of Yalding Yalding and Laddingford Maidstone	Maidstone BC	1.16

Table F-7 Distributional Impact-factored property prices used as the residential capping values

Appraisal Area	DI-factored property price			
	Detached	Semi-Detached	Terraced	Flat
Tonbridge & Hildenborough	£601,978	£387,053	£332,242	£277,490
East Peckham area	£514,602	£335,704	£325,248	£223,374
River Teise including Collier Street	£522,404	£340,793	£330,179	£226,760
River Beult upstream of Yalding	£532,504	£347,382	£336,563	£231,145
Yalding and Laddingford	£600,340	£337,894	£283,507	£172,418
Maidstone	£456,858	£327,889	£258,375	£166,090

All caravans were assumed to have a market value of £75k. Once uplifted by the DI factor, this gave a caravan capping value of between £84k and £89k.

In accordance with the MCM methodology, the market values of non-residential properties were calculated by multiplying the property-specific rateable value by 100 and then dividing by the gross annual rental yield. The latter was calculated from 2014 south-east values published by the letting agent association ARLA on their website (ARLA, 2015). Rateable values for large commercial developments at risk of flooding were obtained from the Valuation Office Agency website (Valuation Office Agency, 2015). For all other non-residential properties, Government rateable value statistics (Department for Communities and Local Government, 2012), published per bulk class code and per m^2 floor area were used, with 2008 data uplifted to a 2015 price date using the Consumer Price Index (CPI).

F.2.6. Evacuation costs

Costs associated with evacuation include renting of temporary or alternative accommodation, food, transport costs and loss of earnings. The cost of evacuation depends on many variables, one of the most important being evacuation duration. Evacuation of flooded properties can range from a short term measure (to limit loss of life, injury and stress) or a much longer term measure (to allow flood damage to be repaired). The MCM makes a direct link between the internal property flood depth and the evacuation rate and time. In this appraisal therefore, and in accordance with the MCM methodology, evacuation costs for individual properties have been estimated as a function of the flood depth and property type. Evacuation costs have only been included for residential properties experiencing above floor level flooding.

F.2.7. Vehicle damages

Vehicle damages were assessed by using the MCM methodology, which assumes that:

- The average value of a UK motor vehicle is £3,100; and
- The total number of vehicles likely to be damaged during a flood will equate to 28% of the total number of properties (residential and commercial) at risk. This percentage was calculated using historic data on the 2007 and 2012 UK floods.

Vehicle damages were therefore calculated by: number of vehicles likely to be damaged x £3,100.

This method does not require an assumption to be made on the presumed location of the vehicles when the flooding occurs.

F.2.8. Emergency Services

Flood incidents need to be managed when they occur. These emergency costs come from active services from the police, fire and ambulance services, local authority emergency response team, and the Environment Agency’s flood incident teams. The MCM guidance (Table 6.23) estimates that the emergency costs are 5.6% of the total property damages and this has been applied in this appraisal.

F.2.9. Risk to Life

Risk to life can be calculated using estimates of number of people, flood hazard rating, area vulnerability and people vulnerability. The time taken to apply this complex methodology is not proportionate to the scale of this study. Risk to life has therefore been estimated as a broad-brush 1% addition to the total calculated flood damages. This estimate can be refined if the project is taken forward to the OBC stage.

F.2.10. Human Intangibles

The benefits of the human intangible effects on health and stress have been incorporated into the appraisal, in accordance with Defra Supplementary Guidance (Defra, 2004). These were based on the change in SoP offered by each option to each individual property according to the modelling results. Human intangible benefits are listed separately in the option comparison tables and are measured directly as a benefit.

F.2.11. Calculation of Annual Average Damages (AAD)

For each modelled flood event the total of the property and vehicle damages, evacuation and emergency services costs and risk to life was summed. Event probability was then taken into account, and the AAD calculated as the area under the curve of the plotted flood event damages.

F.2.12. Climate Change

The impact of climate change has been incorporated into the economic appraisal in accordance with the Environment Agency guidance (Environment Agency, 2011) current at the time of the appraisal. This guidance provides an upper end, lower end and change factor estimate for the potential increase in peak river flow in each river basin district over the next 100 years compared to 1961 – 1990 baselines. In the Thames river basin district for the 2080s (covering the period from 2070 – 2099), these percentage increases are 70%, -5% and 25% respectively. These increase to 100%, 0% and 30% for the South East river basin district.

