MEDWAY, BEULT AND TEISE ADDITIONAL FLOOD ALLEVIATION OPTIONS

Initial Assessment

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Incorporating

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1 Introduction

1.1 Background

Maidstone Borough Council (MBC), along with Kent County Council (KCC) and Tonbridge & Malling District Council (TMDC), have contributed to the joint-funded River Medway Flood Storage Areas Initial Assessment (the ‘Medway IA’) commissioned by the Environment Agency to consider improved flood alleviation for the Medway valley and Weald Basin.

The Medway IA considered a range of potential flood alleviation options including improving the existing Leigh Flood Storage Reservoir (FSR) on the River Medway upstream of Tonbridge, provision of flood storage areas on the River Beult and/or the River Teise, raised embankments / walls protecting properties around Yalding and improved downstream conveyance along the River Medway.

The Medway IA indicated the currently proposed flood alleviation solution provides significant improvement to flood protection within Tonbridge and Malling, but relatively little improvement to flood risk in the communities within MBC’s area. This is due to the very high costs and relatively low benefit/cost ratio available on the options considered in the Medway IA.

Maidstone Borough Council have requested that Arcadis review the Environment Agency’s conclusions regarding the Beult and Teise FSA options and investigate additional options to see if a more cost-effective solution might be available to help the communities at risk of flooding within MBC’s area. This has been assisted by the Joint Parishes Flood Group (JPFG) who have provided local information and suggested possible options to be considered. This report is the output of investigations into those additional options.

1.2 Locations, Geology and Topography

The focus of this study is to consider options that can provide improved flood protection to the area known as the Weald Basin (**Figure 1**). This area is a large, flat basin between high ground to the north (the North Downs) and south (the High Weald). It is underlain by clay, and fed by three rivers. The largest of these, the Medway, enters the basin from the west, and features the large, actively controlled Leigh Flood Storage Reservoir (FSR) approximately 15km upstream of Yalding. The Medway is maintained as a navigation and, within the study area, is controlled by weirs at Twyford Bridge, Teston and East Farleigh.

The second largest river in the Weald Basin is the Beult. This rises to the east and features a very shallow gradient as it runs along the floor of the basin. It joins the Medway just downstream of Yalding adjacent to Hampstead Marina.

The third river is the Teise. This rises in the hills to the south and has a steeper gradient and faster response time than the other two rivers. Near the top of the River Teise catchment is the Southern Water supply reservoir at Bewl. The River Teise separates into two near Horsmonden. Downstream of here the western channel (which continues to be the River Teise) flows north-west to join the River Medway immediately downstream of Twyford Bridge Weir, while the eastern channel (the Lesser Teise) flows north to join the Beult upstream of Yalding.

In the relatively flat land between the two channels (**Figure 2**) is the widespread community of Collier Street, and the low-lying southern part of Yalding. Laddingford is a community close to the right bank of the River Teise upstream of Twyford Bridge, and Hunton is on the right bank (north) of the River Beult.

Yalding, Collier Street, Laddingford and Hunton are the four communities most at risk from flooding in the Maidstone part of the Weald Basin.

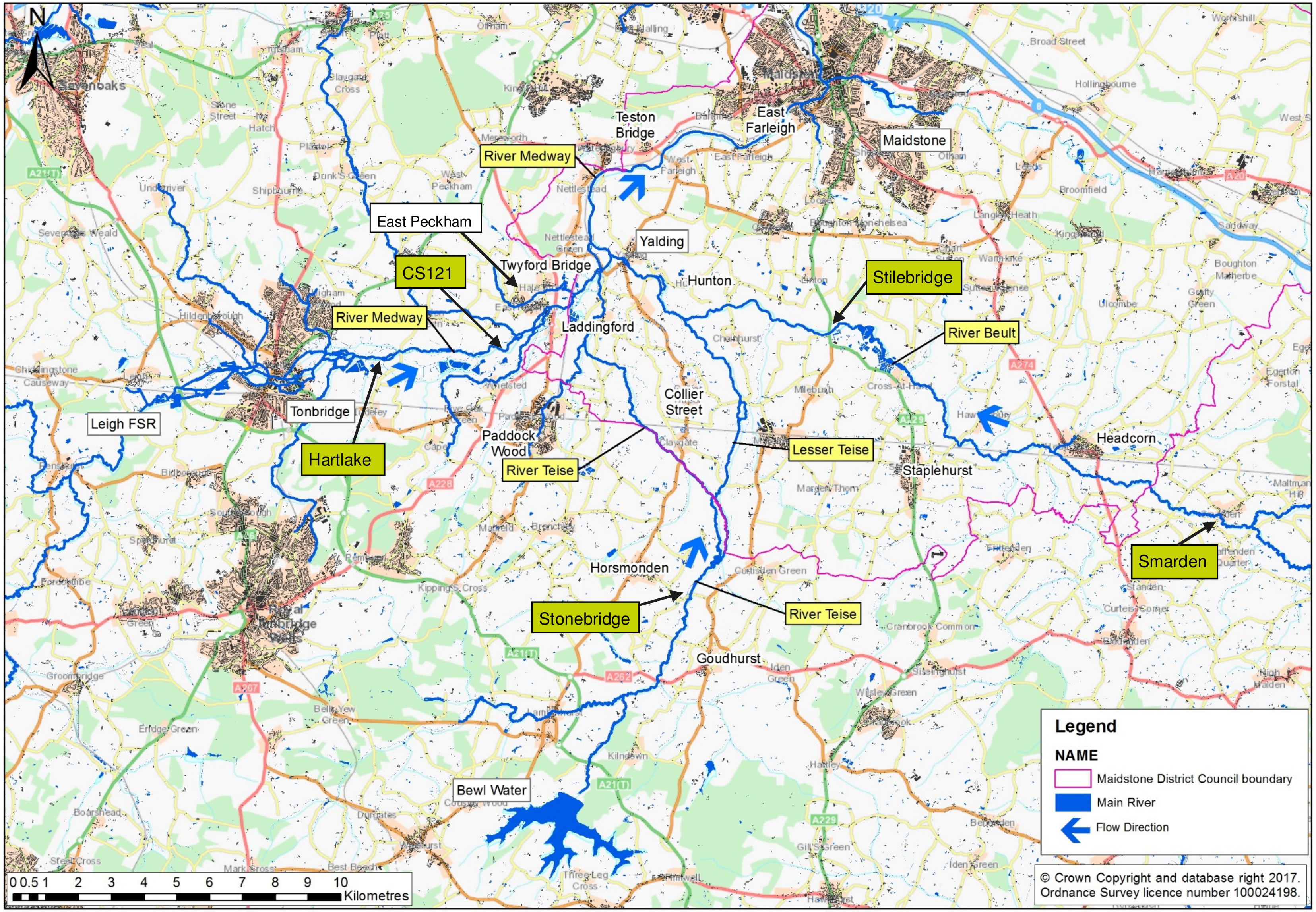

Figure 1 Location Plan

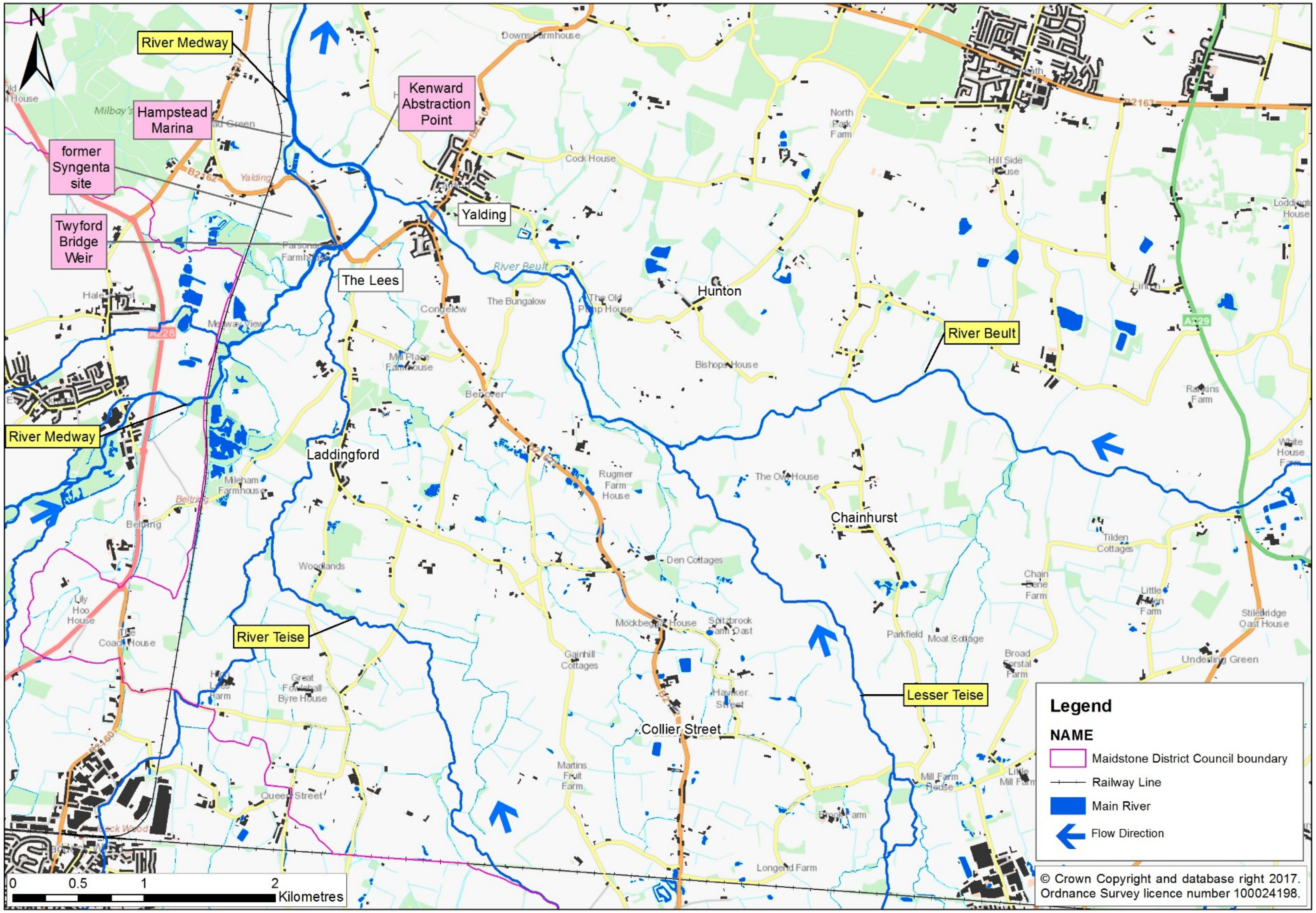

Figure 2 Key Study Area

1.3 Methodology

Data Sources

Information has been gathered from the Environment Agency, Southern Water, Maidstone Borough Council, JBA Consulting and the Joint Parishes Flood Group (JPFG).

A site visit has been undertaken walking along the River Medway from Hampstead Lock at Yalding to East Farleigh weir to assess if the weirs at Teston and East Farleigh could be fully drawn ahead of a flood to lower the river level and provide more downstream channel storage in a flood event.

Additional flood storage volumes have been assessed initially using LiDAR ground elevation data in a GIS mapping package to determine if there is any possibility to raise the crest level of the storage areas considered in the Medway IA or if this would place too many further properties at increased flood risk.

The Environment Agency have provided their hydraulic model of the Medway, Beult and Teise catchments and this has been used to assess some of the options. This uses a Continuous Simulation Hydrology (CS) as developed by JBA Consulting. CS has been used to simulate 5000 years of synthetic flood history based on collected data from river and rainfall gauges throughout the Medway, Beult and Teise catchments, and has ranked these to identify the events considered to be 1% (1 in 100 year) and 2% (1 in 50 year) Annual Exceedance Probability (AEP) events. These have then been calibrated against known flood extents. The hydrology is explained in *2013s7661 - Medway Hydrology Report (FINAL)* (JBA Consulting, April 2015), which has been referred to in the preparation of this study. It should be noted that the model is set up primarily to assess maximum flood depth and extent, and there are therefore potential risks with using it to assess other aspects such as flood timing. These risks and the constraints they impose are detailed below.

For every run of the hydraulic model, Arcadis have assumed that the Environment Agency's 'Leigh Improved' option (raising the crest height of the Leigh FSR embankment to a Normal Maximum Operating Water Level (NMOWL) of 28.85mAOD) is already in place as per the currently proposed scheme, so these options are considered alongside (and compared against) a baseline of the increased Leigh FSR storage which has been recommended in the Medway IA. In order to use this as a baseline we have made additional model runs from those provided by JBA Consulting, to provide raised Leigh FSR output data for all the design flood events we are considering, including Beult- and Teise-dominated floods (see Table 1 below).

Understanding flood terminology

Floods are historically measured and estimated using a system called 'Return Periods'. These are also expressed as a probability or a percentage likelihood of flooding in a given year. They are calculated based on historic data assuming flooding in future is as frequent as it has been historically, so a 1% Annual Exceedance Probability (AEP) or '1 in 100 year' flood is on average as large as the largest flood in the past 100 years at any given location. However, very few rivers have been gauged to modern standards for the whole of the past 100 years and so calculations have to be made based on what data is available, and extrapolated to estimate larger floods where the recorded period is not long enough.

As the system works on probabilities, it is possible that two very large floods (for example 1 in 100 year flood events) could occur in consecutive years.

Also, many factors are likely to have changed, such as extent of woodland, building of housing and industrial estates on former farmland and other land use changes, changes in river management practice and also climate change. Many of these changes will result in large floods becoming more frequent. Therefore what is considered only a 1 in 10 year flood in years to come might be as large as a flood we estimate to be a 1 in 100 year flood today, based on historic information.

Assessment and Reporting Methodology

The large and complex catchment draining through the Weald Basin means that particular large storms producing flooding could originate over one or more sub-catchments but not necessarily all of them for any one event. Therefore the storm that causes a 1% (1 in 100 year) AEP event at Stonebridge is not necessarily the same as the one that causes the same magnitude of event at Smarden. The CS hydrology generates independent storm rankings for each inflow. This means that, for every inflow point built into the model each modelled storm has a separate, distinct rainfall volume which is more like a real storm, showing variability in rainfall across the catchment. The model runs representing the key design events for the different model inflows within the Weald Basin area are given in **Table 1**. Arcadis have based the design events for our option modelling on three specified nodes (model location points):

- options which primarily affect the Medway sub-catchment will use design events for node CS121 which is approximately 2km upstream of Twyford Bridge. In the text below this will be described as "a 1 in x year AEP event as modelled for East Peckham", This means all inflows will use the 28Nov26221500 modelled value;
- options which primarily affect the Beult sub-catchment will use design events for Smarden which is at the upstream end of the model along the Beult sub-catchment. In the text below this will be described as "a 1 in x year AEP event as modelled for Smarden", This means all inflows will use the 01Dec44462100 modelled value; and
- options which primarily affect the Teise sub-catchment will use design events for Stonebridge which is at the upstream end of the model along the Teise sub-catchment. In the text below this will be described as "a 1 in x year AEP event as modelled for Stonebridge", This means all inflows will use the 28Nov38710900 modelled value for a 2% (1 in 50 year) event or the 18Feb61962000 modelled value for a 1% (1 in 100 year) event.

For options affecting the river downstream of Yalding the Medway sub-catchment is assumed to take preference as average flow volumes are greater, although it is possible to have a flood which affects the Beult or Teise to a much greater degree than the Medway. This variability is a key constraint in identifying effective flood alleviation options, as any particular option might theoretically provide a relatively robust solution for flooding from one direction, and no protection at all from flooding by a different source. We will assess the options in this study against the relevant 2% (1 in 50 year) flood event in every instance, and additionally will assess against the 1% (1 in 100) year flood event for the Teise sub-catchment for options where there is a reasonable prospect of an improved standard of protection indicated by the Medway IA.

Table 1 Continuous simulation event date used to provide design event inflows for the given output zone. Highlighted events are the ones used in this study.

		Return Period and Corresponding Continuous Simulation Event			
Routing model node informing design event	**Output zone**	**1 in 20**	**1 in 50**	**1 in 75**	**1 in 100**
CS121	**2**	26Dec42251600	28Nov26221500	18Nov40812200	18Feb61962000
Smarden	**4**	31Jan65802200	01Dec44462100	03Dec32970800	09Jan28672100
Stilebridge	**5**	14Jan34412200	29Dec37922000	20Nov56061800	25Dec24260900
Stonebridge	**6**	16Jan46292100	28Nov38710900	29Dec68331400	18Feb61962000

We have not attempted to re-work the hydrology. The volumes of water being generated in the model look reasonable by comparison with the magnitude of floods that have been observed in recent flood events. The CS method demonstrates a relatively realistic random pattern of storm focus, rather than more conventional hydrology methods which would assume a simple scaling factor for each inflow. Consequently we have reasonable confidence in the performance of the hydrology. We are also confident that the hydraulic model is satisfactory for determining worst case peak flood levels, which is the usual criteria for developing a hydraulic model to assess flood risk.

Understanding the Relationship between the Rivers Medway, Beult and Teise

One of the options we were asked to consider involved assessing how controlling the timing flooding on one river could reduce the overall flood level further downstream. Unfortunately the model is currently not best set up to assess the timing of flooding (see Risks and Constraints section below). However, we have looked at how the flood flows on each of the tributaries interact at the points of convergence at the downstream reaches.

Table 2 shows the relationship between design events at the selected nodes. For example, a 1 in 50 year flood event at Stonebridge (28Nov38710900) is equivalent to a much smaller, 1 in 8 year event at Smarden. This would represent a storm largely centred south of the Weald basin in the High Weald around Bewl, which is also quite heavy in the headwaters of the Medway and Beult but causes relatively small rainfall in the Low Weald around Headcorn. A 1 in 50 year flood event at Smarden (01Dec44462100) is actually an even larger event at Stonebridge, but a smaller one on the Medway – this would represent a storm focussed to the south and east of the Weald Basin that affects the westwern, Medway sub-catchment to a lesser degree.The 18Feb61962000 event is a 1 in 100 year event at both CS121 and Stonebridge, but a much smaller event on the Beult – this would represent a storm centred over the south and west of the catchment with relatively little rainfall over the Beult. However, it is also apparent that flows on the Medway can be significantly larger than those on the other rivers, even if the design event is smaller. For example, the 28Nov38710900 simulated event, which is a 2% (1 in 50 year) AEP event on the Teise, is only a 1 in 18 year event on the Medway, but the flow at CS121 is greater than at Stonebridge.

We have also included in **Table 2** flows at Stilebridge which is on the Beult further down from Smarden but upstream of the Lesser Teise confluence (see **Figure 1**), to demonstrate that the much higher flows on the Beult would be as a result of the tributaries and surface water runoff as it approaches Yalding.

Table 2 Continuous simulation approximate equivalent design events compared across the routing model nodes in Table 1, and flow rates for comparison.

	Routing Model Node and Corresponding Return Period (Flow)			
Continuous Simulation Event	**CS121 (Medway)**	**Smarden (Beult)**	**Stonebridge (Teise)**	**Stilebridge (Beult)**
28Nov38710900	1 in 18 (117.88 m^3/s)	1 in 8 (37.50 m^3/s)	1 in 50 (110.57 m^3/s)	1 in 18 (78.14 m^3/s)
01Dec44462100	1 in 11 (107.23 m^3/s)	1 in 50 (62.71 m^3/s)	1 in 60 (116.45 m^3/s)	1 in 19 (79.69 m^3/s)
28Nov26221500	1 in 50 (157.30 m^3/s)	Less than 1 in 5 (53.22 m^3/s)	1 in 7 (27.74 m^3/s)	Less than 1 in 10 (62.55 m^3/s)
18Feb61962000	1 in 100 (197.34 m^3/s)	1 in 12 (40.64 m^3/s)	1 in 100 (140.03 m^3/s)	1 in 24 (86.58 m^3/s)
18Nov40812200	1 in 75 (183.65 m^3/s)	1 in 40 (57.30 m^3/s)	Less than 1 in 5 (47.00 m^3/s)	1 in 22 (83.29 m^3/s)
03Dec32970800	1 in 7 (94.48 m^3/s)	1 in 75 (70.02 m^3/s)	1 in 17 (76.37 m^3/s)	1 in 62 (114.11 m^3/s)
29Dec68331400	1 in 40 (148.05 m^3/s)	1 in 18 (46.85 m^3/s)	1 in 75 (126.44 m^3/s)	1 in 75 (120.02 m^3/s)

It is also helpful to consider the peak flows, which are shown alongside the design event return periods in **Table 2**. Taking the example of the 28Nov38710900 event, although the flood event at Stonebridge (a 2% (1 in 50 year) AEP event) is much greater than the 1 in 18 year event on the Medway at node CS121, the flow on the Medway is greater. Also, note that the peak flow at Stonebridge is greater than at Stilebridge on the Beult, however, if we then look at the flow hydrographs (the plot of flow rate against time for a given location) for this event (**Figure 3a** to **3x**) we can see that, although the peak on the Teise is higher it is for a relatively short duration, while the peak on the Beult extends over a much greater period (thereby conveying greater volumes of water). The hydrograph shape is also a good indicator of which river is dominant at a confluence. **Figures 3a** to **3x** show the flow hydrographs at nodes a significant distance upstream of key confluences (the Medway/Teise; the Medway/Beult and the Beult/Lesser Teise), together with flow profiles immediately upstream and downstream of each confluence. By comparing the peak flow values and the hydrograph shape we can infer relationships between the rivers at these confluences, such as which river is dominant, and is there evidence of water from one river backing up another. We could carry out this exercise for every simulated event, but we have chosen the 28Nov38710900 event for the reason that it is a Teise-dominated event, and is considered a much smaller flood on both the larger rivers. If flows in the Medway and the Beult are much greater at the confluences than flows in the Teise and Lesser Teise for an event when the Teise is experiencing a larger magnitude of flood than the other two rivers, this indicates that the Teise presents a comparatively smaller contribution to flooding in the Weald Basin than the Medway and the Beult.

Figures 3a and **3b** show the flow hydrograph at points approximately 3km upstream from the Medway / Teise confluence, and **Figure 3c** shows the flow hydrographs just upstream and downstream of the confluence. From these, we can see that the flow reduces in both rivers on the approach to the confluence, although the effect on the Medway is small. The significant reduction in flow in the Teise could be due to a combination of backflow from the Medway and the flow dispersing as water spreads out across The Lees. Although the hydrograph does change shape across the confluence from the upstream to downstream Medway profiles it is clear that the Medway is far more dominant than the Teise at this location, even for a 2% (1 in 50 year) AEP flood event as modelled for the Teise.

Figure 3d shows the modelled flow hydrograph on the River Beult approximately 2km upstream from the confluence with the River Medway, at Mill Lane. **Figure 3e** shows the flow hydrographs upstream and downstream of the Medway/Beult confluence. From these, we can see the flow hydrograph on the Beult has changed very little on the approach to the confluence – the shape is very similar between nodes B22In1 in **Figure 3d** and B1U in **Figure 3e**, and the peak flow rate has dropped very slightly, probably due to a combination of backflow and cross-floodplain flow at Mill Lane. The flow from the Beult appears to have a greater impact on the downstream flow hydrograph than the flow from the Teise did in **Figure 3c**, including influencing both the peak flow rate and timing of peak flow.

Figure 3f and **3g** show modelled flow hydrographs approximately 3km upstream from the River Beult / Lesser Teise confluence. It should be noted that, in a major flood event, surface water flows from the River Beult can flow through Tilden and join the course of the Lesser Teise upstream of the confluence, so at the confluence a proportion of the water flowing from the Lesser Teise actually came from the Beult catchment and reached the Lesser Teise as surface water flow, consequently slightly reducing the flow in the Beult through the valley between Chainhurst and Hunton (see **Figure 2**). **Figure 3h** shows the modelled flow hydrographs around the confluence. The hydrograph shape is largely preserved along the course of the Beult, although there is a significant increase in flow across the confluence.