Although the River Medway falls within the Thames river basin district, it is on the edge of the South East river basin district and hence to take a more precautionary approach, the change factor estimate of a 30% increase in peak river flow has been taken forward for use in the appraisal.

The impact of climate change was not included in the hydraulic model simulations. The future change in flood risk because of climate change was instead incorporated at the economic appraisal stage by amending the probability of an event causing a certain amount of damage as set out in Table F-8.

Table F-8 Incorporating climate change by changing event probability

2015 event probability	Present day modelled peak undefended River Medway flow upstream of Tonbridge (m^3/s)	Assumed 2070 peak flow (m^3/s) (30% increase on present day)	Calculated 2070 event probability
1 in 5 (20%)	91	118	1 in 2 (50%)
1 in 20 (5%)	154	200	1 in 10 (10%)
1 in 50 (2%)	198	257	1 in 20 (5%)
1 in 75 (1.3%)	227	295	1 in 35 (2.9%)
1 in 100 (1%)	260	337	1 in 50 (2%)
1 in 250 (0.4%)	325	423	1 in 100 (1%)

Using the model results, the AAD for property, evacuation costs, emergency services, vehicle damages and risk to life were calculated for the present day. The same event damages were then applied to the increased event probabilities to calculate the AADs for 2070. Annual damages between 2015 and 2070 were linearly interpolated, assuming a steady increase in flood damage due to climate change. Annual damages beyond 2070 used the 2070 calculated results.

This approach to climate change is proportionate to the stage of this assessment. The inclusion of climate change can be refined if the project is taken forward for detailed appraisal.

It is noted here that the inclusion of climate change was based on the guidance available at the time of the assessment (November 2015). In February 2016 the Environment Agency published revised climate change guidance. This includes updated peak river flow allowances for each river basin district (Environment Agency, 2016), with the recommendation to design flood risk management schemes to the “Central” allowance (50^{th}

percentile) but to undertake sensitivity testing using the higher allowances. The new peak river flow allowances for the 2080s are given in Table F-9.

Table F-9 New climate change guidance (Environment Agency, 2016)

Allowance category	Thames river basin district 2080s peak river flow increase (compared with 1961 – 1990 baseline)
Upper end (90th percentile)	70%
Higher central (70th percentile)	35%
Central allowance (50th percentile)	25%

The 30% increase in peak river flow applied in the current appraisal lies between the Central allowance of 25% and the Higher central allowance of 35%. Given the stage of this assessment and the high-level approach to the incorporation of climate change, use of a different percentage is not expected to change the outcome of the appraisal. The appraisal has therefore not been updated to make use of the new guidance.

F.2.13. Discounting

The annual average damages were discounted over a period of 100 years to provide a result in Present Value (PV) terms. The same approach was taken for the capped property damages and the human intangible benefits.

F.2.14. Property Counts

Property counts are given in the main report in Section 6.3.1 and have been sub-divided into the two LA areas: Tonbridge & Malling BC and Maidstone BC. This method of sub-division was undertaken solely to help funding partners understand the benefits of each of the potential schemes in their respective areas and use this to inform any decisions made about partnership funding contributions. It is also noted here that the economic analysis was undertaken using the JBA model output areas. For Tonbridge & Malling the counts relate to properties in the Model 2 (Tonbridge and Hildenborough) area and the Model 3 Output Zone 1 & 2 areas. The Maidstone counts are for properties in the remaining Model 3 output zones and the Model 4 area. While there is a good match, the model output areas do not perfectly coincide with LA boundaries. There are also a very small number of properties which are actually in Sevenoaks BC (immediately d/s of Leigh), but have been included in Tonbridge & Malling BC, and also a few in Tunbridge Wells BC, included in either Tonbridge & Malling BC or Maidstone BC. Furthermore it is noted that property counts are only given for the Medway IA study area and do not necessarily record all of the properties at risk of flooding in any given LA area.

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