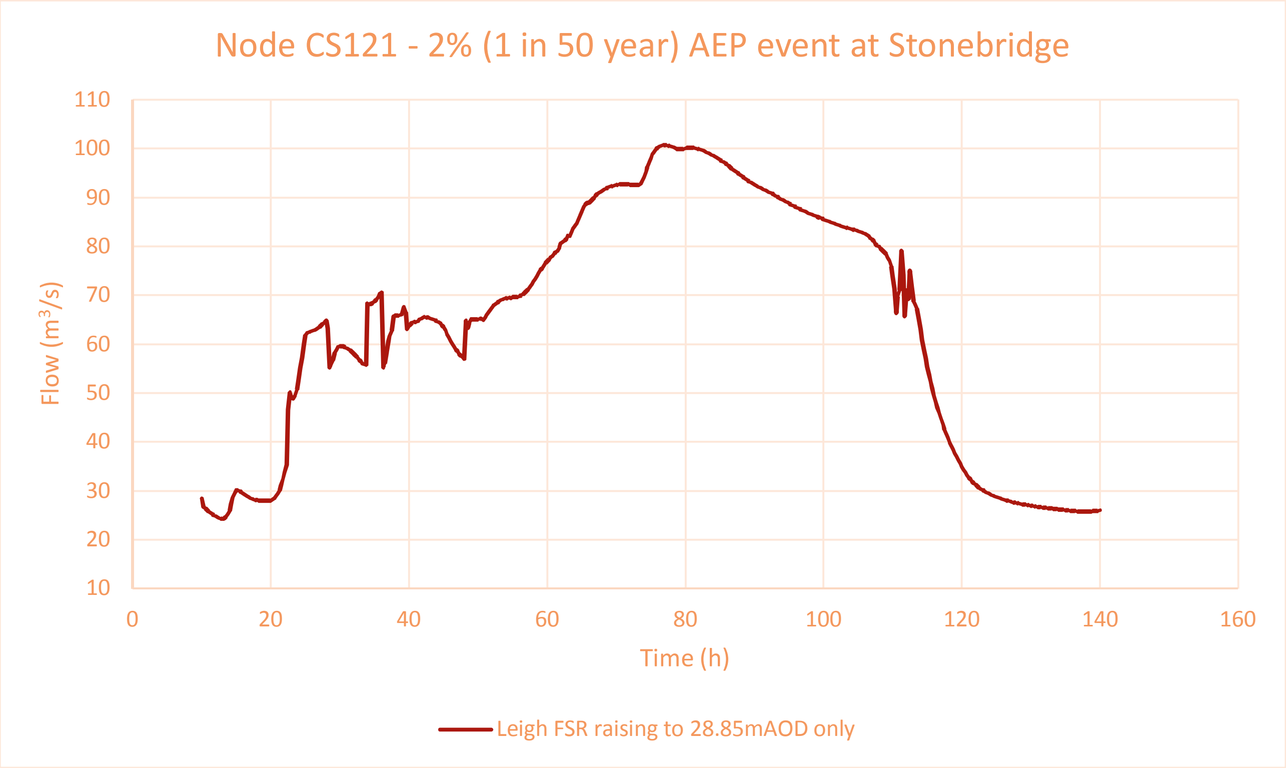

Figure 3a Modelled Flow Hydrograph at node CS121 on the River Medway near East Peckham, 2% (1 in 50 year) AEP flood event as modelled for Stonebridge

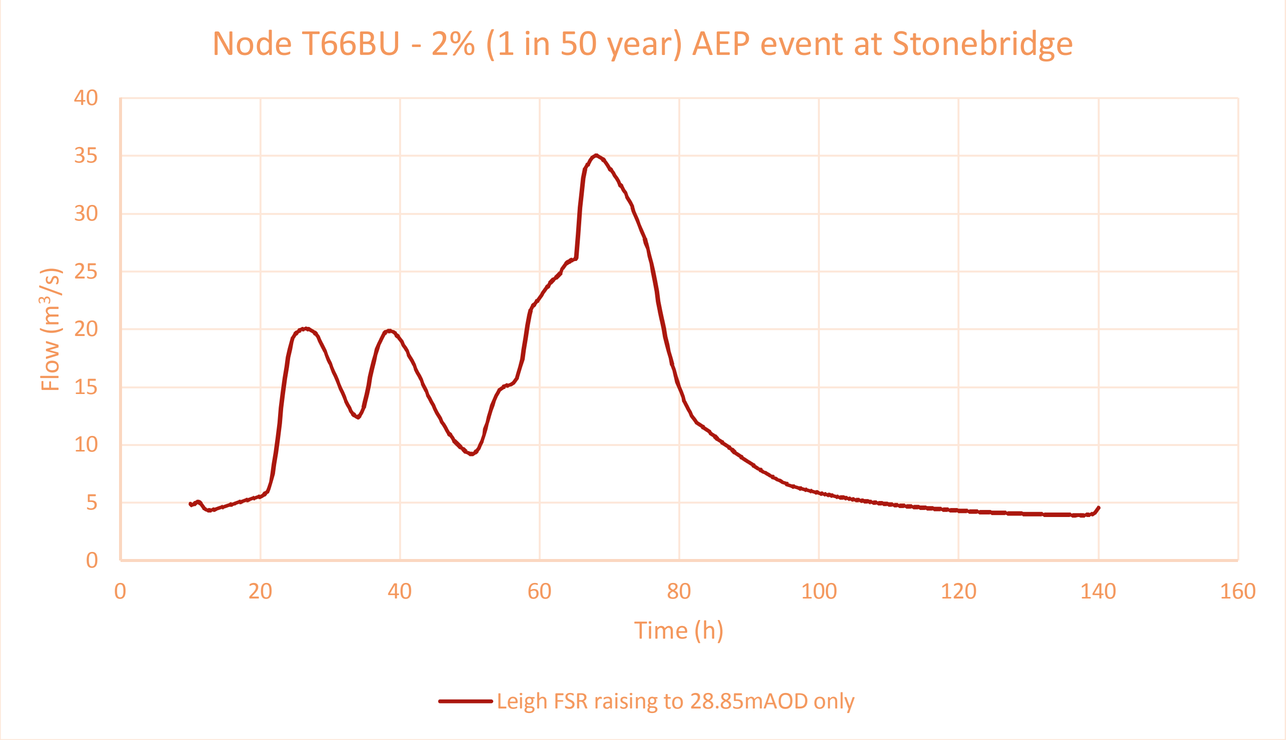

Figure 3b Modelled Flow Hydrograph at node T66BU on the River Teise upstream of the confluence with the River Medway at Twyford Bridge, 2% (1 in 50 year) AEP flood event as modelled for Stonebridge.

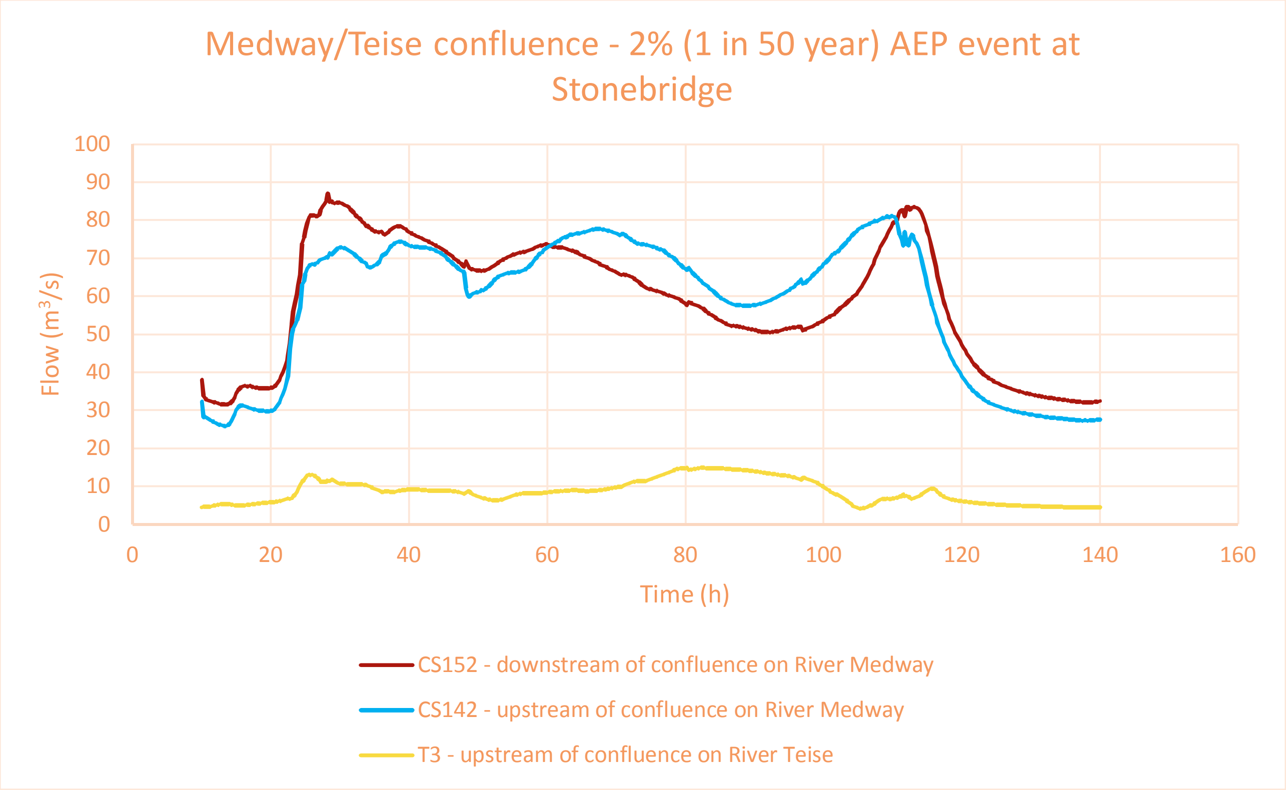

Figure 3c Modelled Flow Hydrographs at nodes CS142 on the River Medway and T3 on the River Teise upstream of the confluence with the River Medway at Twyford Bridge, and at node CS152 downstream of the confluence at The Lees. 2% (1 in 50 year) AEP flood event as modelled for Stonebridge.

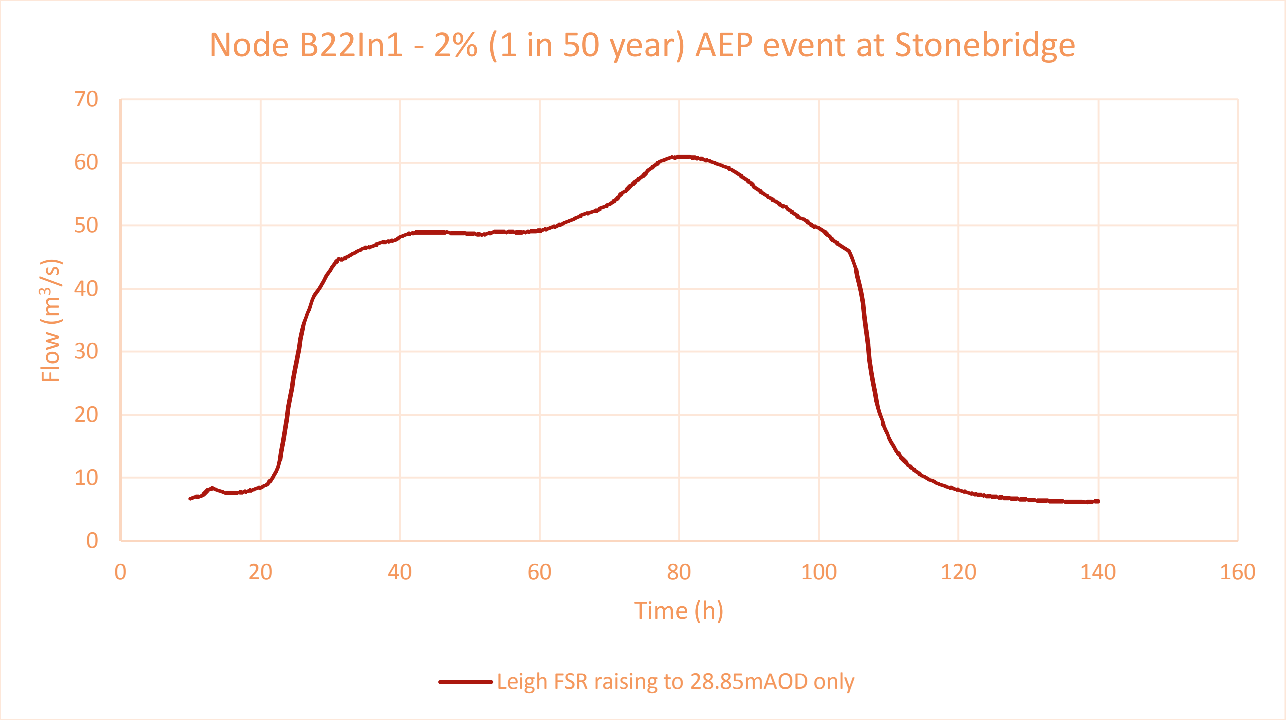

Figure 3d Modelled Flow Hydrograph at node B22In1 on the River Beult at Mill Lane, 2% (1 in 50 year) AEP flood event as modelled for Stonebridge.

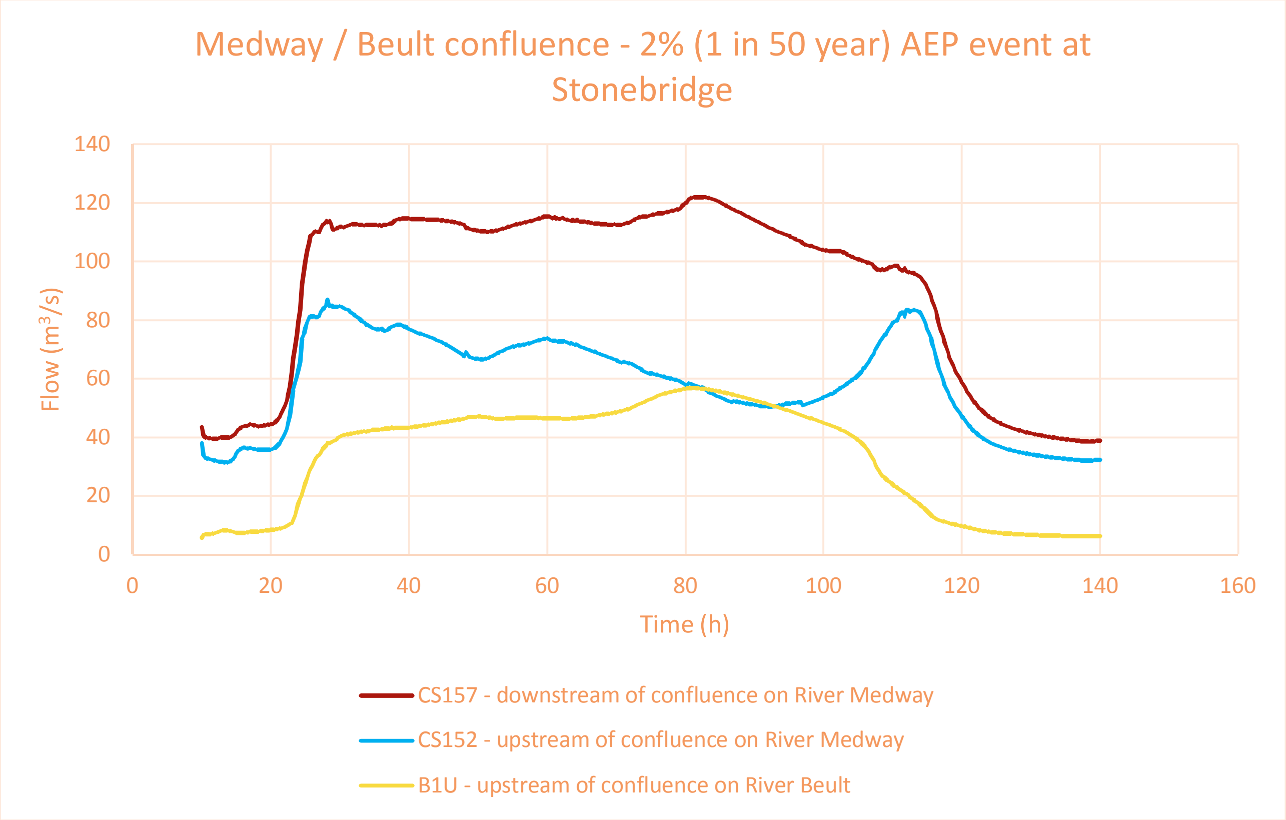

Figure 3e Modelled Flow Hydrographs at nodes CS152 on the River Medway and B1U on the River Teise upstream of the confluence with the River Medway, and at node CS157 downstream of the confluence. 2% (1 in 50 year) AEP flood event as modelled for Stonebridge.

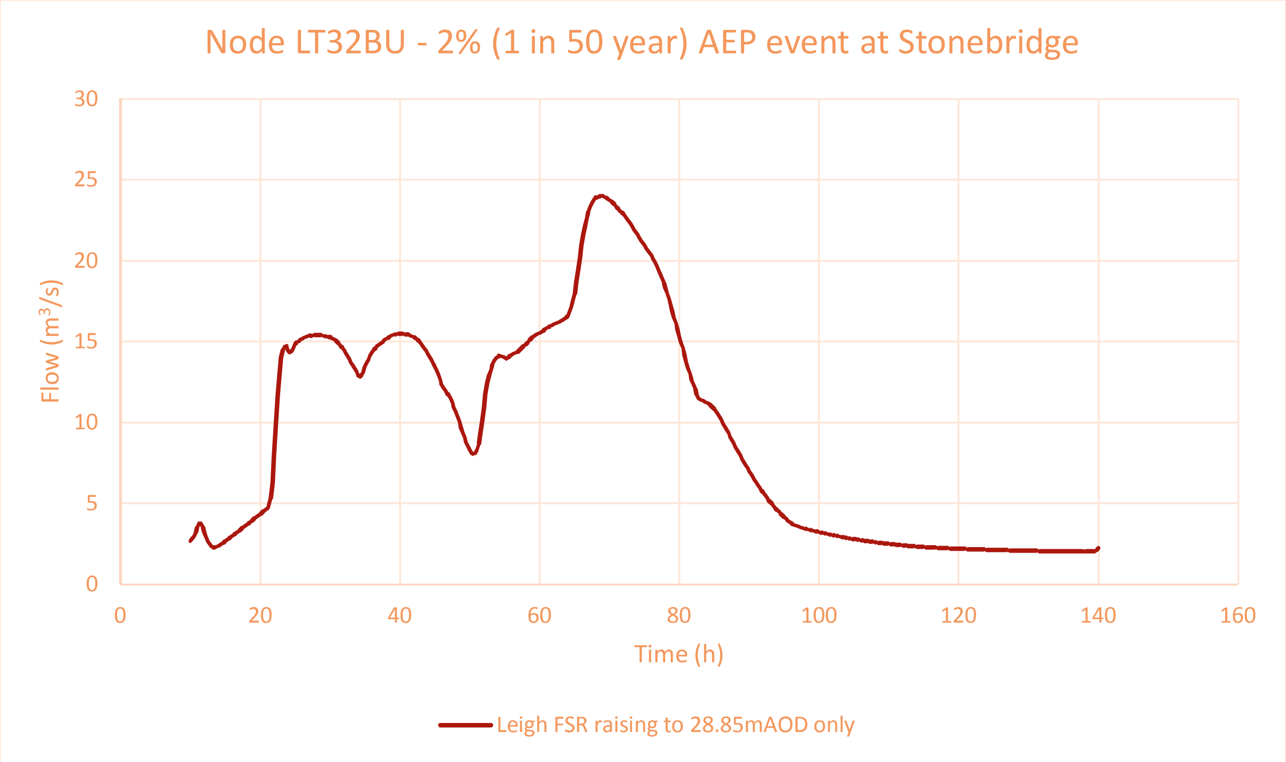

Figure 3f Modelled Flow Hydrograph at node LT32BU at Spits Bridge (Green Lane) on the Lesser Teise, 2% (1 in 50 year) AEP flood event as modelled for Stonebridge.

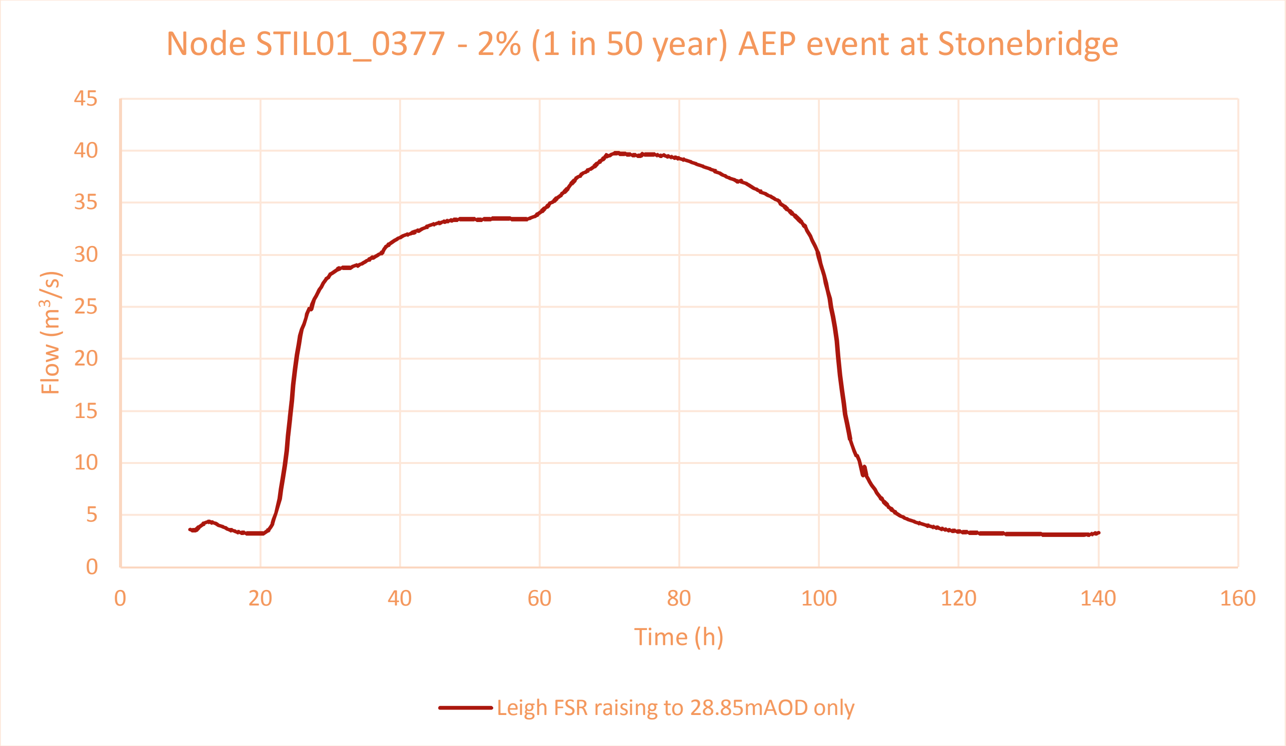

Figure 3g Modelled Flow Hydrograph at node STIL01_0377 at Stilebridge on the River Beult, 2% (1 in 50 year) AEP flood event as modelled for Stonebridge.

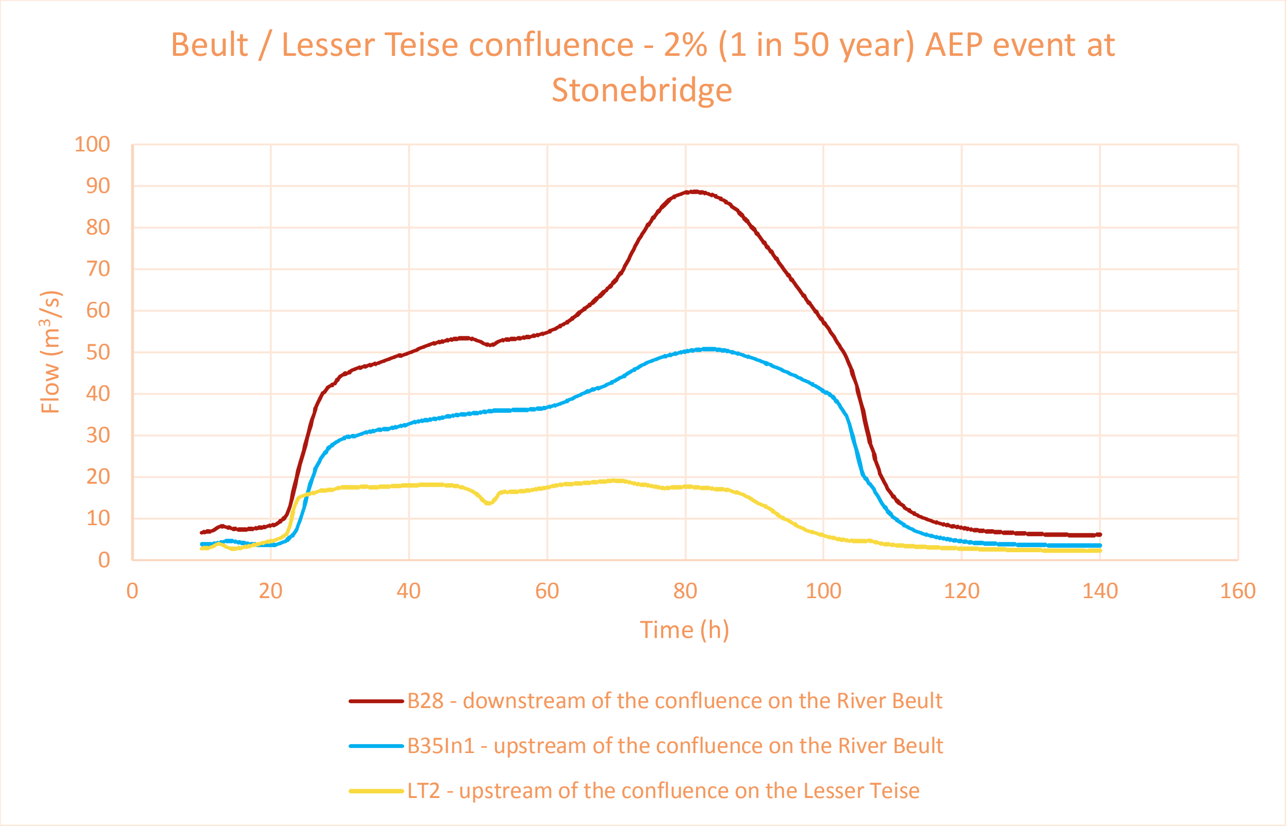

Figure 3h Modelled Flow Hydrographs at nodes B35In1 on the River Beult and LT2 on the Lesser Teise upstream of the confluence with the River Beult, and at node B28 downstream of the confluence. 2% (1 in 50 year) AEP flood event as modelled for Stonebridge.

It is important to note that these relationships are a product of the CS hydrology and are not necessarily indicative of how a particular large storm event would affect one part of the catchment to a greater or lesser degree than another. For example, it is certainly possible in practice to have a storm of 1 in 50 year event magnitude at Stonebridge that is equal or larger on the Beult.

Of course, the above sequence indicated in **Figures 3a** to **3h** relates to a single simulated event, and different events may produce different signals, but the key indication is that, even for a very large flood focussed on the River Teise catchment, the Beult is likely to be the dominant source of flooding over flows in the Lesser Teise, and the Medway is likely to be the dominant source of flooding over flows in the River Teise and in the River Beult.

Risks and Constraints

Properties at risk of flooding have been identified simply by their location in relation to flood extent, and are assumed to be at the same level as the surrounding ground. This means if the ground around a building is low enough to flood in a given flood event, then the building is assumed to be at risk of flooding. There will be instances where buildings are sufficiently raised above the surrounding ground where this is not the case, therefore the number of properties at risk of internal flooding is likely to be overestimated in this study. It would be necessary to carry out a threshold survey of every property identified as being potentially at risk of flooding to confirm whether the risk applied to that property. There is detailed threshold survey data for many properties in Yalding, but less so elsewhere and so for consistency the approach of basing flood risk on surrounding ground levels is applied across the catchment. Where threshold data has been collected we will comment on this within the relevant options section below. However, note that some properties within the Weald Basin area are traditional timber post construction with earth floors. In those cases, where there is no damp course, it is the lowest internal floor level and not the threshold level which should be used. ***Therefore the model could overestimate the number of properties at risk of internal flooding***.

It is understood by Arcadis from communication with the JBA hydrology lead that the CS has been set up to assume instantaneous onset of a storm across the catchment (i.e. in the model the rainfall commences at the same time over Edenbridge in the west and Smarden in the east), with an identical shape of hyetograph (plot of rainfall intensity against time). This is unlikely to be the case, as in most observed storms the rainfall impacts the western part of the catchment first. This is partly compensated for by adjusting the relative amount of rainfall in different locations for different storm events (so the hyetograph is the same shape but a different size for each inflow), but there is still the probability of significantly different onset times affecting the timing of peaks arriving in Yalding. Actual peak flood flows at and downstream of Yalding could potentially be greater than as modelled once relative flow travel times on the River Medway and the River Beult, coinciding with the delayed rainfall impacting on the eastern catchment from an easterly-moving storm are taken into account. ***Therefore the model is not optimally set up to assess the effects of peak flow timing***.

It should be noted that the significant observed flood events show a series of peaks due to consecutive events, rather than one major storm. **Figures 4a, 5a, 6a and 7a** show observed stage hydrographs (plot of river water level against time) at Smarden and Stonebridge (at the upstream ends of the hydraulic model on the Beult and the Teise respectively), and also at Hartlake on the Medway upstream of the confluence with the Beult and Teise, and at Teston downstream of both confluences, see **Figure 1** for locations) for the Winter 2013-14 floods. **Figures 4b and 4c** show the modelled baseline stage hydrographs for example 2% (1 in 50 year) and 1% (1 in 100 year) AEP events at Smarden, and similarly **Figures 5b and 5c** for Stonebridge, **Figure 6b** for node CS121 and **Figure 7b** for Teston, for comparison. Note **Figures 4a, 5a, 6a and 7a** cover a time period of 49 days (= 1176 hours), while the model runs in **Figures 4b, 4c, 5b, 5c, 6b and 7b** cover only 140 hours. It is noticeable that the 2013-14 floods involved a series of peaks varying in average depth. The modelled events for the Beult and Teise also show the effect of multiple peaks of varying intensity, and the 1% (1 in 100 year) AEP event for Smarden indicates a further peak continuing beyond the 140-hour model run time. The modelling results on the Medway indicate that the multiple peaks tend to merge into a single large peak downstream, although this is not a good representation of what happened in the observed 2013-14 flood events. Comparison of the observed figures show a steady escalation in flood peaks on the Beult, culminating in the Christmas 2013 flood, followed by a second series of events over 2nd – 7th January and a third, smaller series around 14th – 18th January. On the Teise the Christmas flood and the first peak of the 2nd January flood were significantly higher than the other events and the 14th-18th January event is not observed, while on the Medway the same three extended events are observed but with flattened peaks showing evidence of attenuation from the Leigh FSR. In this particular event it is apparent that a series of previous storms over both the Medway and Beult had left the catchment saturated, while an intense storm to the south then caused extreme flooding from the Teise in addition to providing further runoff across the whole catchment. This signal is then carried down to the peak at Teston.

Note a direct comparison between CS121 and Hartlake is not possible as these are not in the same location, but we would expect a similar shape of hydrograph for a given event. Other significant historic recorded floods follow a similar pattern to the Winter 2013-14 event, with a sequence of floods of often increasing intensity, onsetting before the preceding flood has completely passed.

Note that the winter 2013-14 peak flood level at Smarden and Stonebridge is substantially below the modelled 2% (1 in 50 year) AEP flood level at both locations, but that at Teston downstream of the Weald Basin is approximately 0.5m higher.

Therefore the typical modelled flood hydrograph reflects the complexity and sequence nature of the observed situation, but could either overestimate or underestimate the effect of coincident peaks due to timing factors.

Figure 8 is included to demonstrate the constriction in the river system downstream of Yalding at Wateringbury, where the inflows from all three rivers are channelled into a narrow section of the Medway Gorge.

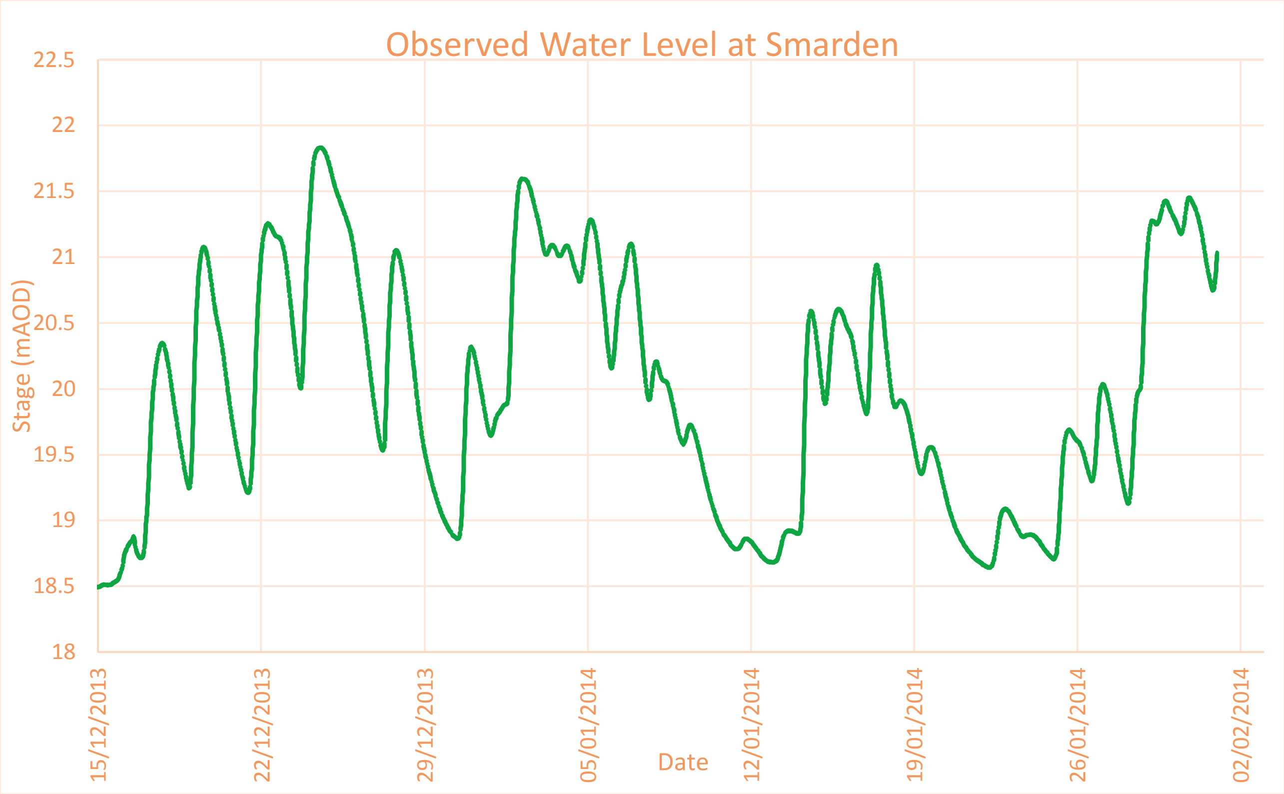

Figure 4a Recorded River Water Levels at Smarden, 15/12/2013 – 02/02/2014

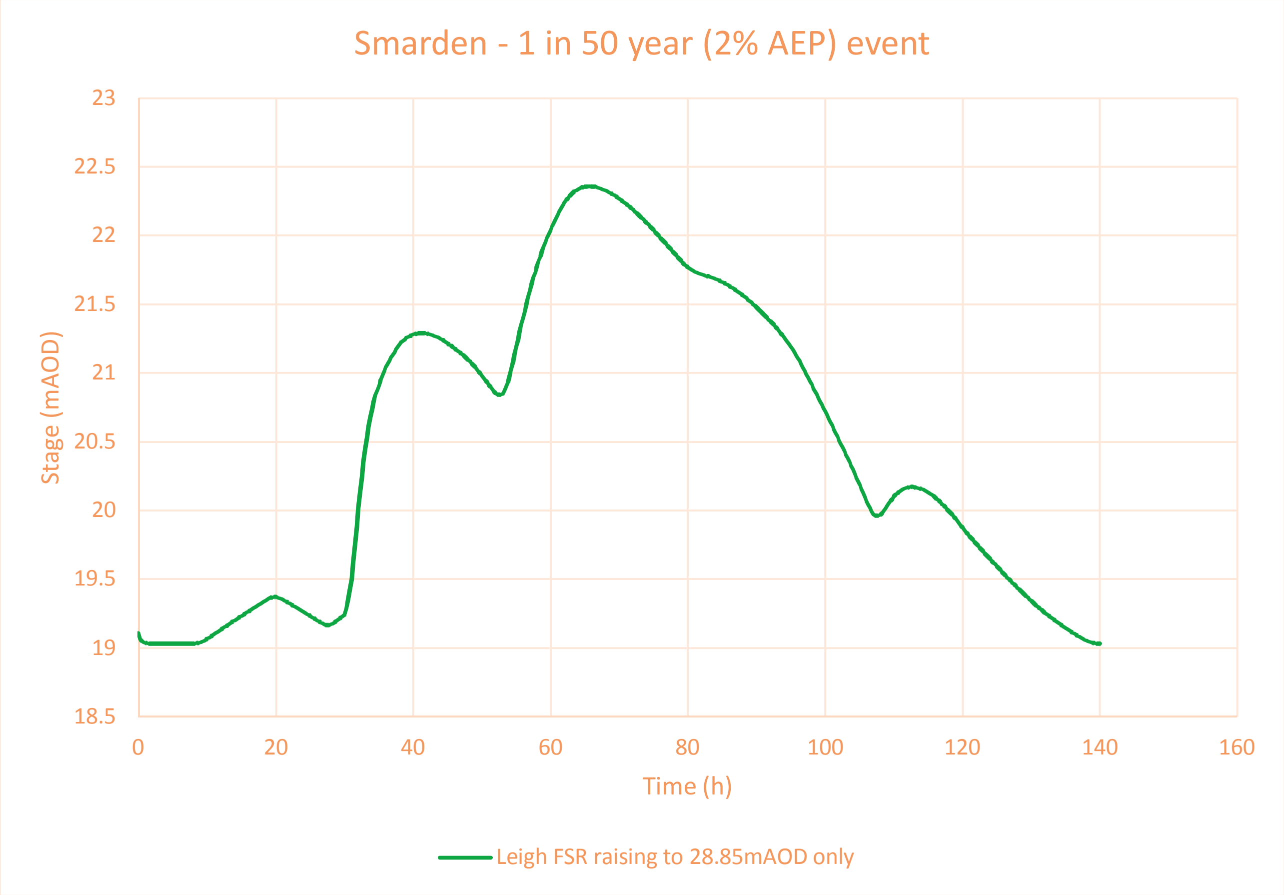

Figure 4b Modelled River Water Levels at Smarden, 2% (1 in 50 year) AEP event as modelled for Smarden

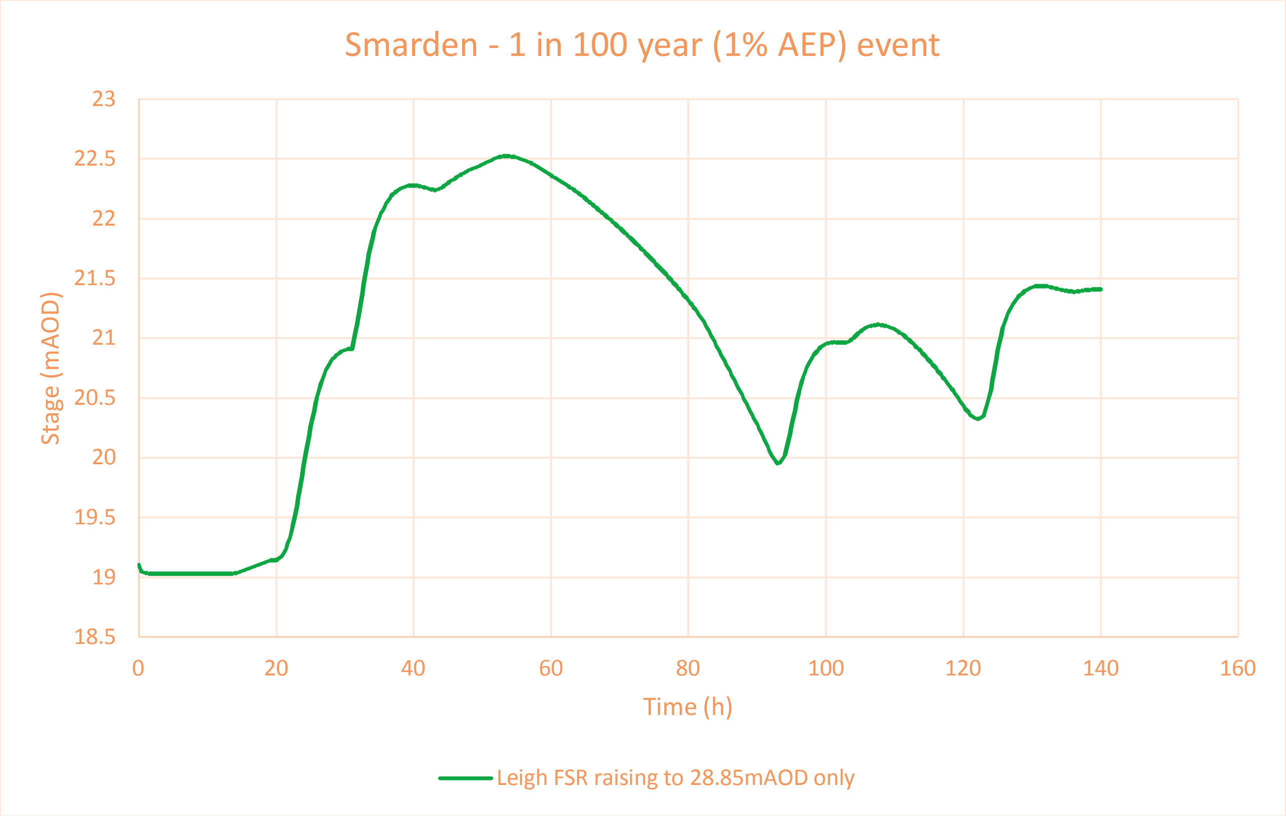

Figure 4c Modelled River Water Levels at Smarden, 1% (1 in 100 year) AEP event as modelled for Smarden

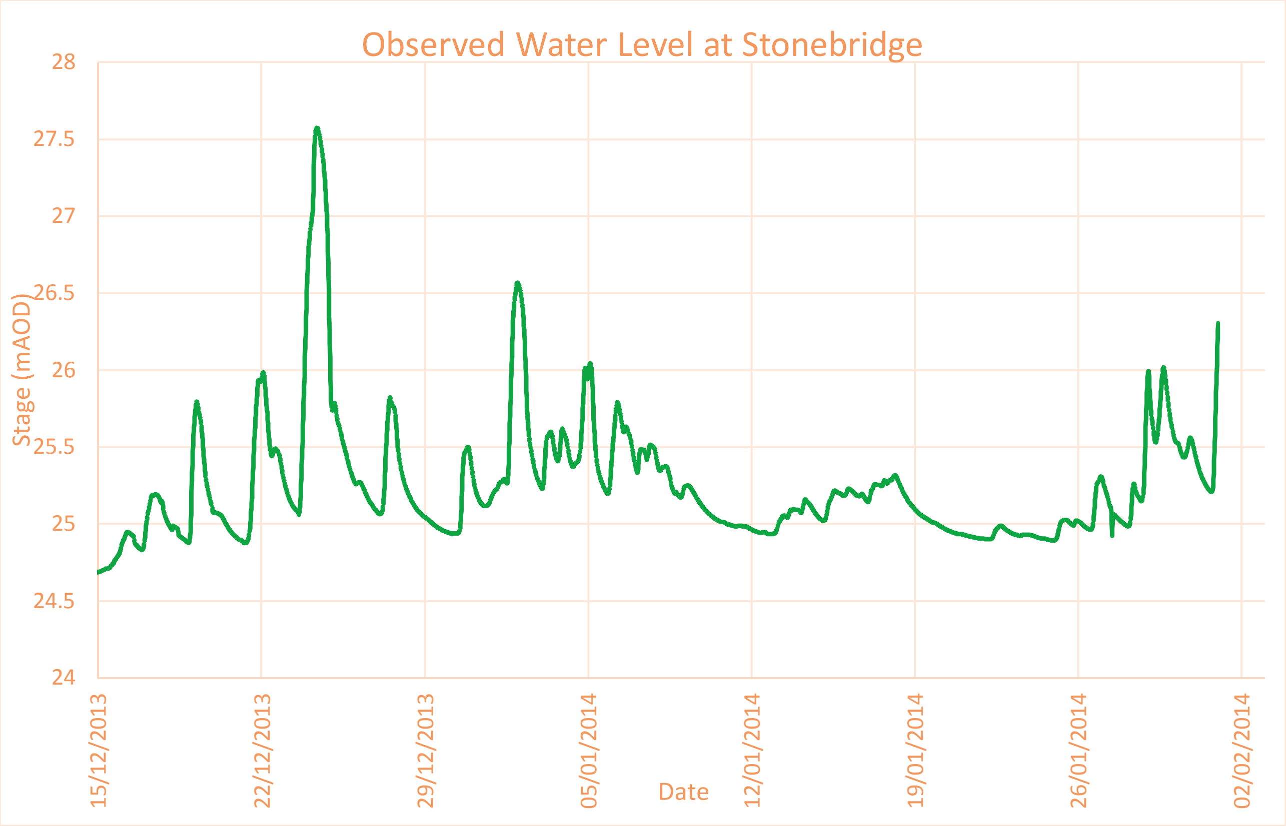

Figure 5a Recorded River Water Levels at Stonebridge, 15/12/2013 – 02/02/2014

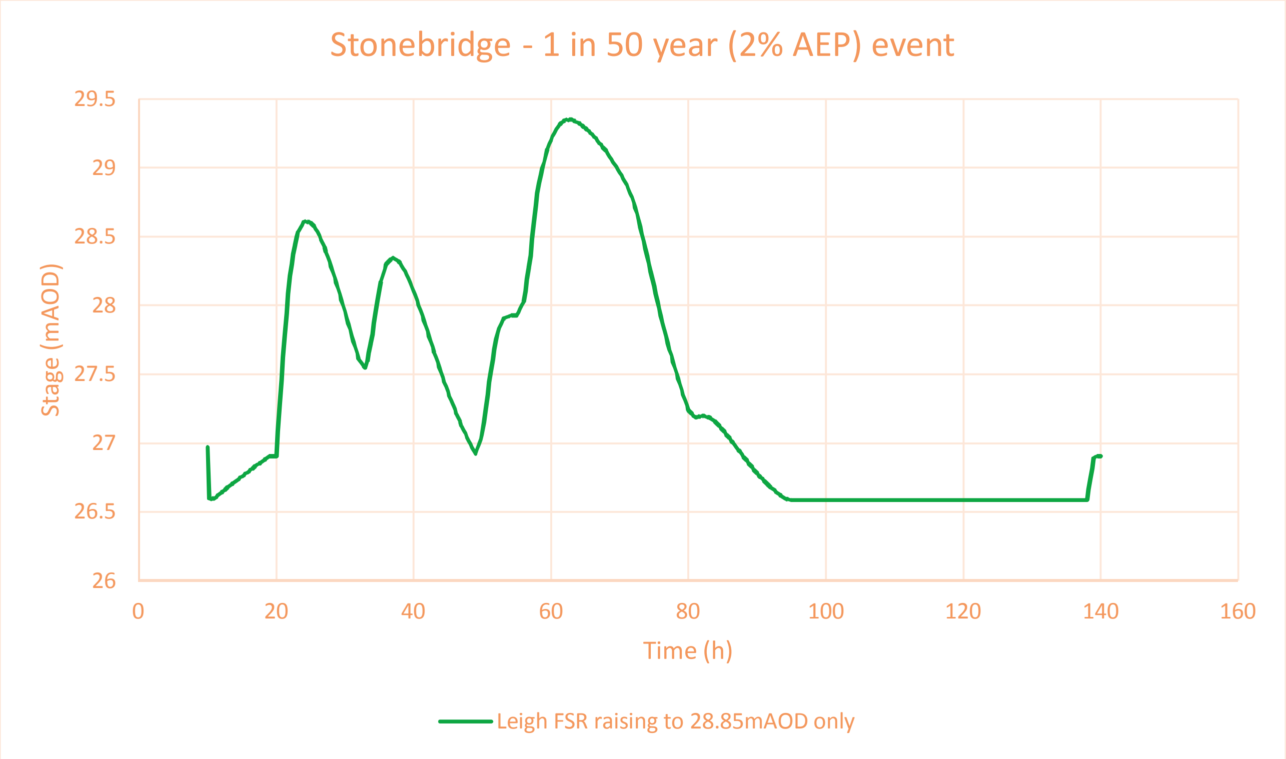

Figure 5b Modelled River Water Levels at Stonebridge, 2% (1 in 50 year) AEP event as modelled for Stonebridge.

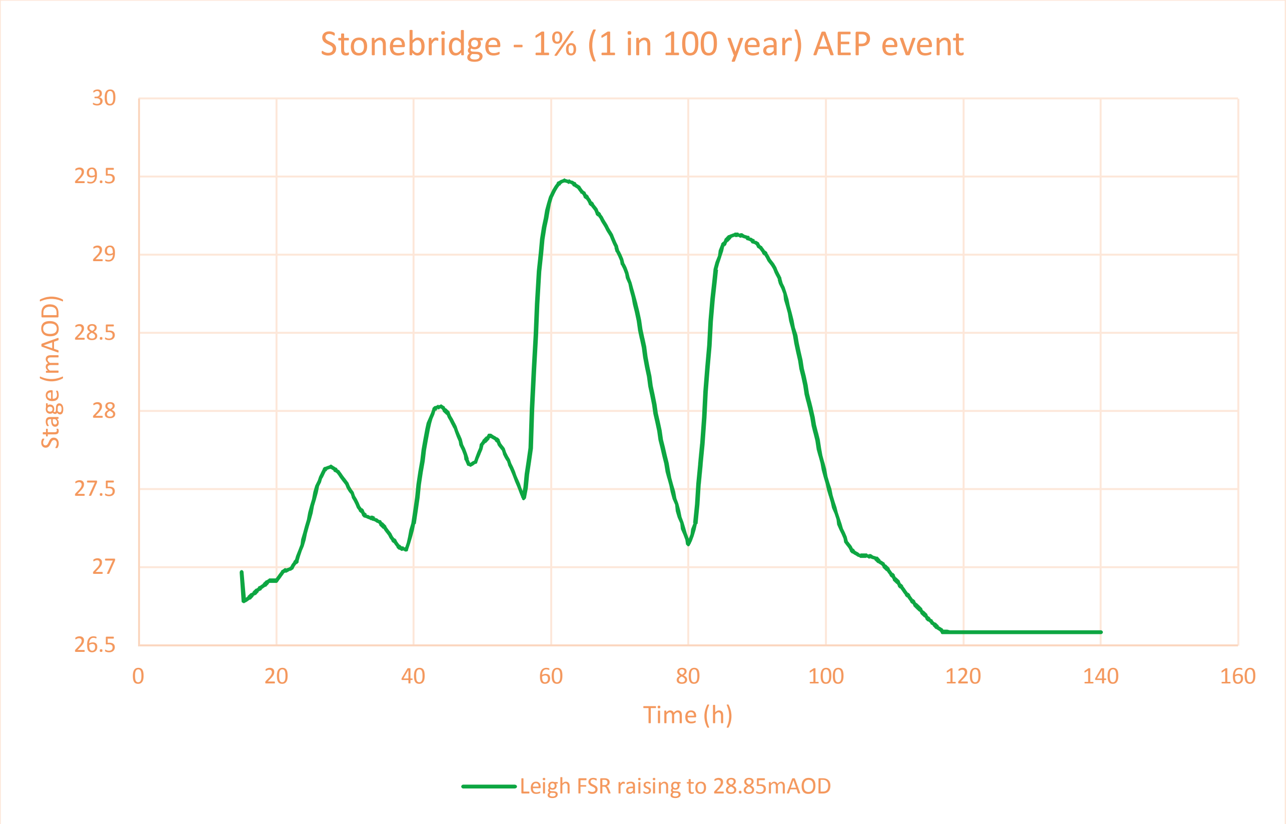

Figure 5c Modelled River Water Levels at Stonebridge, 1% (1 in 100 year) AEP event as modelled for Stonebridge.

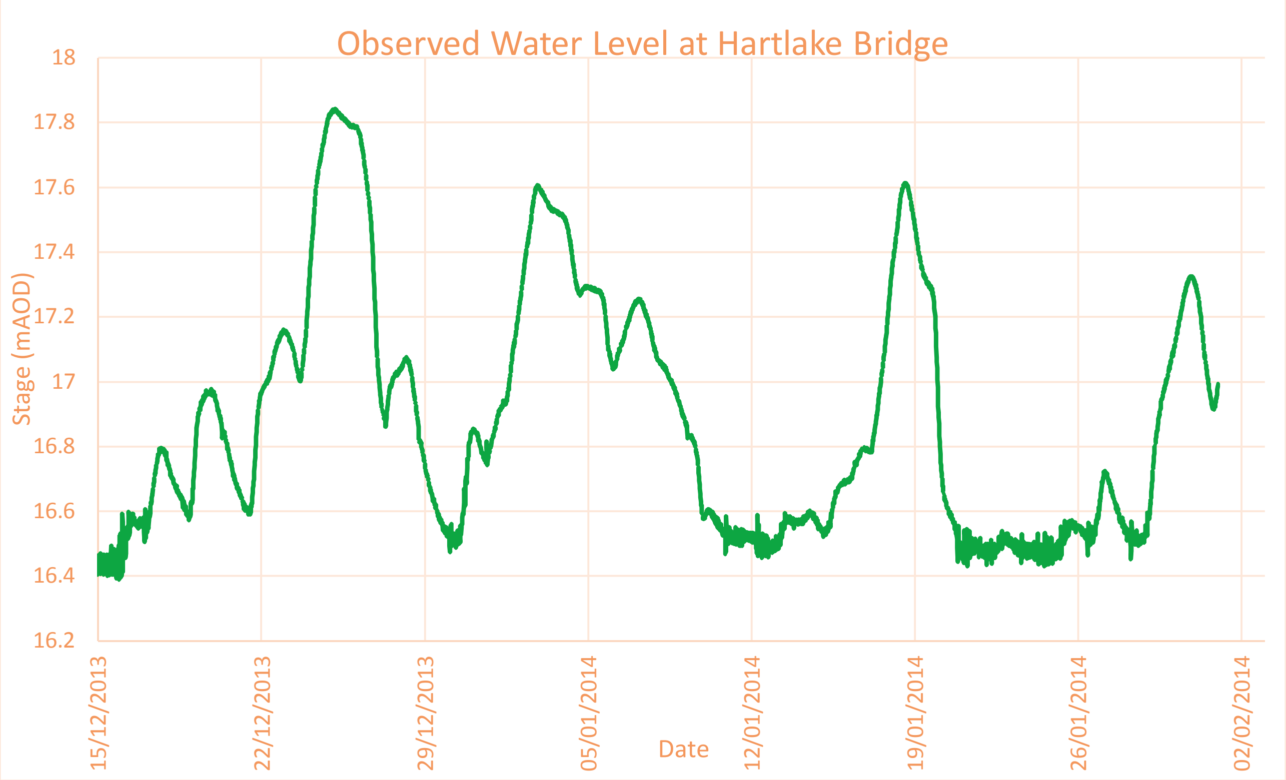

Figure 6a Recorded River Water Levels at Hartlake on the River Medway, 15/12/2013 – 02/02/2014. Note the close fluctuations around the maintained water level in the Medway Navigation

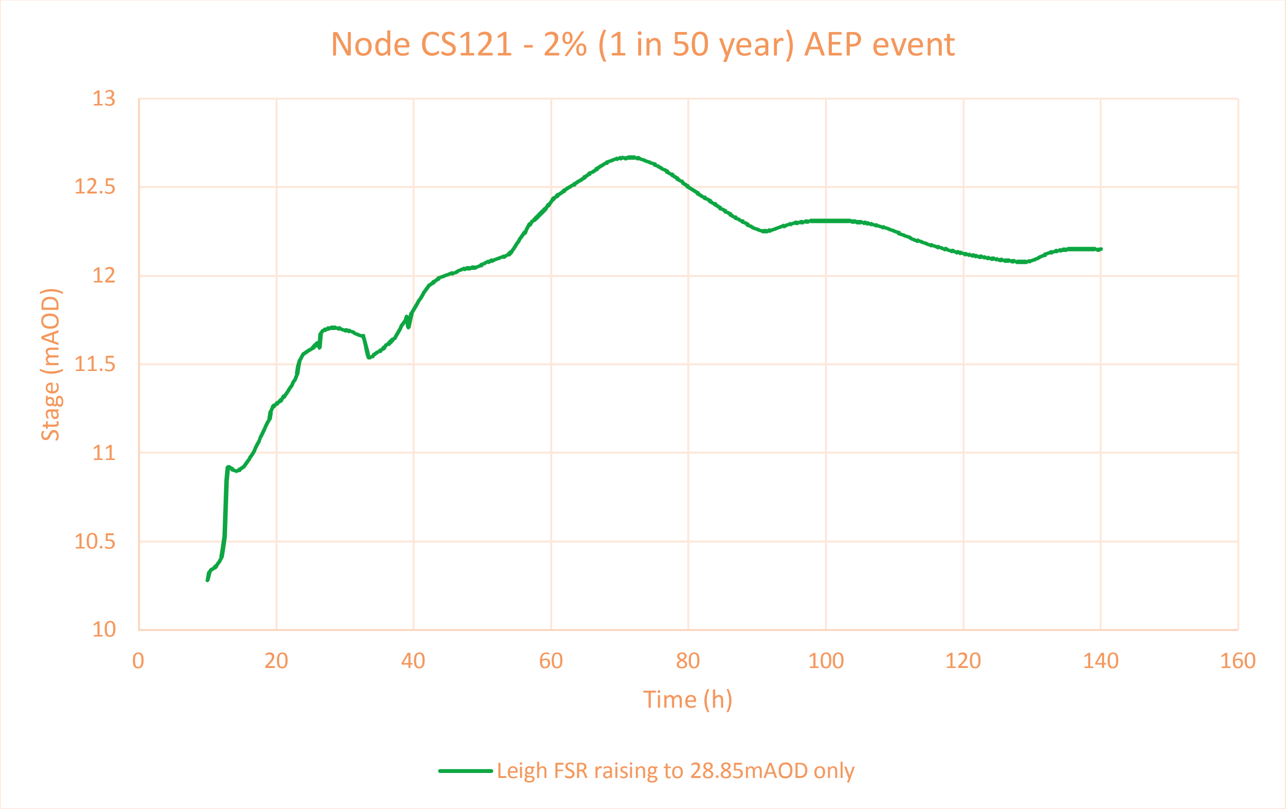

Figure 6b Modelled River Water Levels at node CS121, 2% (1 in 50 year) AEP event as modelled for East Peckham.

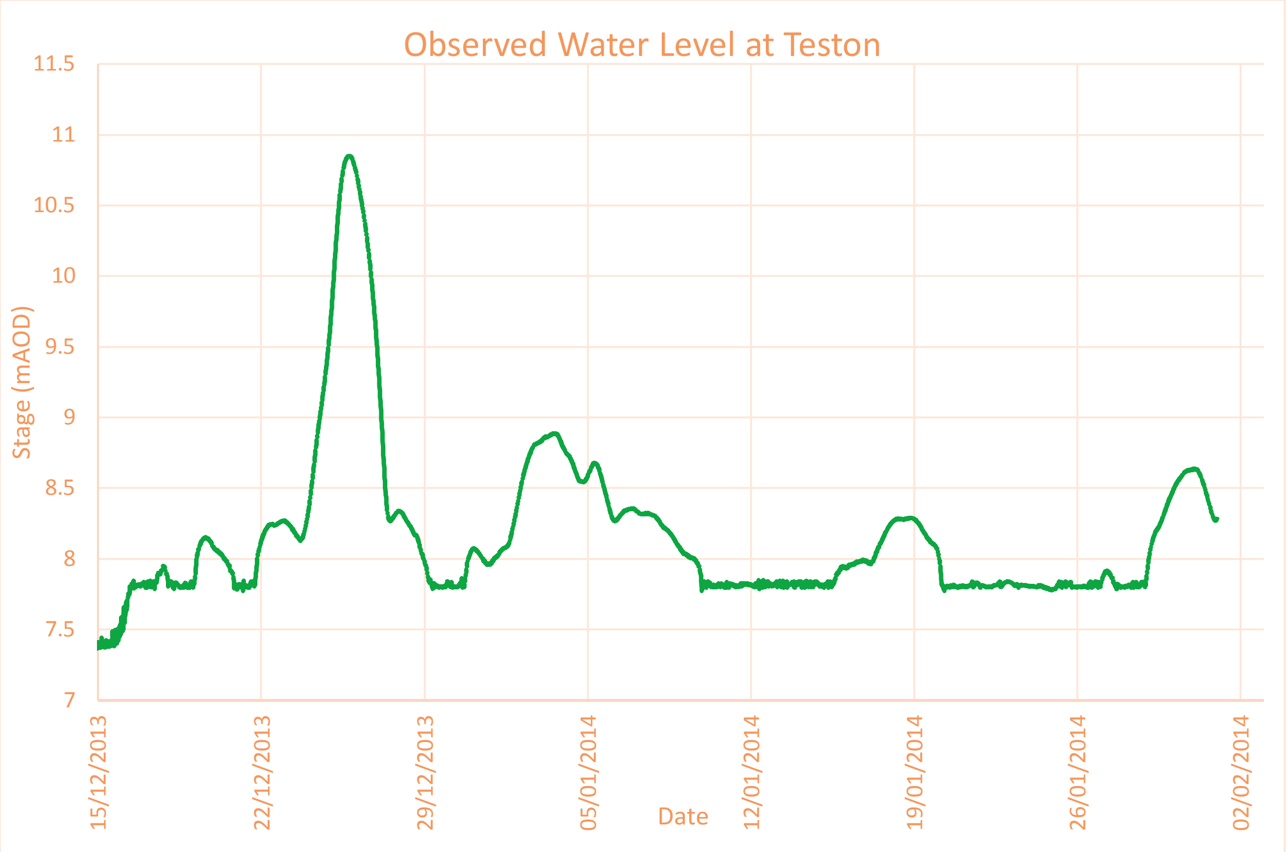

Figure 7a Recorded River Water Levels at Teston on the River Medway, 15/12/2013 – 02/02/2014. Note the close fluctuations around the maintained water level in the Medway Navigation

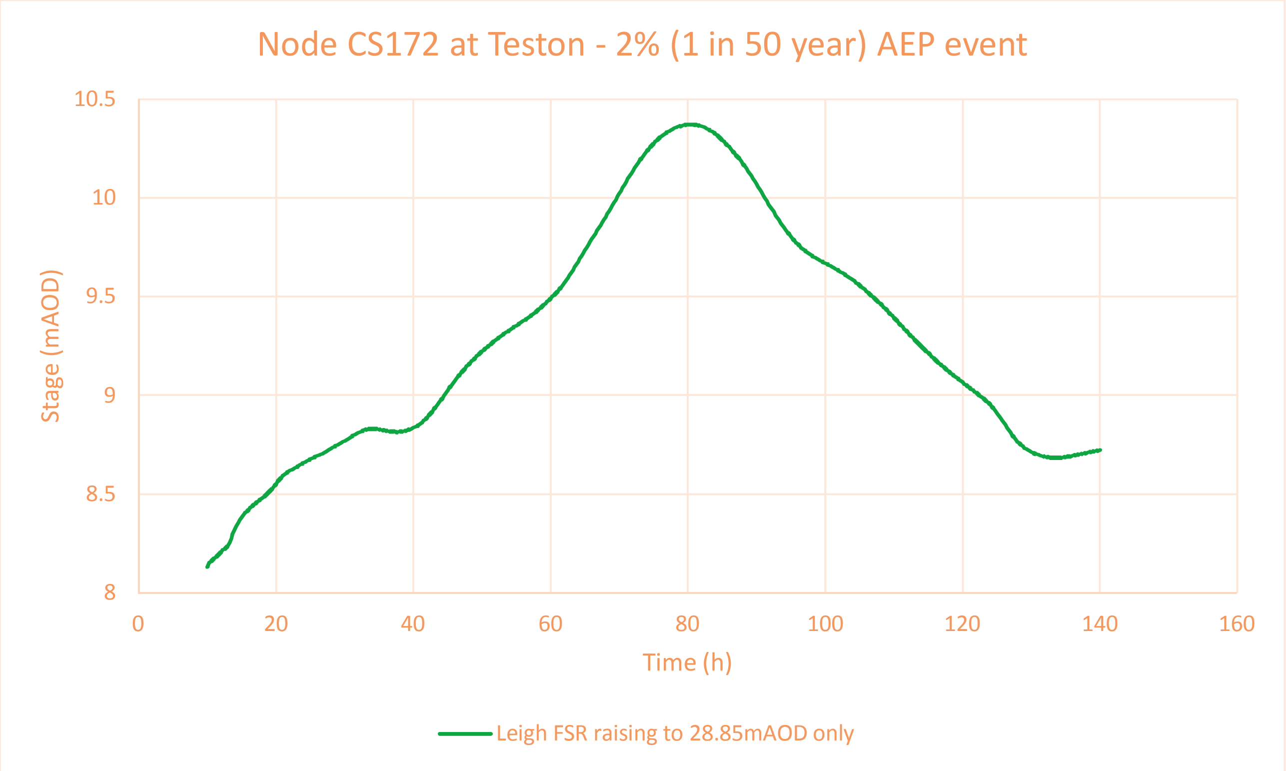

Figure 7b Modelled River Water Levels at Teston on the River Medway, 2% (1 in 50 year) AEP event as modelled for East Peckham.

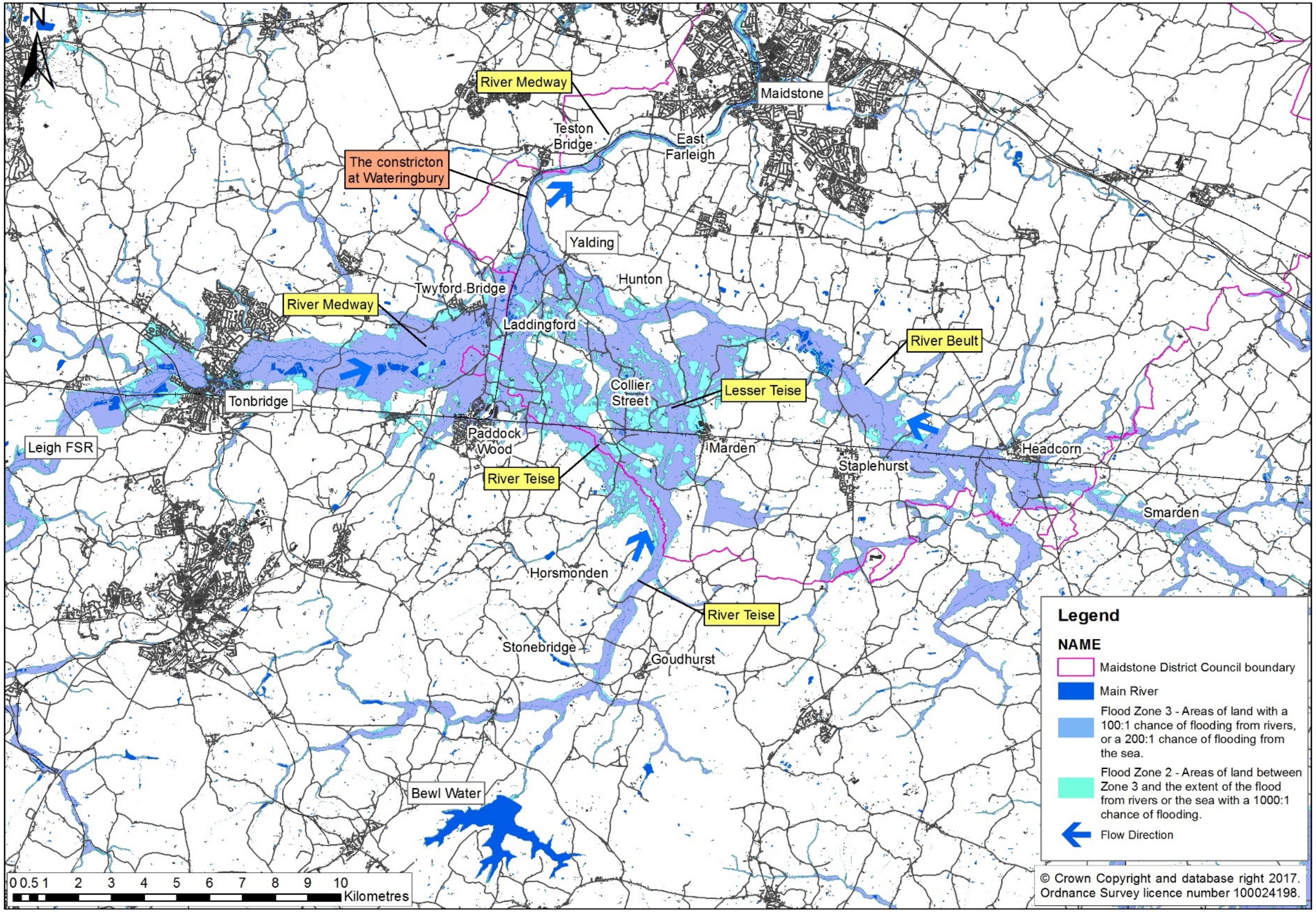

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Figure 8 The Weald Basin showing the extent of Flood Zones 2 and 3, and the narrow constriction to outflow at Wateringbury

2 Options

2.1 General

A range of options have been proposed by the Joint Parishes Flood Group (this is listed in **Appendix A**). To these have been added further options suggested by Arcadis following consultation and study of the area. These options can be classed into the following categories:

- Upstream storage
- Downstream storage
- Conveyance improvements
- Local embankments
- Other

Figure 9 shows the relative locations of these options, with the report section numbers where they can be found below.

Some of the options feature elements that could be placed in more than one of these categories, and it may be that any effective solution involves more than one option used jointly. Any options that generate some improvement in flood risk will be noted and tested in combination using the existing hydraulic model.

The Medway IA indicated that none of the Weald Basin options based around flooding which predominated on the River Medway or Beult came close to providing a Standard of Protection of 1% (1 in 100 years). Therefore we have considered only 2% (1 in 50 year) events for those options affecting predominantly the Medway or Beult. The Medway IA did indicate that up to 1% (1 in 100 year) protection might be possible for flood events predominated on the Teise, so we have modelled 1% (1 in 100 year) floods for those options only.

This study will not consider a solely Property Level Protection (PLP) solution. Many of the properties in the communities at risk are not suitable for fitting with PLP systems due to having no damp course or concrete / brick foundation, or are subject to peak flood levels in excess of 600mm, which is the usual maximum level protected by PLP. However, where an option results in a reduced peak flood level for a property, and the property is suitable for fitting, additional PLP can be considered as a component of the option. If no technically or economically viable option can be identified PLP or localised small-scale embankments will need to be considered for those properties which are suitable for fitting.

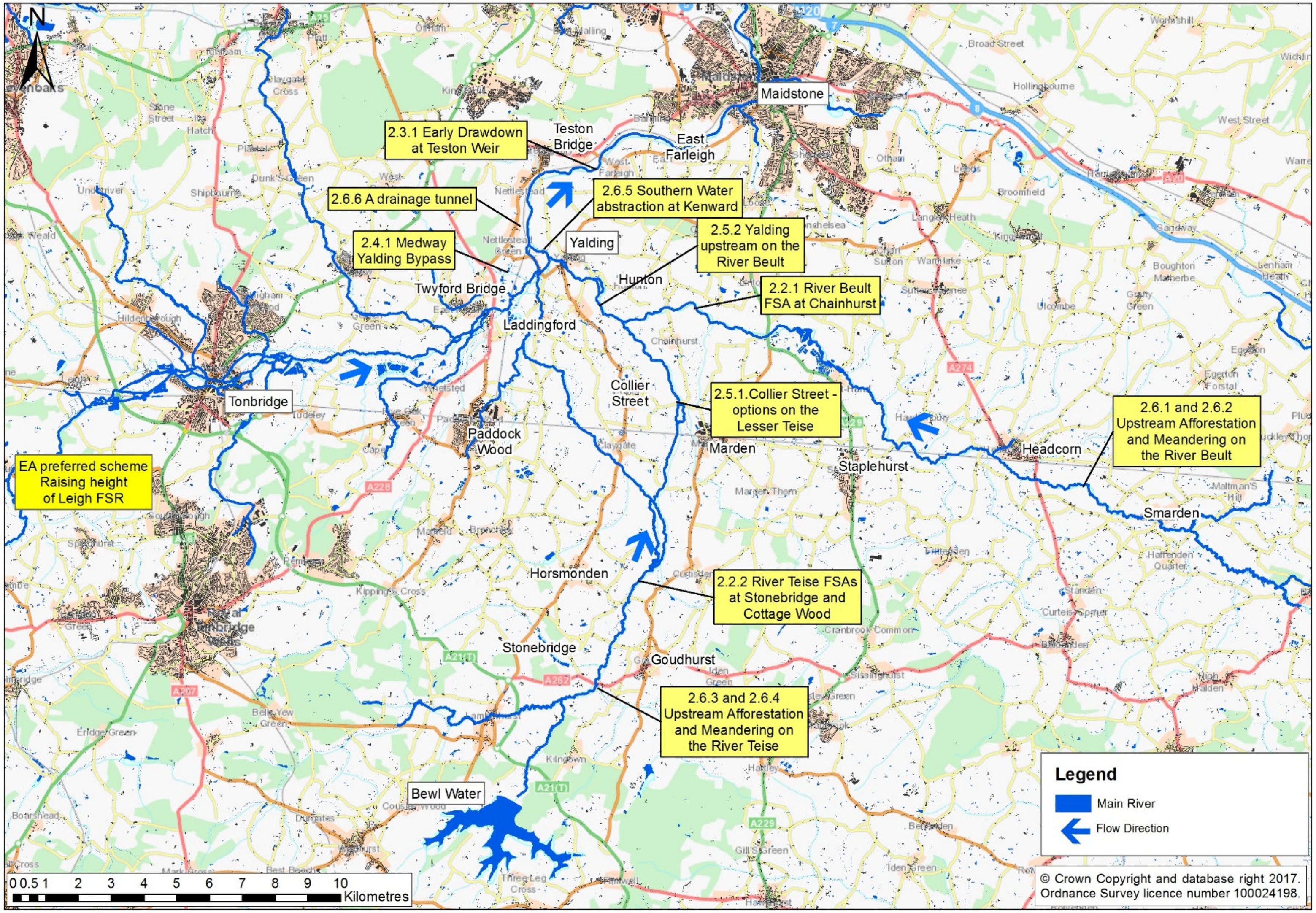

Figure 9 Locations of options assessed in this study.

2.2 Upstream Storage

2.2.1 River Beult FSA

Basic Analysis

The flood storage option for the River Beult considered in the Medway IA featured an embankment up to 3m high, 720m long across the Beult valley at Chainhurst, with a side embankment at Tilden up to 2m high and 3km in length (to avoid flow bypassing the main embankment and entering the Lesser Teise). This would impound up to approximately 7,000,000m^3 of water to a crest level of 15.75mAOD at Chainhurst (and higher on the Tilden side embankment). The approximate alignment of this embankment is indicated in **Figure 10** based on descriptions in the Medway IA. The Medway IA found that, even with an FSA of this size and an outlet throttle set to the 10% (1 in 10 year) AEP event, an FSA at Chainhurst could not provide adequate storage for a 2% (1 in 50 year) AEP flood.

MBC requested that Arcadis consider a higher crest level to improve the downstream standard of protection. This has initially been considered using LiDAR ground elevation data to identify how many properties could be at increased risk of flooding upstream of the embankment at Chainhurst as a result of the higher impounded water level. The result is shown in **Figure 10**. The blue area indicates the 15.75 mAOD contour extending upstream from the embankment. This is the minimum extent of full impoundment with the embankment set at 15.75mAOD. The successive colours indicate raising the embankment crest by 0.5m increments. A 17.75mAOD crest level would impound up to approximately 22,000,000m^3 of water.

This is a simplistic representation – in reality a 15.75 mAOD embankment crest would retain water at a higher level further up the catchment due to the water surface gradient known as a backwater effect, so using the contour only gives the *minimum theoretical* number of properties that could be at risk. The further upstream from the embankment, the higher the maximum impounded water level is likely to be, and the more properties are therefore at risk.

Table 3 lists the *minimum theoretical* number of properties affected at each inundation level. It may be possible to provide additional bunds at each group of impacted properties, but this would add to the cost of the flood storage embankment. All the properties affected in **Table 3** are ground-level residential properties. There is additionally an electricity sub-station at Cross-at-Hand identified as being at risk for an embankment crest level of 17.75mAOD. Due to backwater effect the properties at Cross-in-Hand and Maidstone Road, Staplehurst, being further upstream are likely to experience flooding for any increase in embankment crest height above 15.75mAOD.

Table 3 Minimum theoretical number of properties upstream of the Chainhurst Flood Storage Area embankment within the inundation zone at maximum impoundment. These figures are likely to be exceeded due to backwater effect.

Embankment Crest Level (mAOD)	Minimum number of properties affected by upstream flooding at full impoundment														TOTAL
	Babylon Farm	Bardingley	Chainhurst	Chaney Court	Chickenden Lane	Couchman Green	Cross-at-Hand	Hawkenbury	Hunton	Maidstone Road,	Rabbits Cross	Redwall Lame	Stilebridge	White House Farm	
15.75			10						10				4		24
16.25			10				2		10	1			7		30
16.75		1	10	7		2	3		12	9	3		7		54
17.25		1	10	9		10	4		12	11	7	1	12	1	78
17.75	2	1	10	10	4	11	10	2	15	18	9	1	20	1	114

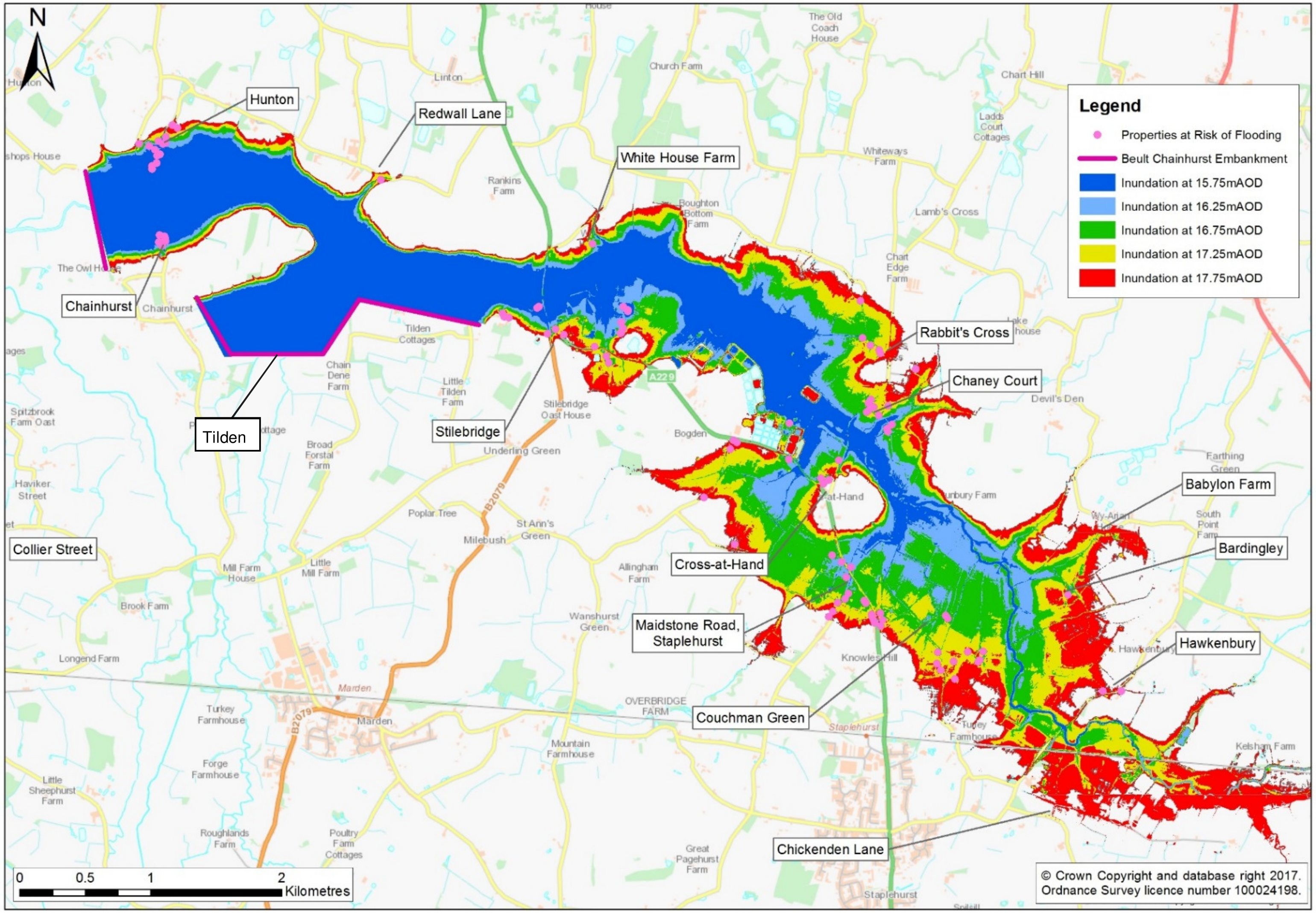

Figure 10 Areas that could be inundated with a larger Beult Chainhurst Flood Storage Area. Alignment of the embankment is indicative, based on descriptions in the Medway IA. Please see also Figures 3 to 6 in Appendix A of the Medway IA for greater detail.

Hydraulic Modelling

The hydraulic model was then run for a 2% (1 in 50 year) AEP event as modelled for Smarden, first as a baseline run with no alleviation and then assuming an embankment as per the one modelled in the Medway IA, but with the embankment crest level raised to 17.75mAOD at Chainhurst and the side embankment at Tilden similarly raised 2m above the value in the IA run. For the purposes of this model run we assumed a maximum controlled outflow of 25m^3/s from the proposed FSA, which is approximately half the peak flow in a 20% (1 in 5 year) AEP flood event on the Beult at this location. This is significantly below the 10% (1 in 10 year) AEP outflow rate used in the Medway IA. Once the flow exceeds this value impoundment will commence to reduce downstream flood levels from the Beult.

This demonstrates not only the potentially greater improvement in flood risk to Weald Basin area, but also the increase in flood risk upstream taking account of the modelled backwater effect. **Figure 11a** shows the peak flood extent (and depths) with no flood alleviation, **Figure 11b** shows the peak flood extent for 2% AEP with the 17.75mAOD embankment in place, and **Figure 11c** shows the change in peak flood depths between the baseline and the modelled option of the 17.75mAOD crest level embankments, together with an indication of the location of properties affected either by reducing or increasing flood depth.

Analysis of these properties using GIS mapping tools indicates that 30 properties, located variously in Headcorn, Cross-at-Hand, Tilden, Stilebridge and Chainhurst would be adversely affected by the increased peak flood levels. Most of these properties would experience flooding increasing by up to 0.4m, with two properties at Tilden around 0.5m and two at Stilebridge higher than this. Due to the lack of detailed threshold survey covering this area (there are only 19 surveyed properties in the Beult catchment data provided by the EA, plus properties in the centre of Yalding) it is not possible without further survey to confirm which properties would actually be subjected to increased internal flood risk. However, 76 properties (including many in Collier Street and some in Yalding) would experience no discernible change in flood level within model tolerances (+/- 0.01m) and 453 properties would experience reduced peak flood levels. As **Figure 11b** shows, even though flood risk is reduced for many properties, flooding will still extend over much of the Weald Basin area.

The modelling has indicated far fewer properties adversely affected (**Figure 11b**) than the basic analysis (**Table 3**). This is because the embankment is not fully impounding in the design event considered. Therefore, although some water is being held back and released more slowly downstream of Chainhurst than would be the case without the embankment, this is insufficient to flood everywhere upstream to the crest level of the embankment.

Close inspection of **Figure 11a** and **Figure 11b** shows that the main areas benefitting from the elimination of flooding as a result of the Chainhurst embankment would be Hunton and the parts of Yalding flooding from Mill Lane, while flooding at Collier Street is reduced in level but still present.

Further model runs could be made to optimise the storage by varying the outflow rate. If the rate is further constrained the embankment would provide improved protection in Yalding, but at the expense of flooding more upstream properties as indicated in **Table 3**. However, as such an embankment would have a highly significant visual impact in the Beult valley, being locally up to 5m in height (this is approximately the height of two storeys of a typical building), the construction cost would be considerable, the standard of protection potentially available is not particularly high and a number of properties would be subject to detriment, therefore we support the findings of the Medway IA that a larger embankment at Chainhurst would not be a reasonable realistic option.

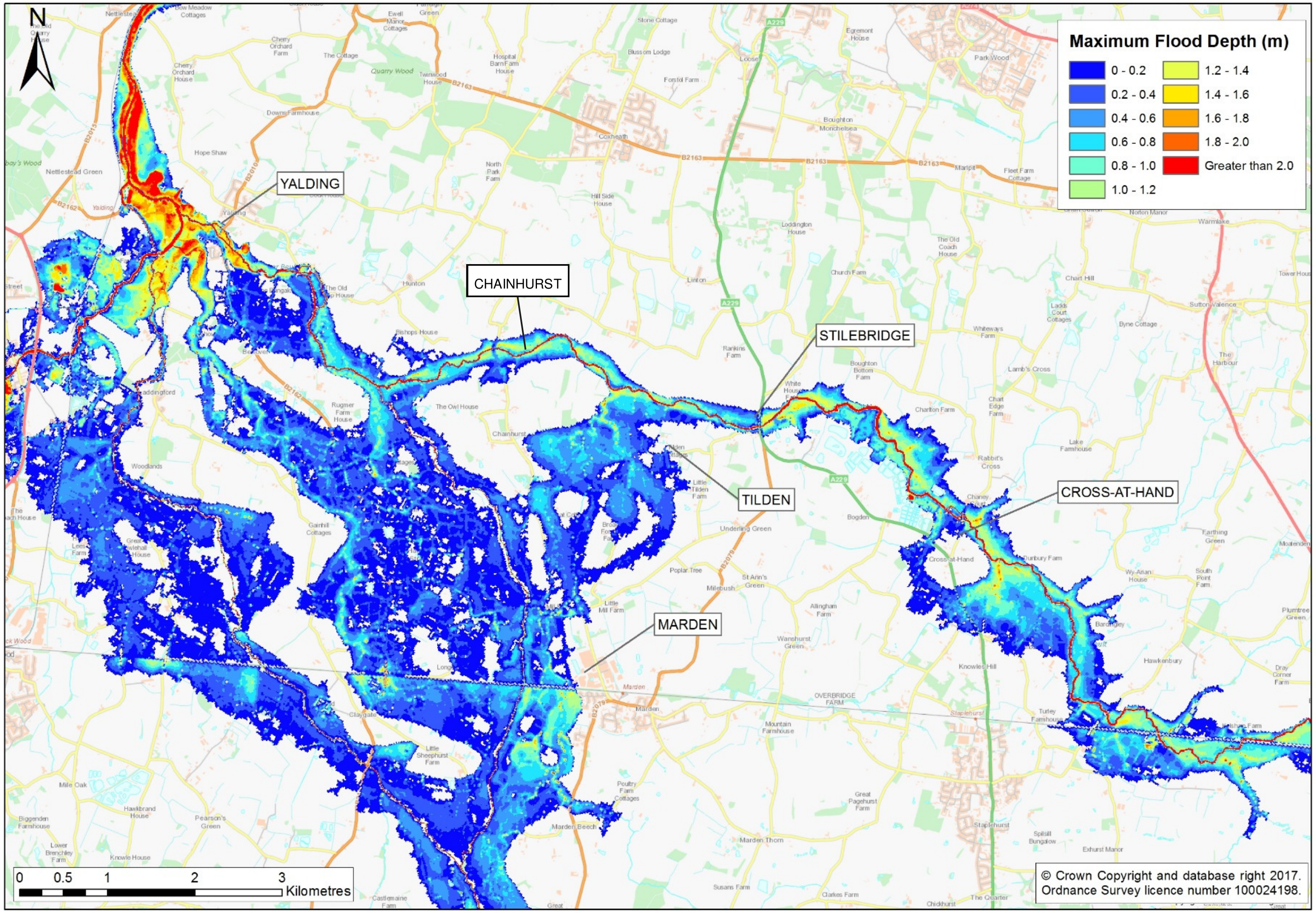

Figure 11a Peak extent of inundation (with depths) for the baseline condition on the River Beult. 2% (1 in 50 year) AEP flood event as modelled for Smarden.

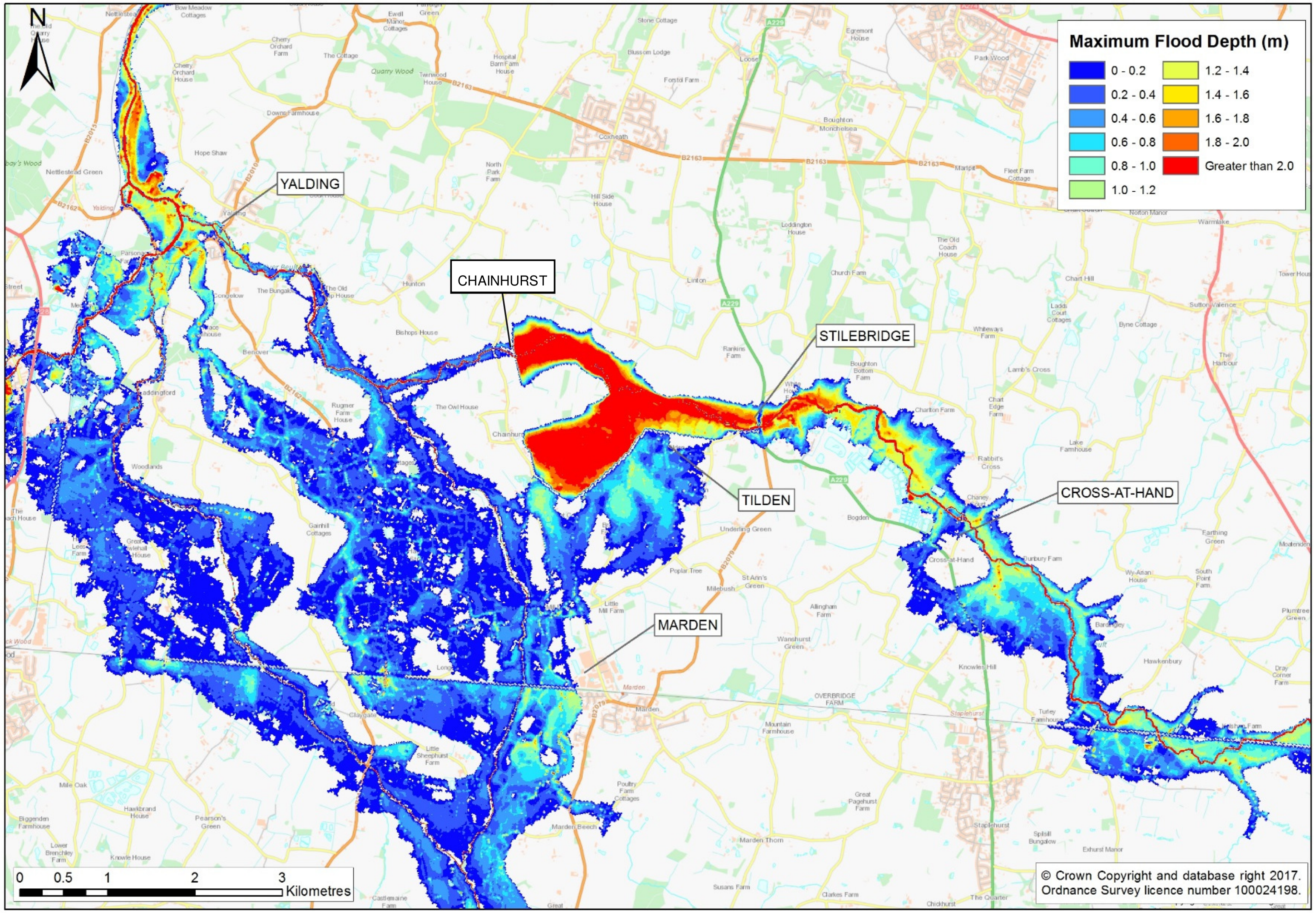

Figure 11b Peak extent of inundation (with depths) for a Beult Chainhurst Flood Storage Area with an embankment crest level of 17.75mAOD. 2% (1 in 50 year) AEP flood event as modelled for Smarden, with output throttled to a maximum of 25m^3/s flow. Alignment of the embankment is indicative, based on descriptions in the Medway IA.

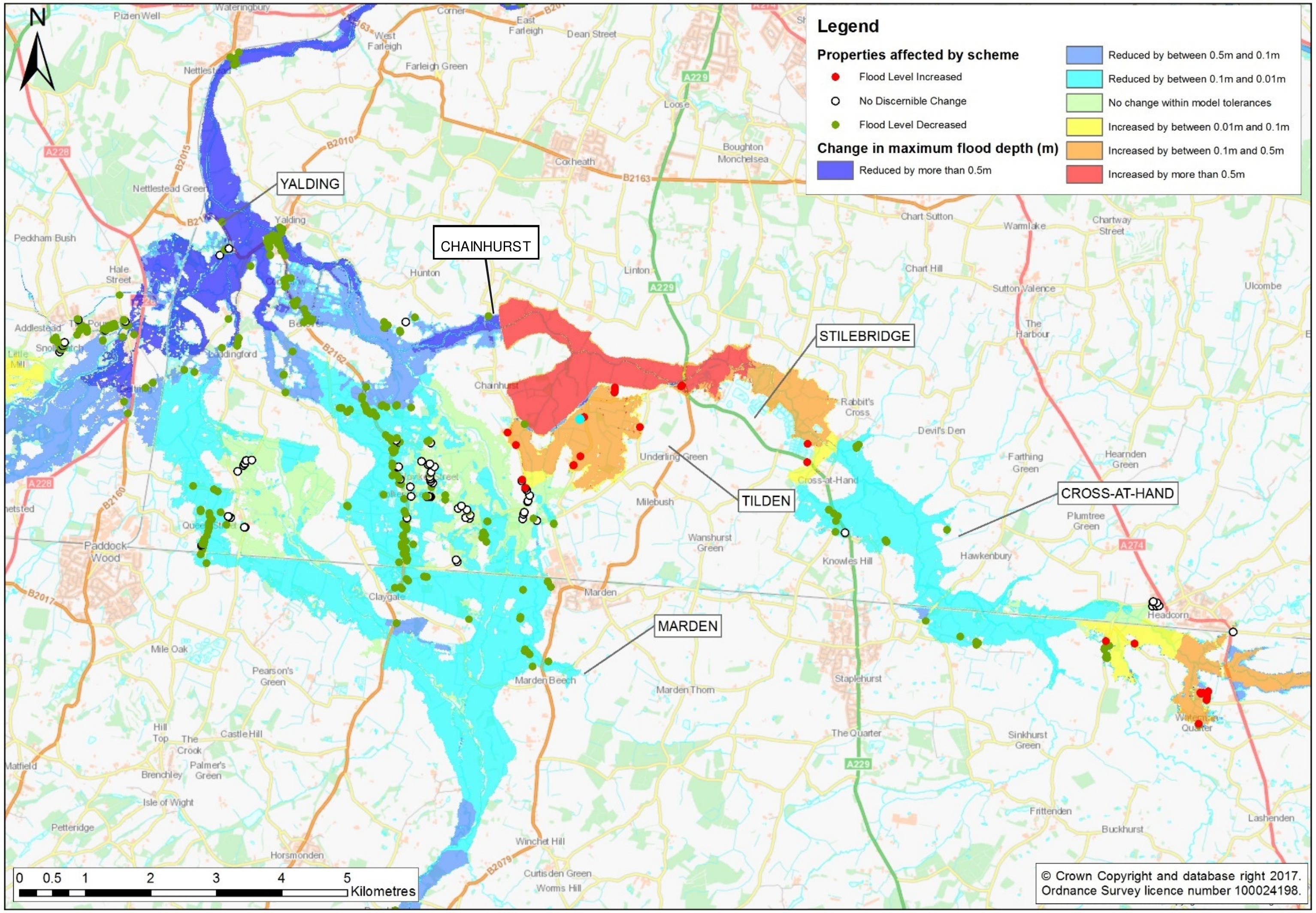

Figure 11c Difference in peak inundation depths for a Beult Chainhurst Flood Storage Area with an embankment crest level of 17.75mAOD compared to the baseline - for 2% (1 in 50 year) AEP flood event as modelled for Smarden, with output throttled to a maximum of 25m^3/s flow. Alignment of the embankment is indicative, based on descriptions in the Medway IA.

2.2.2 River Teise FSA

The Medway IA identified two locations for the proposed FSA embankments to be placed across the Teise valley, at Cottage Wood near Horsmonden and at Stonebridge. These are shown in **Figure 12**. Note these locations are inferred from the Medway IA and are not necessarily exact locations. The Medway IA indicated that, using the two FSAs together and with the outflow throttled to a 5% (1 in 20 year) AEP event, adequate storage for 94% of a 1% (1 in 100 year) AEP event can be achieved. This is a good standard of protection given the difficulties of the catchment. However, this assessment of the capacity of the two FSAs was undertaken using basic volumetric calculations (Appendix C of the Medway IA) and is not supported by any hydraulic modelling. The output from the hydraulic model from this updated study suggests that attenuation of a 2% (1 in 50 year) AEP event is fairly effective immediately downstream of the Stonebridge (**Figure 13a**) and Cottage Wood (**Figure 13b**) FSAs but becomes less effective further down both the Teise and Lesser Teise catchments due to additional surface runoff and rainfall entering the rivers between the FSAs and Yalding (**Figures 13c to 13j**).

It should be noted that while any Teise FSA might improve flood risk to Collier Street, Laddingford and the western part of Yalding if a flood event is focussed on the Teise, this option would provide no improvement in flood risk arising from a flood event on the River Beult affecting eastern Yalding and Hunton.

It is also noted in the Medway IA that, as the Teise generally rises ahead of the Medway and the Beult, storing the peak flow on the Teise may delay the peak so that it coincides with floods on the other two rivers, actually increasing the peak water level, and thereby also flood risk. This could occur in the event of a very large flood on the Teise that cannot be adequately stored, or in an event similar to the Christmas 2013 floods when a second storm delivers a further wave of flooding before the water stored in the FSA can be released.

MBC have requested that Arcadis investigate how storage could adversely affect flood levels due to these timing effects. As noted above in Methodology – Risks and Constraints the way the hydrology has been set up is not optimal for determining timing effects, but we can run a design event hydrology with and without the Teise storage options to see how this affects peak levels and infer the effects of different timings.

To do this it is necessary to obtain model outputs just upstream and downstream of the key confluences (Lesser Teise / Beult and Teise / Medway) and compare these for the scenarios with and without the Teise FSAs in place. This is shown in **Figures 13e, 13f** (for the Teise/Medway confluence) and **Figures 13i, 13j** (for the Lesser Teise / Beult confluence). We can see that the model indicates the magnitude of peaks reduced only marginally and delayed by approximately 10 hours as a result of both Cottage Wood and Stonebridge FSAs being present.

It is apparent by inspection of these hydrographs that both the Teise and the Lesser Teise become strongly dominated by the Medway and the Beult respectively close to their confluences. In Table 2 we noted that a 1 in 50 year flood (110.57 m^3/s at Stonebridge) on the Teise (using the CS hydrology) rated as only a 1 in 18 (117.88 m^3/s at East Peckham) on the Medway or a 1 in 8 (37.50 m^3/s at Smarden) on the Beult. While a real event might not have the same relationship between different sources, this does show that even a very significant flood on the Teise will generally convey much less water than more frequent events on the Beult and Medway resulting in the backwater effects dominance on the downstream river reaches in the study area. Therefore storage on the Teise could be relatively ineffective for properties near the confluences at Yalding.

Figure 14 indicates the locations of the model nodes used in producing the individual hydrographs in **Figure 13a to 13j**.

The output of these model runs indicates that, while the timing of peaks on the different rivers may cause an issue, the most significant argument against the River Teise flood storage embankments is that they do not seem to be very effective at protecting sufficient properties to be financially viable.

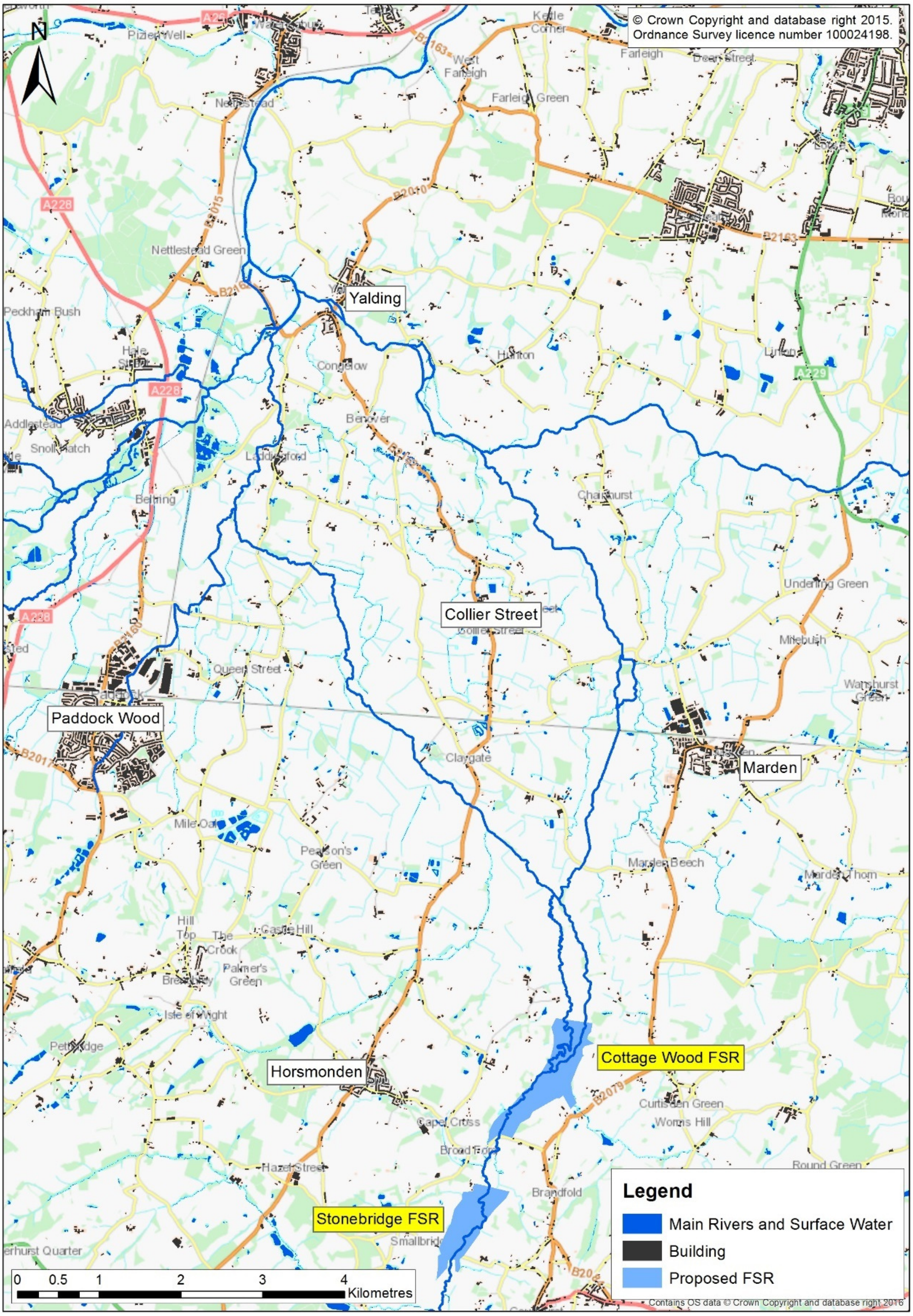

Figure 12 Indicative locations of the Cottage Wood and Stonebridge flood storage reservoirs. Locations inferred from the Medway IA.

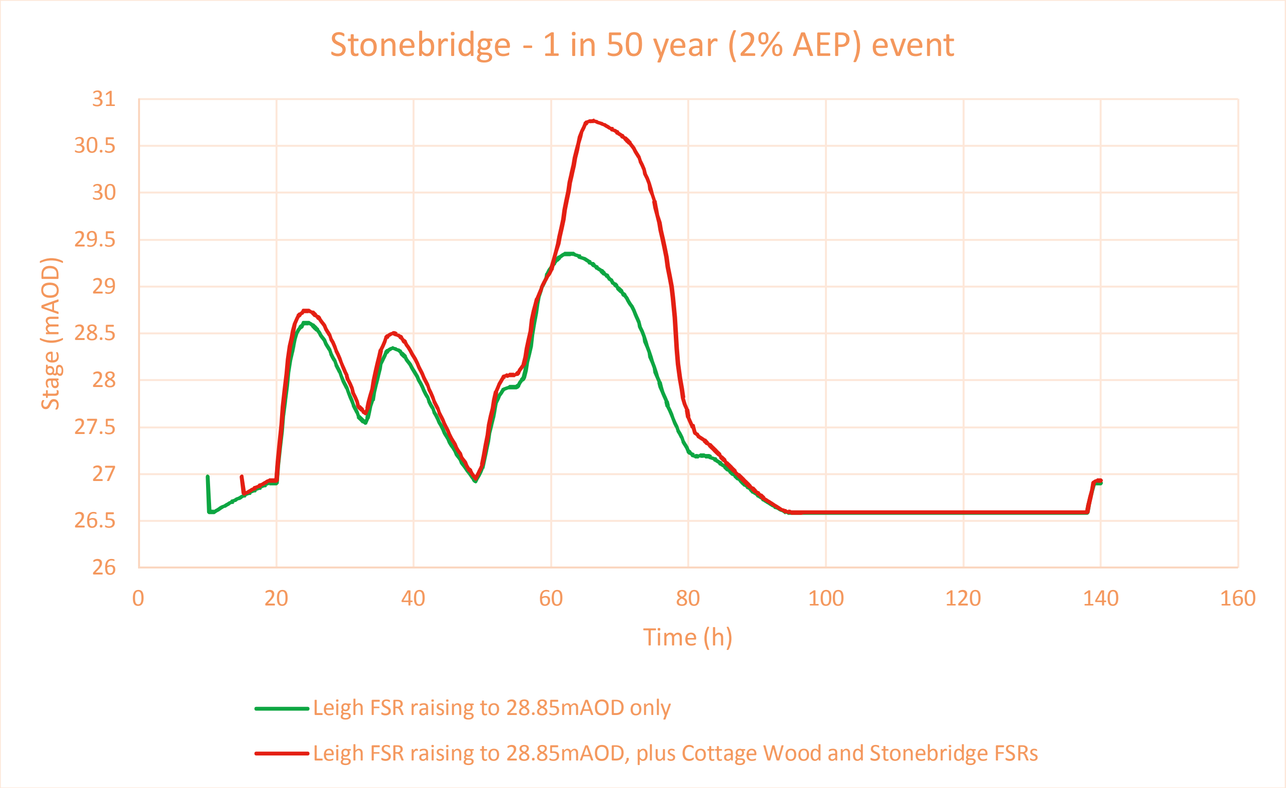

Figure 13a Modelled peak water levels at node Stonebridge immediately downstream of Stonebridge FSA and upstream of Cottage Wood FSA with and without the Cottage Wood and Stonebridge FSAs in place. 2% (1 in 50 year) AEP event as modelled for Stonebridge. (Note the defended hydrograph is actually higher for this location – this is because of downstream impoundment at Cottage Wood)

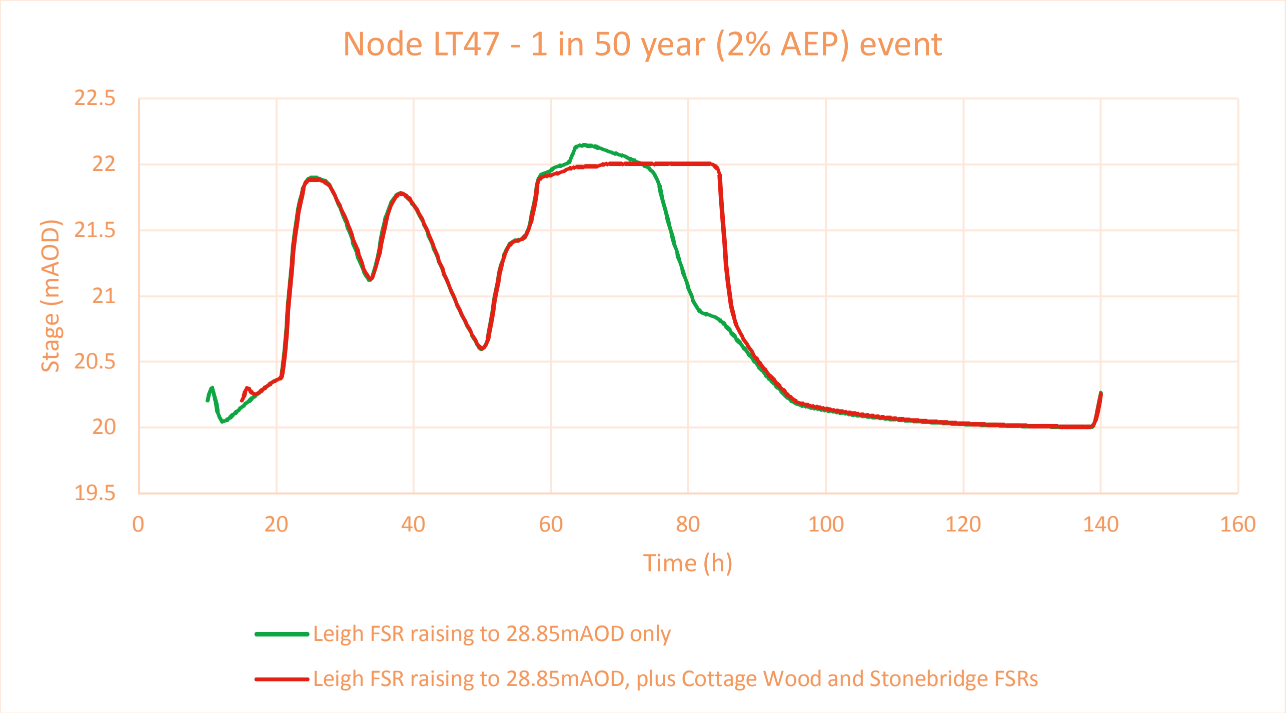

Figure 13b Modelled peak water levels at node LT47 immediately upstream of the divergence between the Teise and Lesser Teise with and without the Cottage Wood and Stonebridge FSAs in place. 2% (1 in 50 year) AEP event as modelled for Stonebridge. The peak is lowered by 0.14m and delayed by 12.5 hours.

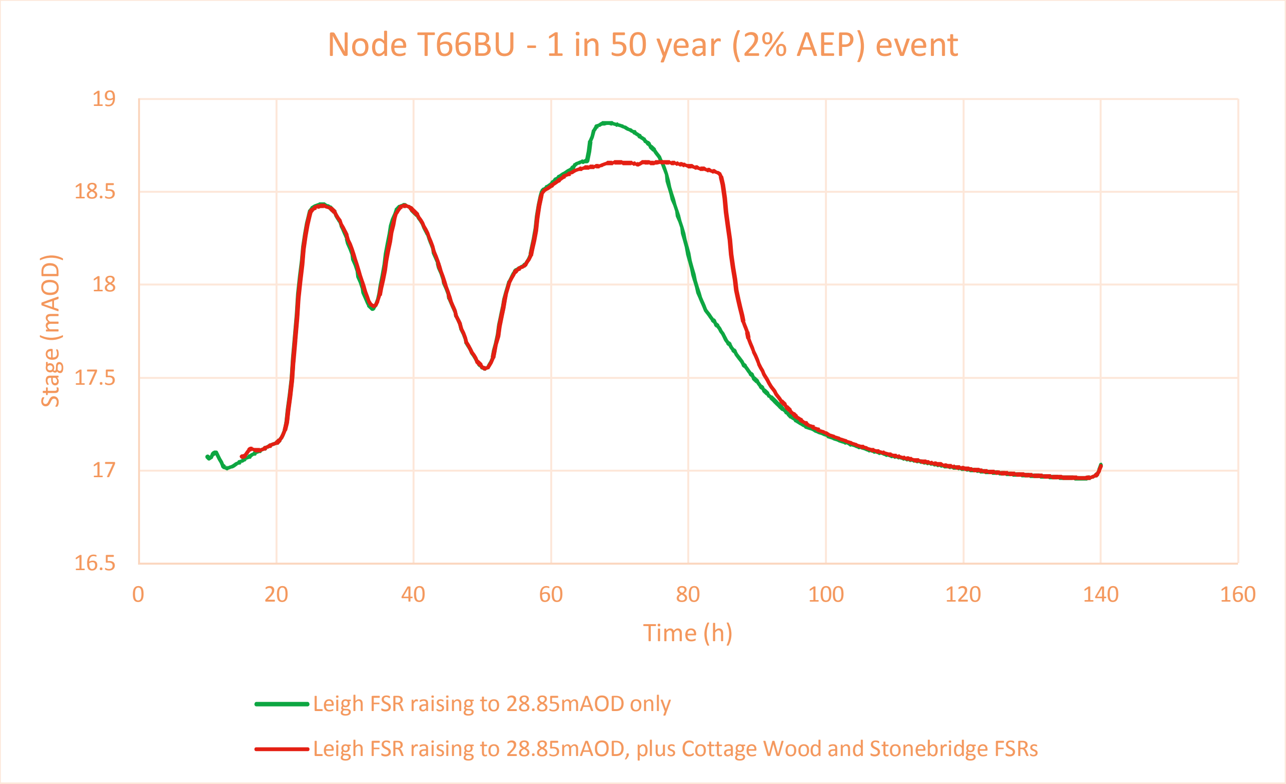

Figure 13c Modelled peak water levels at node T66BU at the B2162 Maidstone Road bridge over the Teise south of Claygate, with and without the Cottage Wood and Stonebridge FSAs in place. 2% (1 in 50 year) AEP event as modelled for Stonebridge. The peak is lowered by approximately 0.21m and delayed by 5.5 hours.

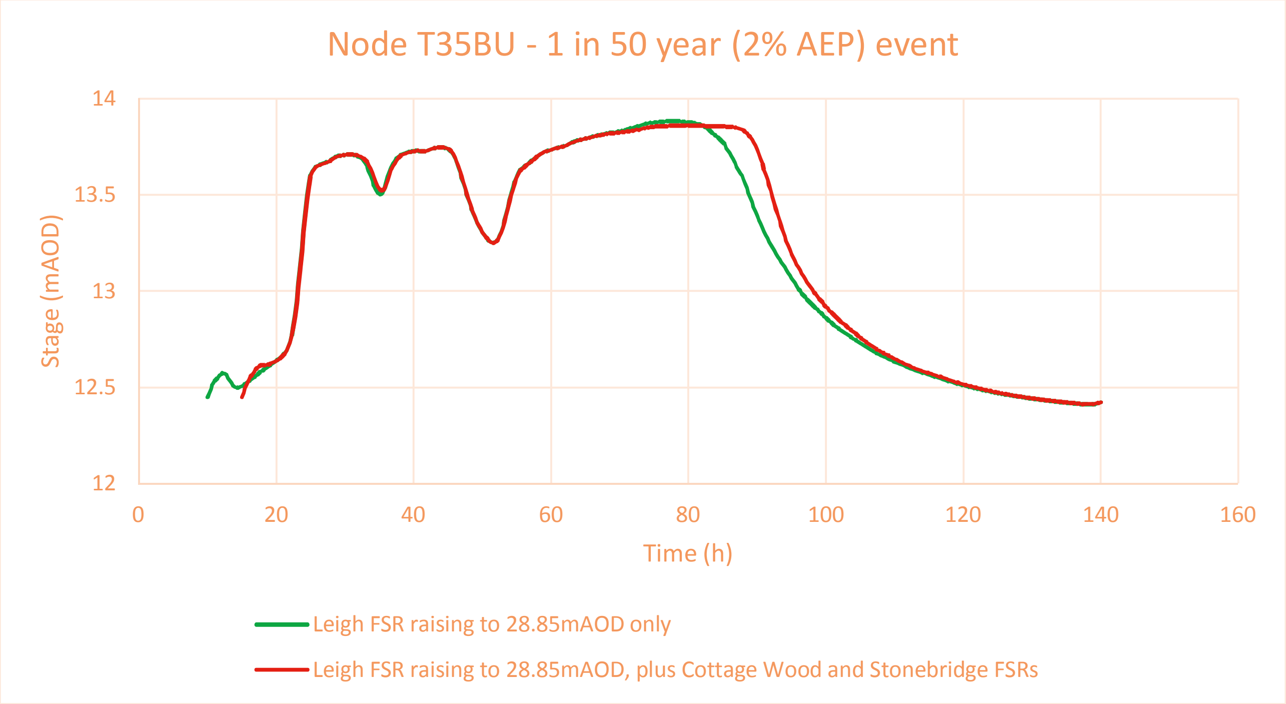

Figure 13d Modelled peak water levels at node T35BU at the Pikefish Lane bridge over the Teise south of Laddingford, with and without the Cottage Wood and Stonebridge FSAs in place. 2% (1 in 50 year) AEP event as modelled for Stonebridge. The peak is lowered by approximately 0.02m and delayed by 2 hours.

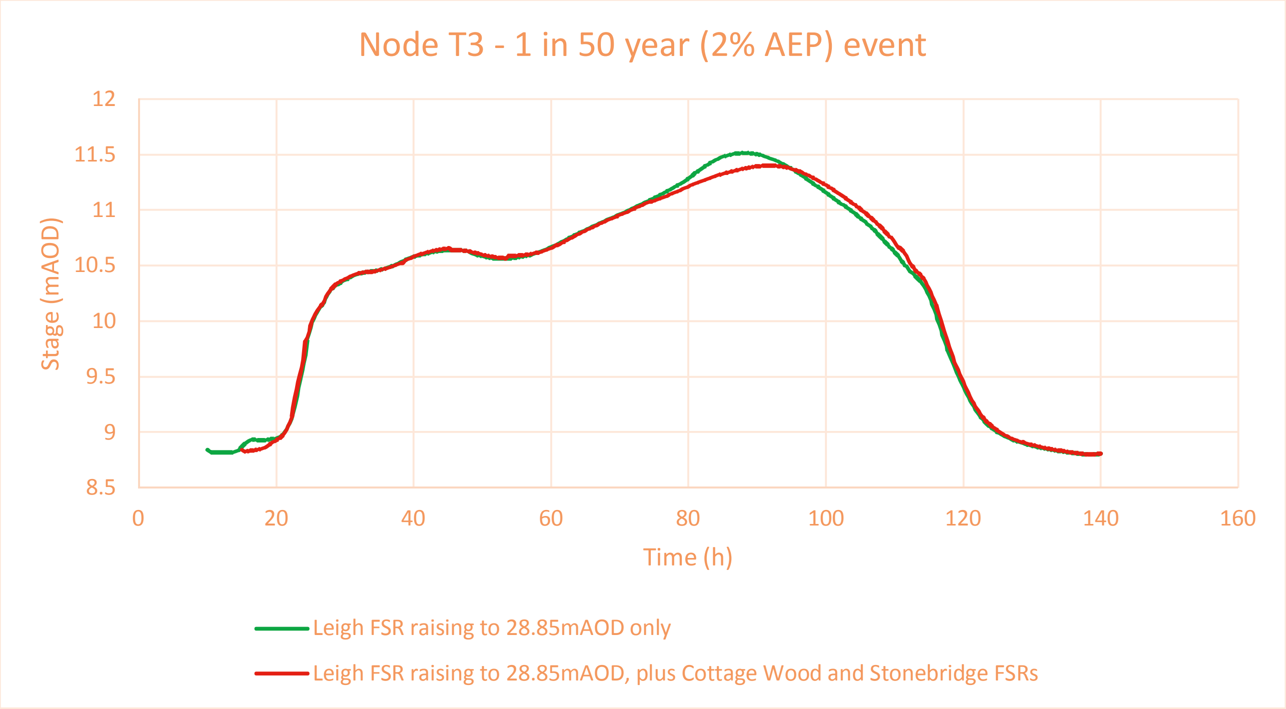

Figure 13e Modelled peak water levels at node T3 immediately upstream of the confluence of the River Teise and the River Medway at Twyford Bridge, with and without the Cottage Wood and Stonebridge FSAs in place. 2% (1 in 50 year) AEP event as modelled for Stonebridge. The shape of the hydrograph being much more like the downstream (River Medway) profile than the upstream (River Teise) profile shows that any flooding is Medway-dominated at this point. The peak is lowered by approximately 0.11m and delayed by 3.25 hours.

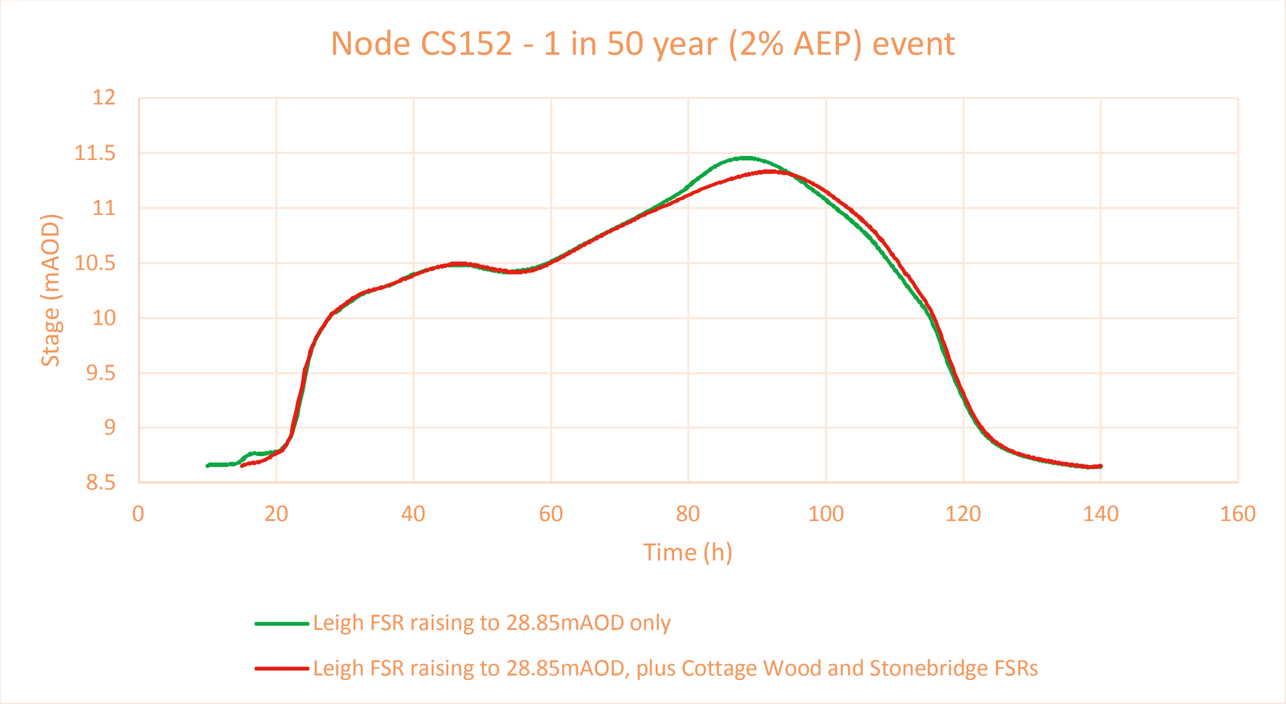

Figure 13f Modelled peak water levels at node CS152 immediately downstream of the confluence of the River Teise and the River Medway at Twyford Bridge, with and without the Cottage Wood and Stonebridge FSAs in place. 2% (1 in 50 year) AEP event as modelled for Stonebridge. The peak is lowered by approximately 0.12m and delayed by 2.5 hours.

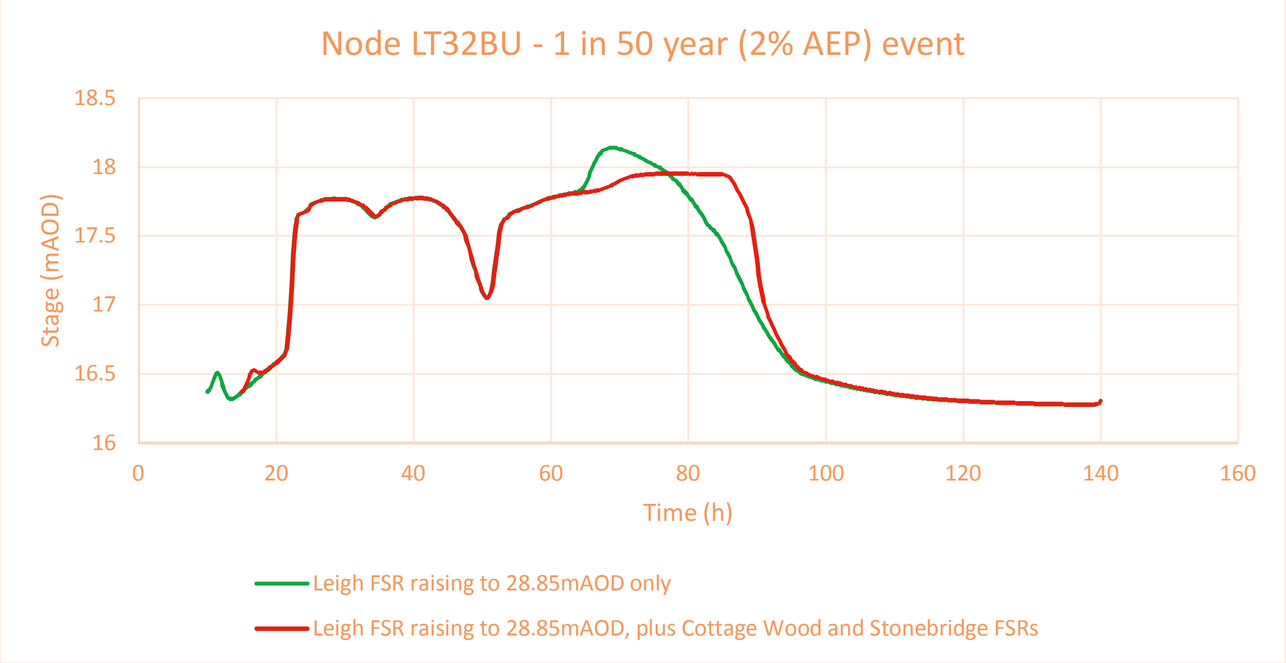

Figure 13g Modelled peak water levels at node LT32BU at Spits Bridge (the bridge over the Lesser Teise at Green Lane), with and without the Cottage Wood and Stonebridge FSAs in place. 2% (1 in 50 year) AEP event as modelled for Stonebridge. The peak is lowered by approximately 0.18m and delayed by 8.5 hours.

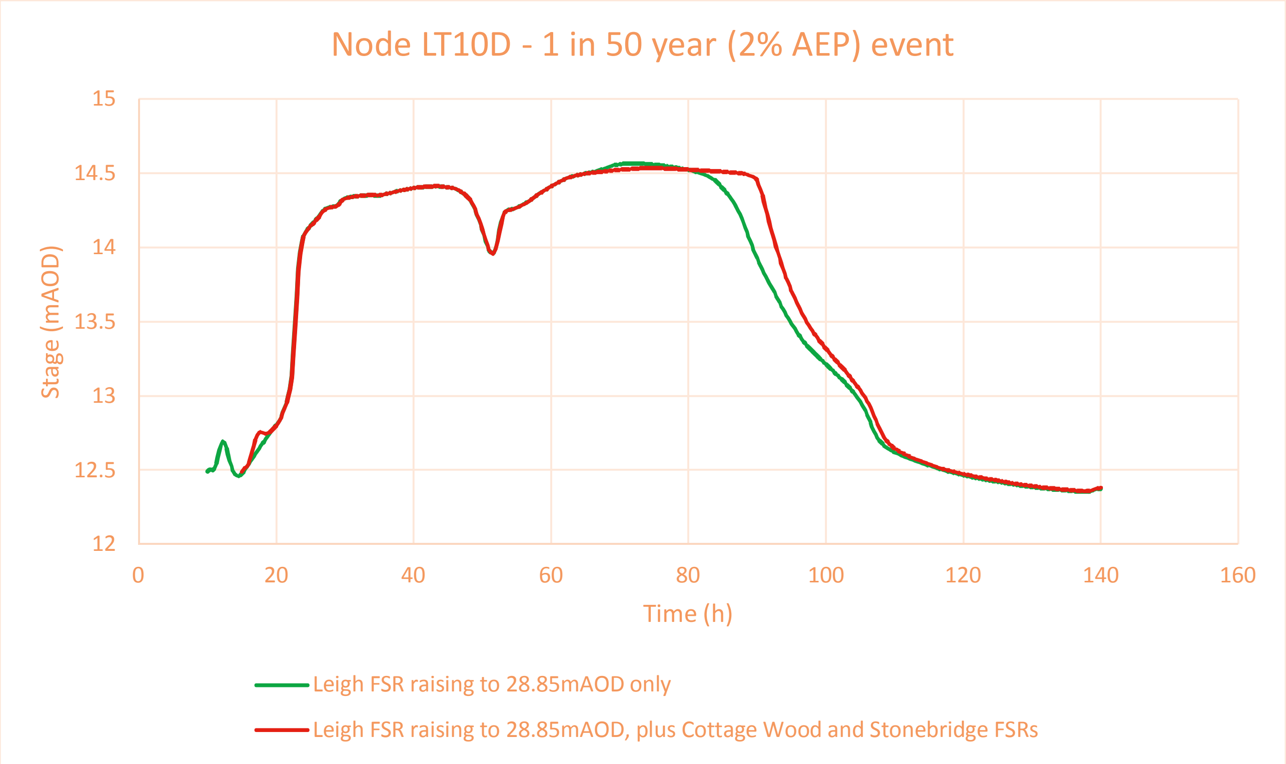

Figure 13h Modelled peak water levels at node LT10D immediately downstream of the 90 degree corner in the Little Teise near Spitzbrook Cottages, with and without the Cottage Wood and Stonebridge FSAs in place. 2% (1 in 50 year) AEP event as modelled for Stonebridge. At this point the peak is lowered by approximately 0.03m and delayed by 2.5 hours, but also extended.

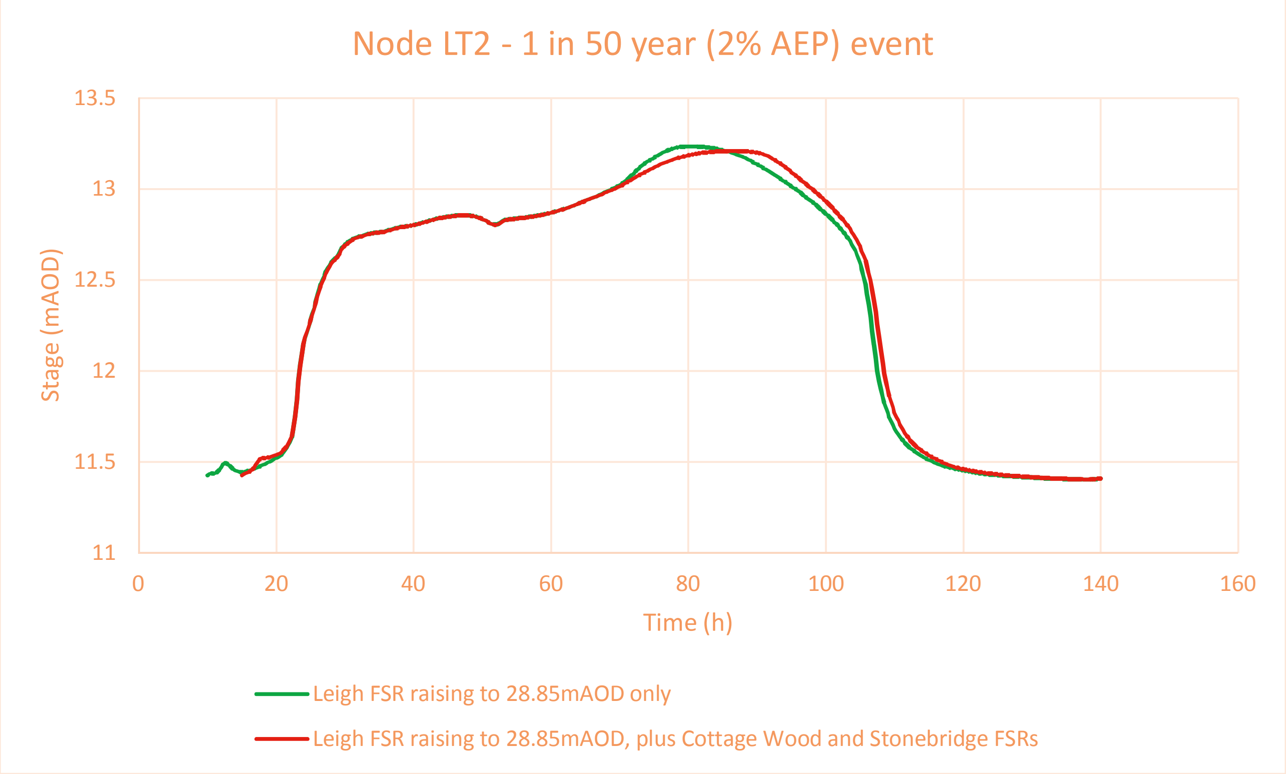

Figure 13i Modelled peak water levels at node LT2 immediately upstream of the confluence of the River Beult and the Lesser Teise, with and without the Cottage Wood and Stonebridge FSAs in place. 2% (1 in 50 year) AEP event as modelled for Stonebridge. As with Figure 11e, the shape of the hydrograph shows the dominant effect of the larger river, in this case the Beult, even though a 1 in 50 event on the Teise equates to a much smaller flood on the Beult (see Table 2). The peak is lowered by approximately 0.03m and delayed by 6.25 hours.

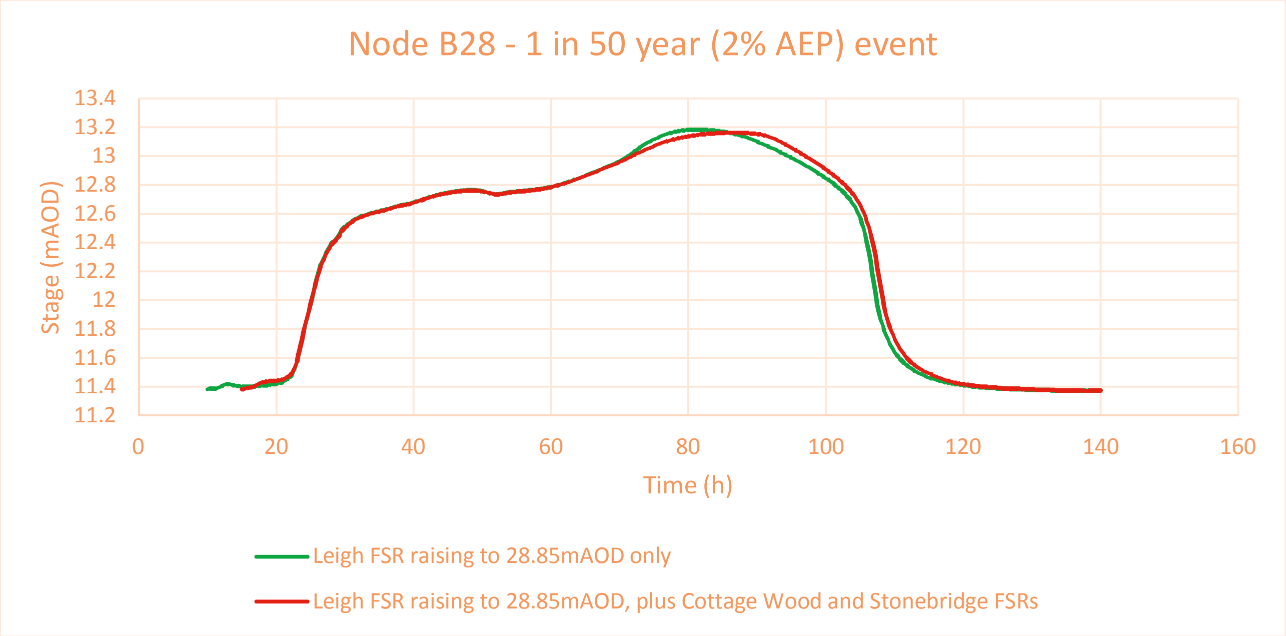

Figure 13j Modelled peak water levels at node B28 immediately downstream of the confluence of the River Beult and the Lesser Teise, with and without the Cottage Wood and Stonebridge FSAs in place. 2% (1 in 50 year) AEP event as modelled for Stonebridge. The peak is lowered by approximately 0.02m and delayed by 5 hours.

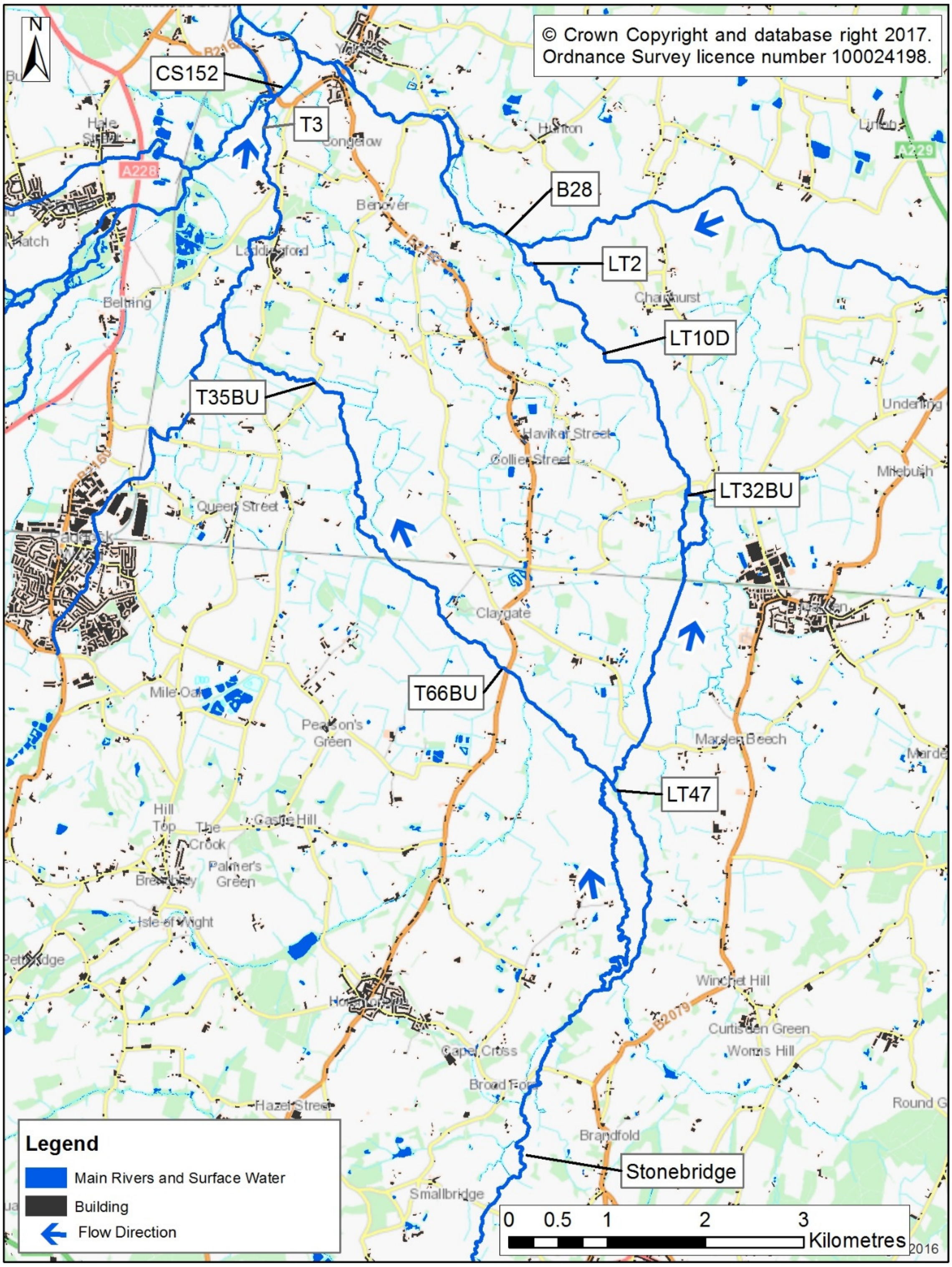

Figure 14 Locations of nodes used in Figures 13.

2.3 Downstream Storage

2.3.1 Early Drawdown at Teston

Downstream of the confluence of the Beult and Medway at Yalding the River Medway is maintained as a navigable channel, with levels controlled by the single lifting sluice at Teston. This sluice can be drawn up to allow flood flows to pass downstream and reduce the period that the river experiences out-of-bank flow. Similarly, the next weir downstream, at East Farleigh, contains two lifting sluices which can help control water levels between Teston and East Farleigh. For locations see **Figure 15**.

We have considered whether the sluice at Teston could be drawn when warning of a flood approaching along the catchment is first received, i.e. when impoundment commences at Leigh FSR, or flood warnings are received from the Smarden (Beult) or Lamberhurst (Teise) level gauges. This would allow approximately 24 hours for the water level in the Medway to be lowered before the flood arrives. In turn this would provide downstream storage before the level is high enough to cause backing-up along the Beult and Teise.

The hydraulic model has been used to assess whether the early drawdown would provide a significant volume of storage. Using a 2% (1 in 50 year) AEP event as modelled for East Peckham on the Medway we set the Teston sluice fully open half an hour after the onset of heavy rainfall (to allow time to notify the boat owners). The hydraulic model output starts 10 hours into the event to allow time for any start-up stability issues to be settled (this is standard modelling practice).

We observe in the model that water levels between Hampstead Marina and Teston are reduced up to 11 hours 40 minutes into the flood (**Figures 16a, b**), but then start to rise again, exceeding bank level around Wateringbury after 15 hours (**Figure 16c**), coming out of bank at Hampstead Marina at 20 hours (**Figure 16d**) and proceeding to rise (**Figure 16e**) until reaching a peak at 80 hours (**Figure 16f**). The difference in water level between the baseline (undefended) scenario and the early drawdown at Teston Sluice is measurable up to 40 hours into the flood at Hampstead (**Figure 17a**) and slightly later at Teston (**Figure 17b**) but negligible at the peak. **Figures 16a to 16f** are taken from an animated sequence of water levels output from the hydraulic model. They show a long section along the Medway from Kenward (CS157), upstream of Hampstead Marina on the far left to Teston Weir (node CS172), followed by Teston Bridge (node CS176U), on the right. As the water level rises downstream of Teston Weir the relative effect of the constriction at Teston Bridge develops a greater significance, and the backwater gradient (the slope of the water surface heading downstream) also increases upstream from Teston Weir. This demonstrates that, although opening the sluice early could provide additional protection in a small flood event, such events are unlikely to generate out-of-bank flooding in Yalding. Those events that are large enough to cause widespread property flooding (e.g. 2% AEP modelled event above) would be too large for the early drawdown approach to provide any useful protection.

Further proposals to consider early drawdown at East Farleigh and at Allington further downstream would work on the same principle, but unfortunately would have a minimal effect at Yalding as the constriction at Teston Bridge would still cause backing-up in larger floods.

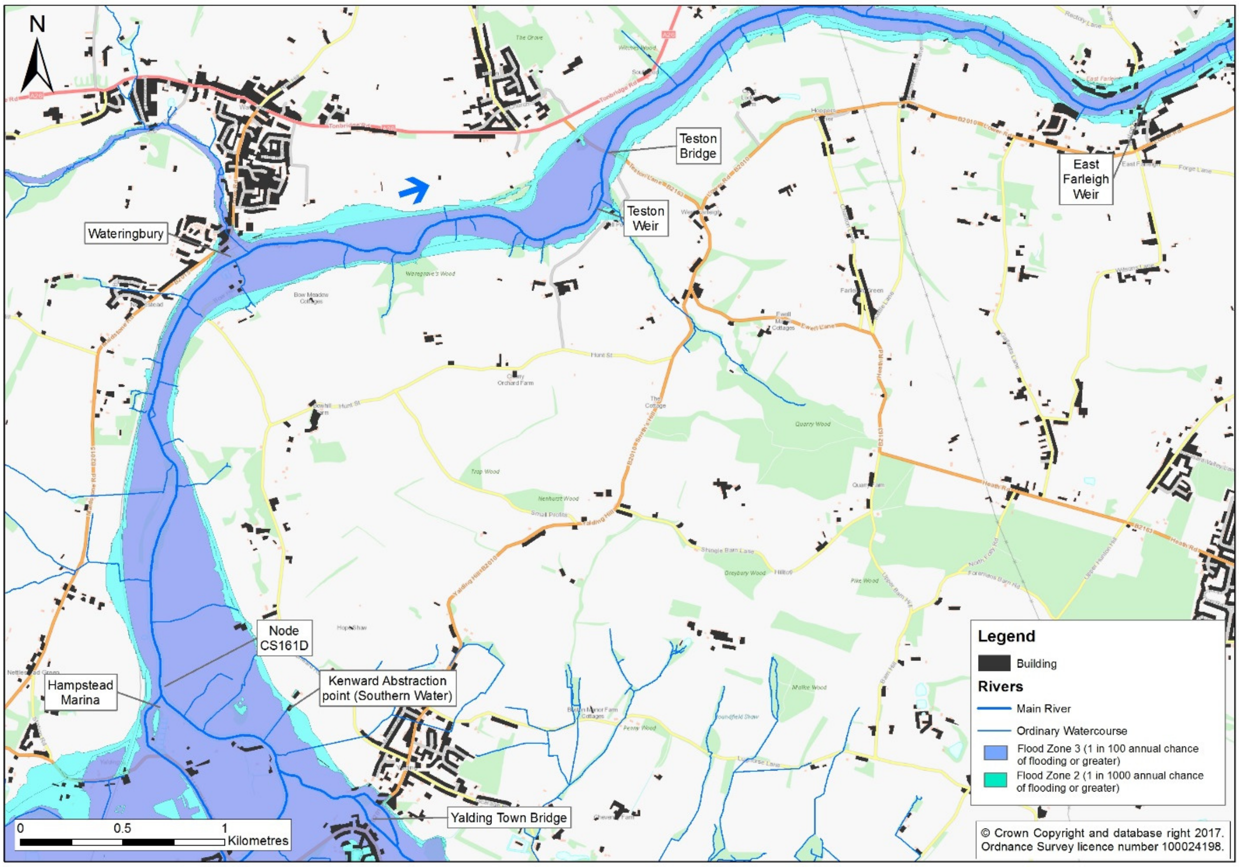

Figure 15 Locations along the River Medway downstream from Yalding, also showing the Environment Agency Flood Zones. This clearly shows how the valley is tightly constrained around Wateringbury (see also Figure 8)

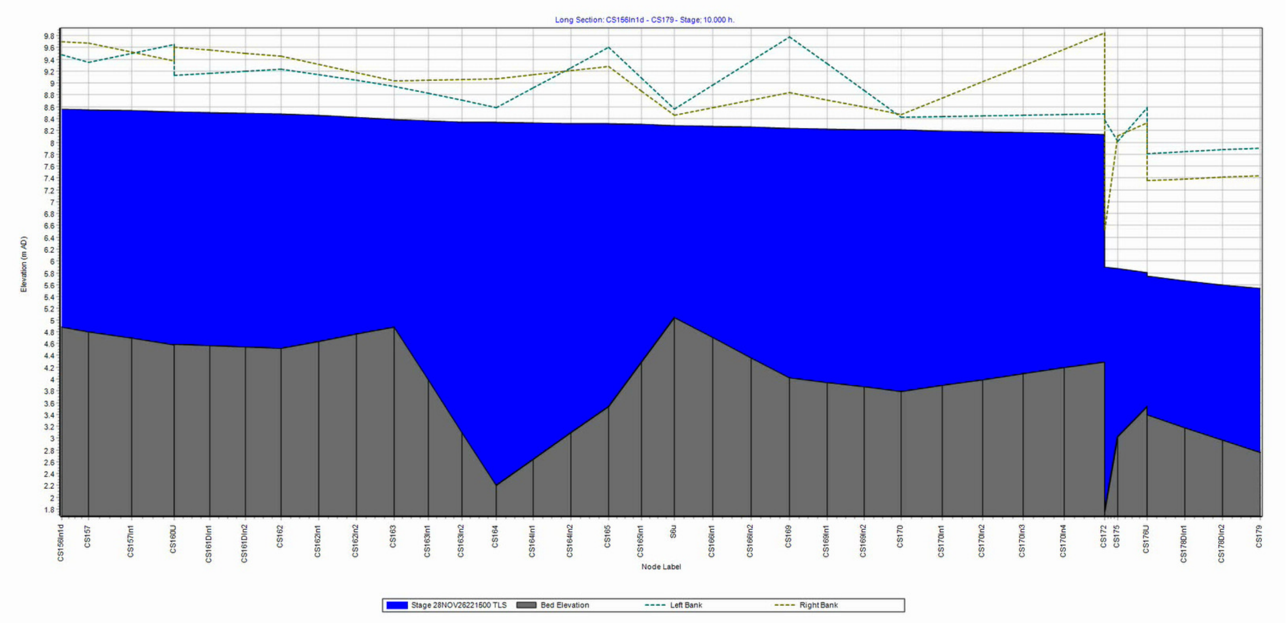

Figure 16a Early drawdown option modelled water levels between Hampstead Marina and Teston Bridge – 10 hours into 2% (1 in 50 year) AEP event as modelled for East Peckham.

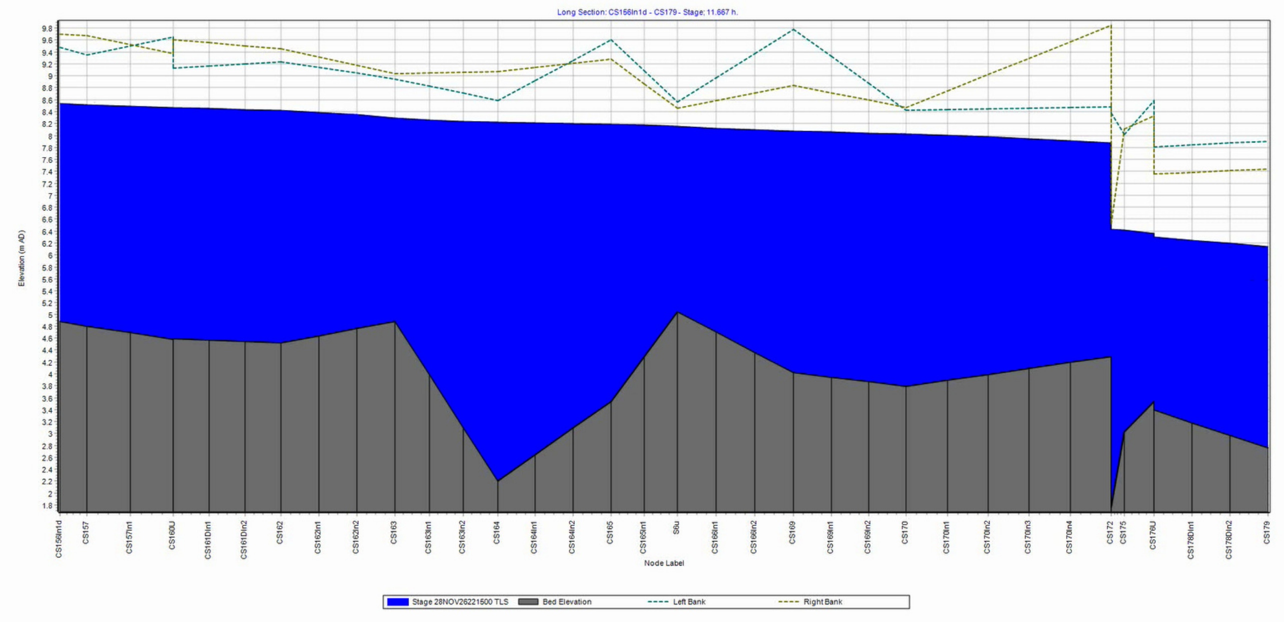

Figure 16b Early drawdown option modelled water levels between Hampstead Marina and Teston Bridge – 11 hours 40 minutes into 2% (1 in 50 year) AEP event as modelled for East Peckham.

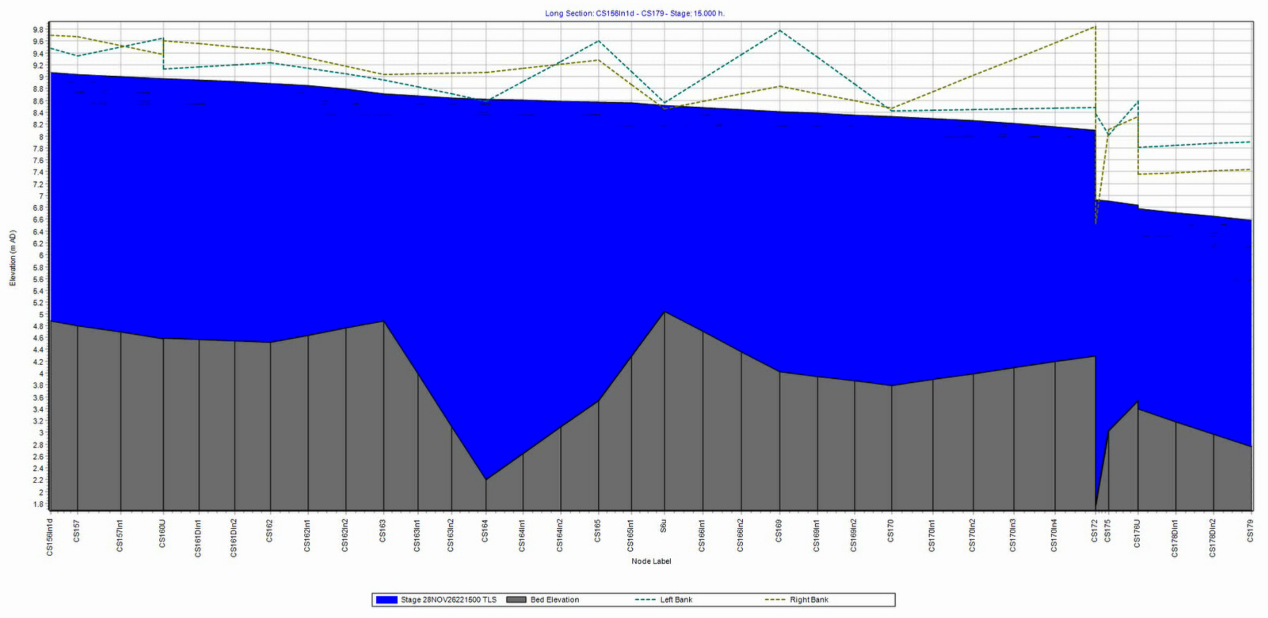

Figure 16c Early drawdown option modelled water levels between Hampstead Marina and Teston Bridge – 15 hours into 2% (1 in 50 year) AEP event as modelled for East Peckham (first flows out of bank).

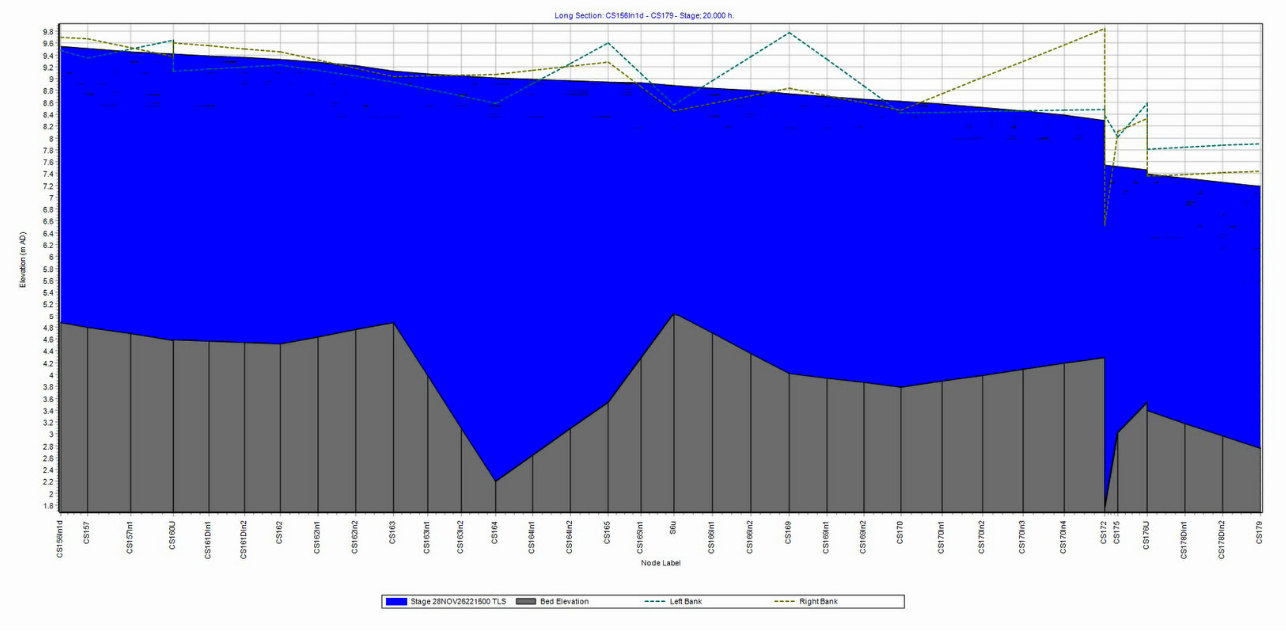

Figure 16d Early drawdown option modelled water levels between Hampstead Marina and Teston Bridge – 20 hours into 2% (1 in 50 year) AEP event as modelled for East Peckham (water out of bank at Hampstead Marina).

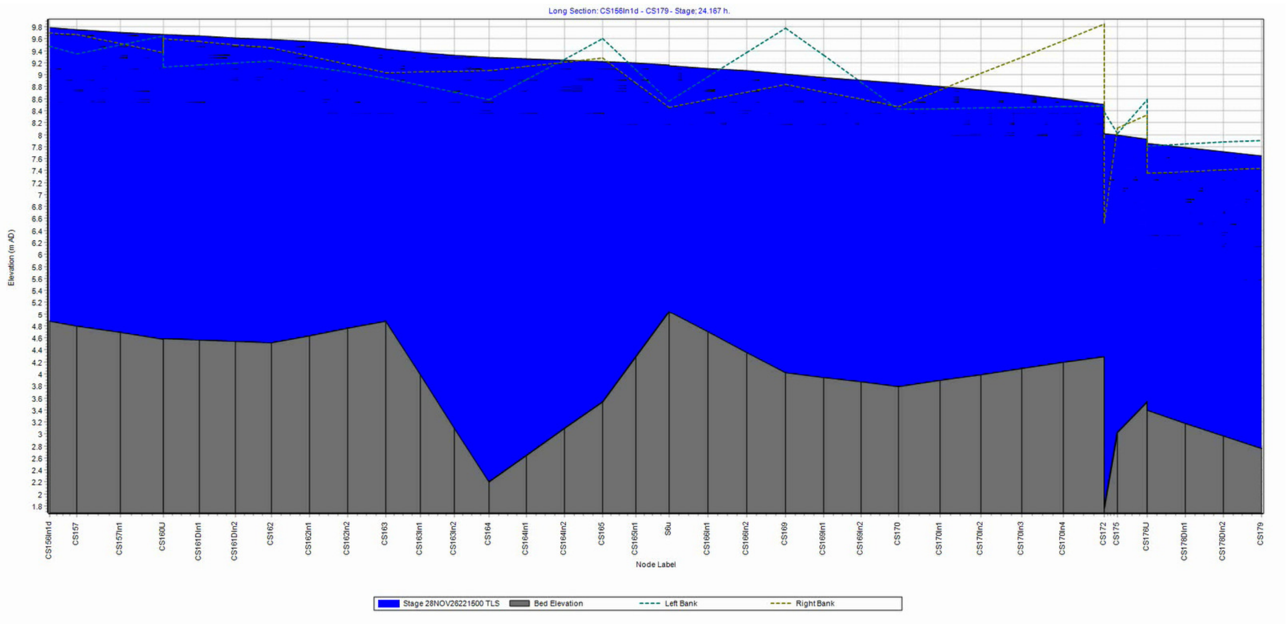

Figure 16e Early drawdown option modelled water levels between Hampstead Marina and Teston Bridge – 24 hours 10 minutes into 2% (1 in 50 year) AEP event as modelled for East Peckham (Water out of bank immediately upstream of Teston Weir).

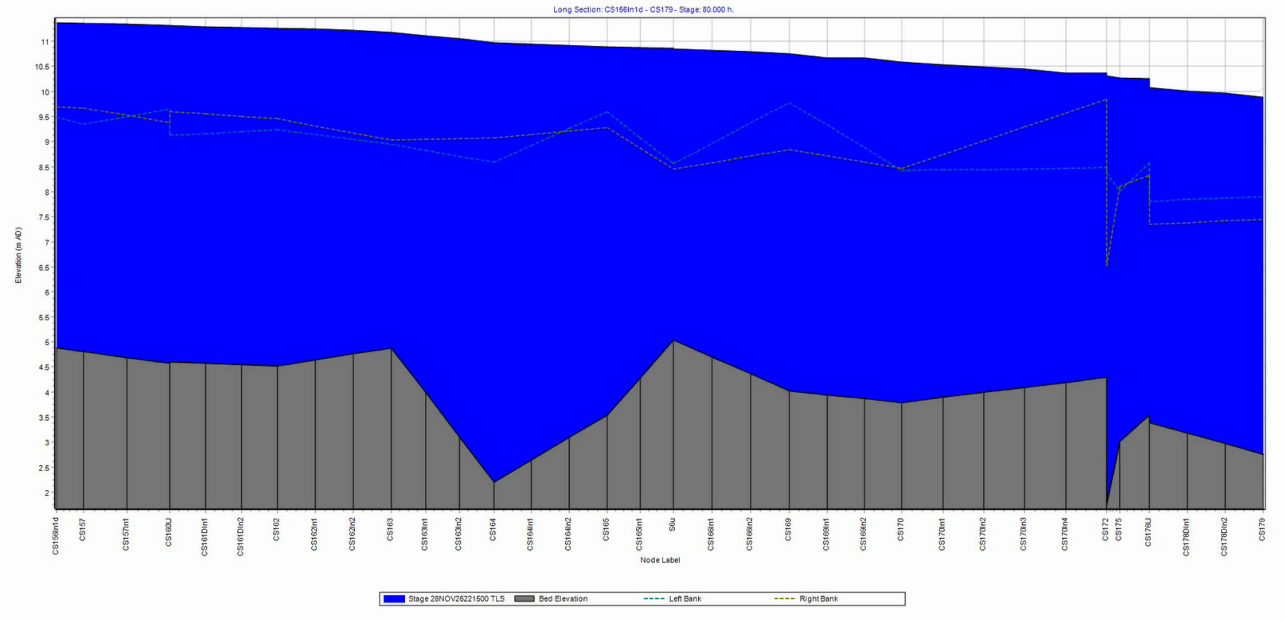

Figure 16f Early drawdown option modelled water levels between Hampstead Marina and Teston Bridge – 80 hours into 2% (1 in 50 year) AEP event as modelled for East Peckham (water 1.75m above bank level at Hampstead Marina).

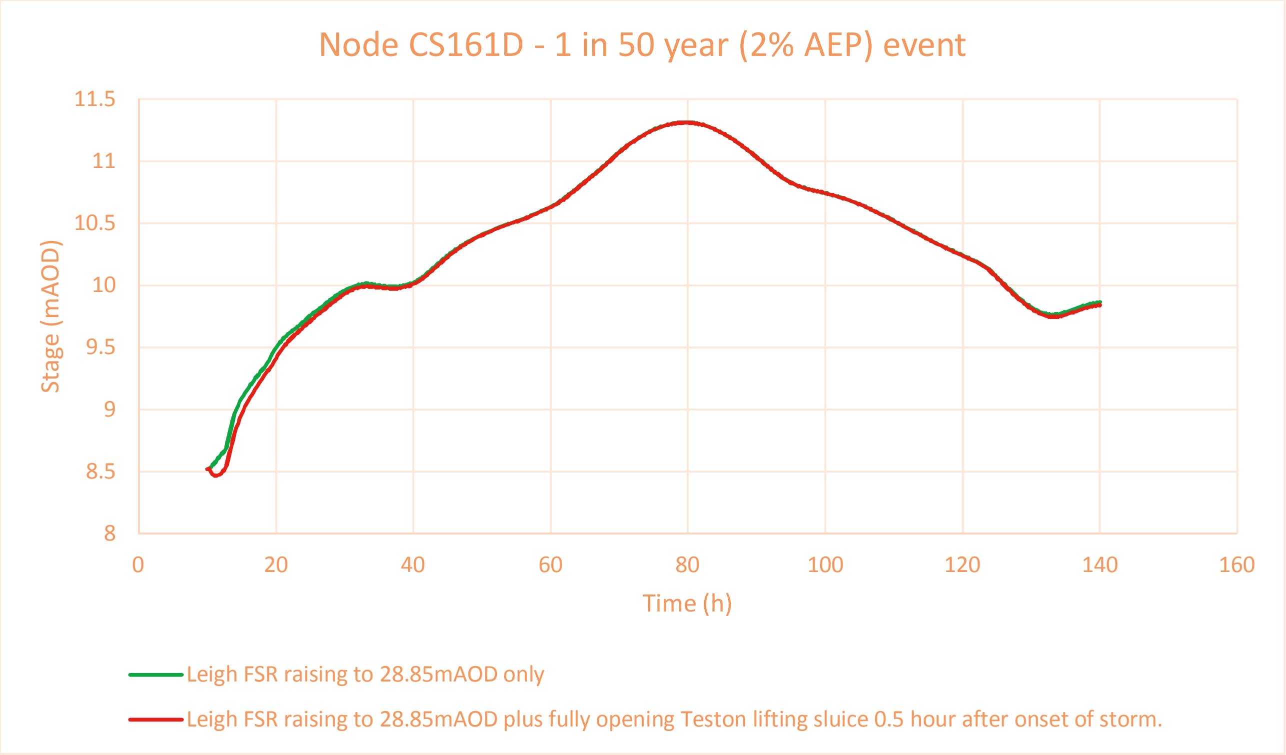

Figure 17a Early drawdown option modelled water levels at model node CS161D at the downstream confluence of Hampstead Lock Cut and the River Medway for a 2% (1 in 50 year) AEP event as modelled for East Peckham. The early drawdown provides marginal additional storage up to 40 hours into the flood event, but still exceeds bank level (9.5mAOD) after 20 hours and reaches a peak of approximately 1.75m above bank level around 80 hours.

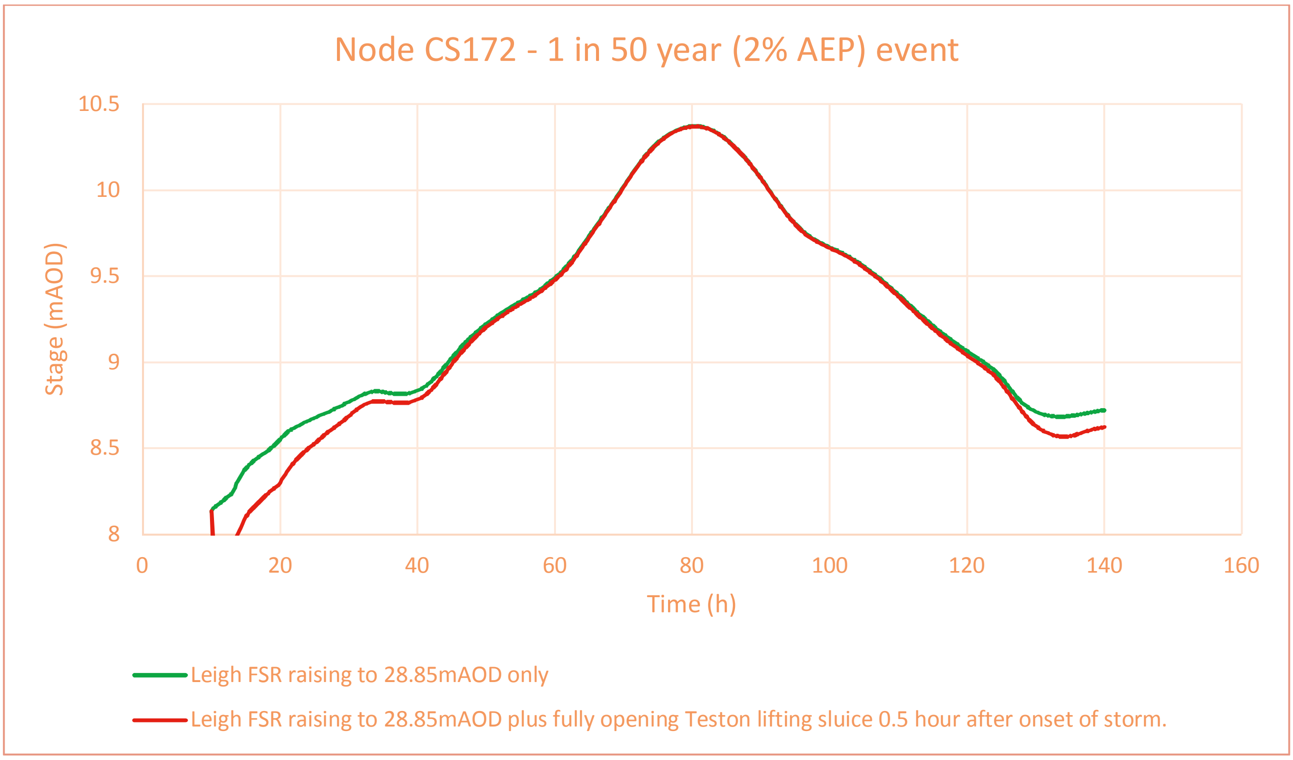

Figure 17b Early drawdown option modelled water levels at model node CS172 immediately upstream of Teston Sluice for a 2% (1 in 50 year) AEP event as modelled for East Peckham. The early drawdown here continues to provide additional storage up to 50 hours into the flood event, but has negligible effect after this point.

2.4 Conveyance Improvements

2.4.1 Medway Yalding Bypass

One option which Arcadis have been asked to consider is the provision of a diversion channel from East Peckham to downstream of Yalding, to take high flows in the Medway away from The Lees and feed these back into the Medway downstream of the Beult confluence at Nettlestead.

There are two possible options for a bypass route. These are:

i. west of the railway, and
ii. east of the railway.

West of the railway would involve a new channel cut from just upstream of the Medway railway bridge downstream of Branbridges, running parallel with the railway to north of the former Syngenta site and passing under the railway in a new bridge to rejoin the Medway north (downstream) of Hampstead Marina (see **Figure 2** for locations). This would involve some particularly deep excavation at the northern end, as well as a new railway bridge. This is the option that has been modelled.

East of the railway would pass through the former Syngenta site. Although the ground here has been remediated, the remediation only covers surface layers and so a deep excavation to take a river channel would expose a considerable volume of potentially contaminated material. This would incur a very high cost for spoil disposal as the ground materials may be classified as Hazardous waste. In view of this the east of the railway option is not progressed with any further. In any event, the effect on flooding would be similar to the west of the railway bypass approach to understand the likely hydraulic impacts of this alternative option.

We have inserted into the model a trapezoidal channel 5m wide at the bed and 10m wide at the bank crests, diverging from the River Medway immediately upstream of the railway bridge, passing along the west side of the railway and intercepting Coult Stream, before passing under the railway at Nettlestead and re-joining the

River Medway at Nettlestead approximately 250m downstream of the confluence of the Hampstead Lock Cut and the River Medway north of Hampstead Marina (**Figure 18**).

The model has been run for a 2% (1 in 50 year) AEP event as modelled for East Peckham, and the stage hydrograph (the plot of water level against time) is given in **Figures 19a and 19b**, comparing the levels with and without the bypass channel at two locations, node CS161D which is at the confluence of the Hampstead Lock Cut and the River Medway downstream from Hampstead Marina (**Figure 19a**) and node CS152 on the River Medway just downstream of Twyford Bridge, adjacent to The Lees (**Figure 19b**).

Figure 19b demonstrates that the peak water level at The Lees could be reduced in a 2% (1 in 50 year) AEP event by approximately 20mm, to a maximum of approximately 11.39mAOD, and would exceed bank level at The Lees (10.1mAOD) for approximately 100 hours.

In **Figure 20** the modelled maximum flood extent, with depths, is marked on the map of Yalding demonstrating the extent of flooding for a 2% (1 in 50 year) AEP event with the bypass channel in place.

The modelling therefore indicates that a bypass channel would have negligible effect in preventing flooding at Yalding and we do not recommend that this is progressed.

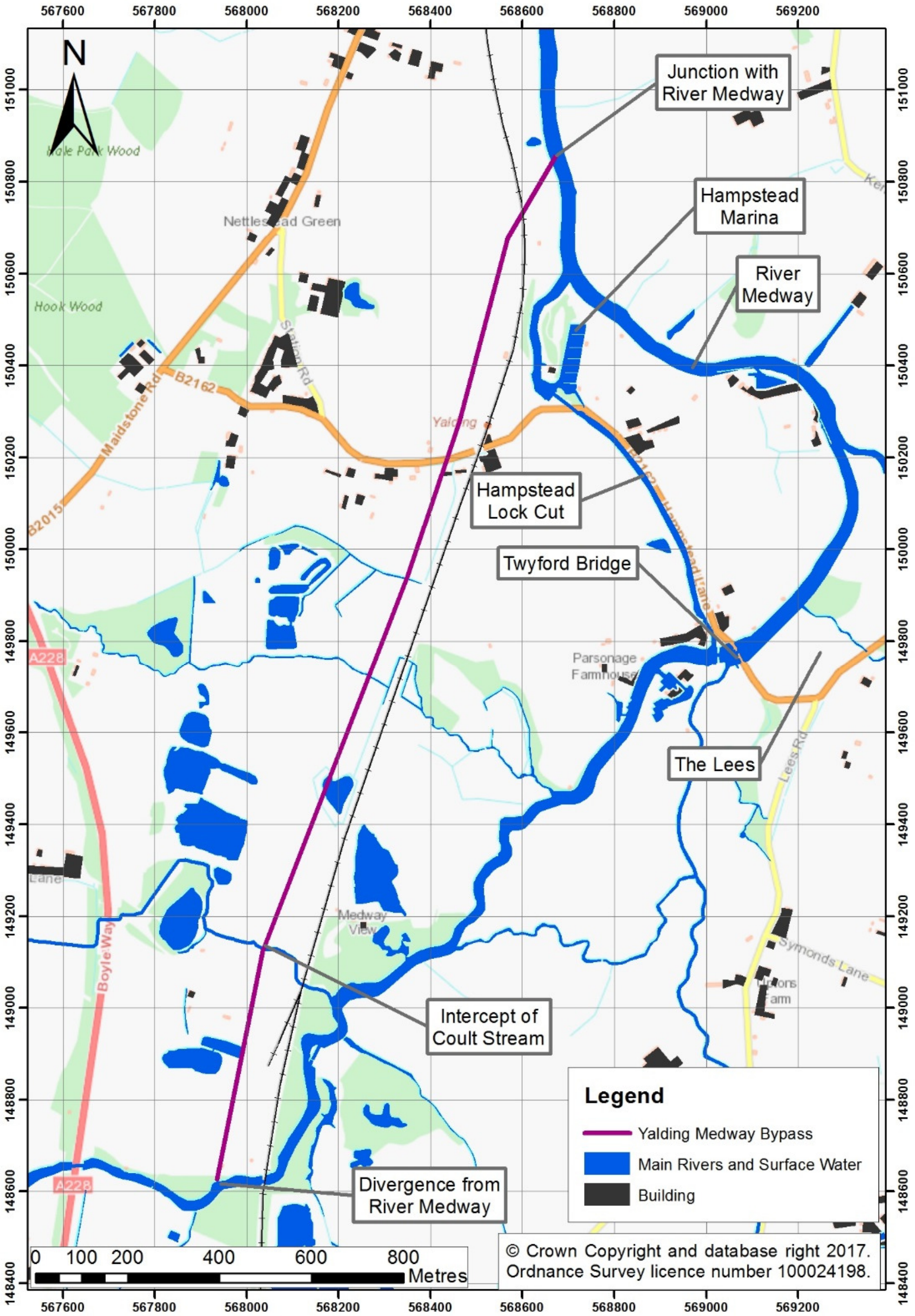

Figure 18 Modelled alignment of Yalding bypass channel.

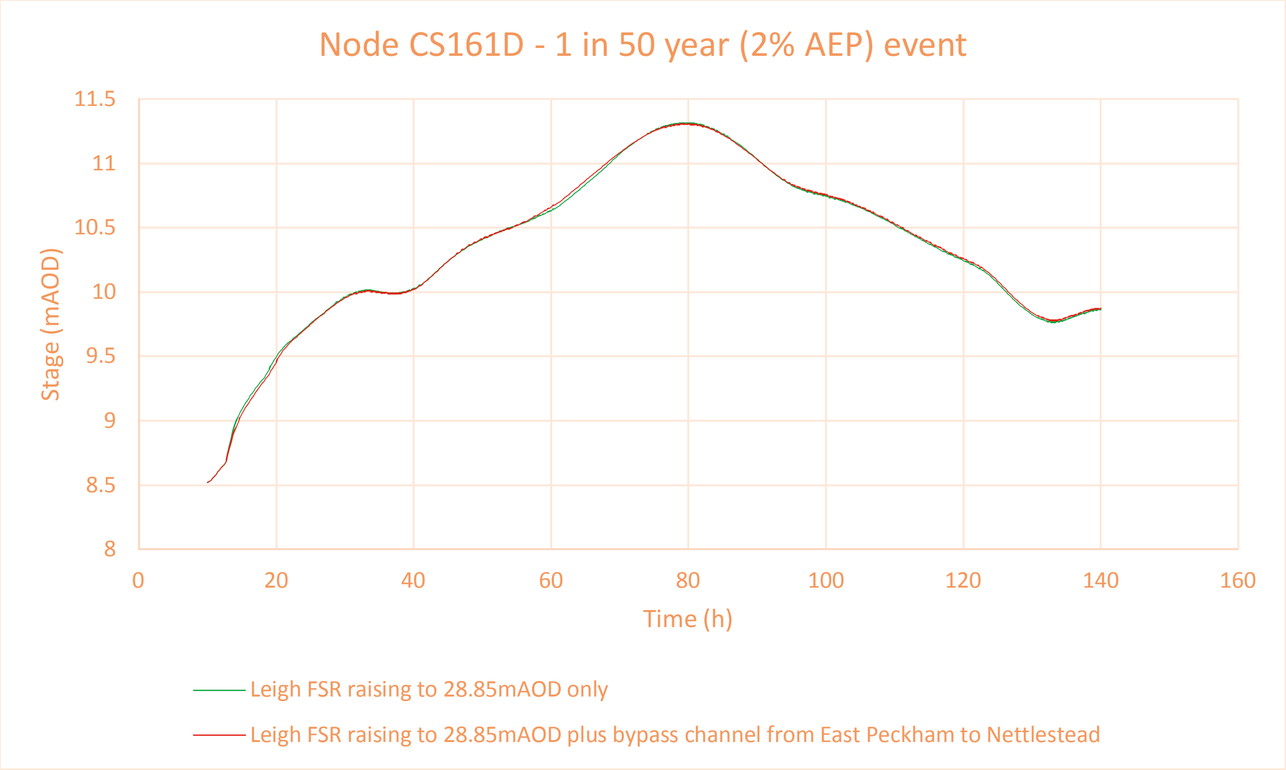

Figure 19a Modelled water levels at model node CS161D at the downstream confluence of Hampstead Lock Cut and the River Medway for a 2% (1 in 50 year) AEP event as modelled for East Peckham, with and without the proposed bypass channel.

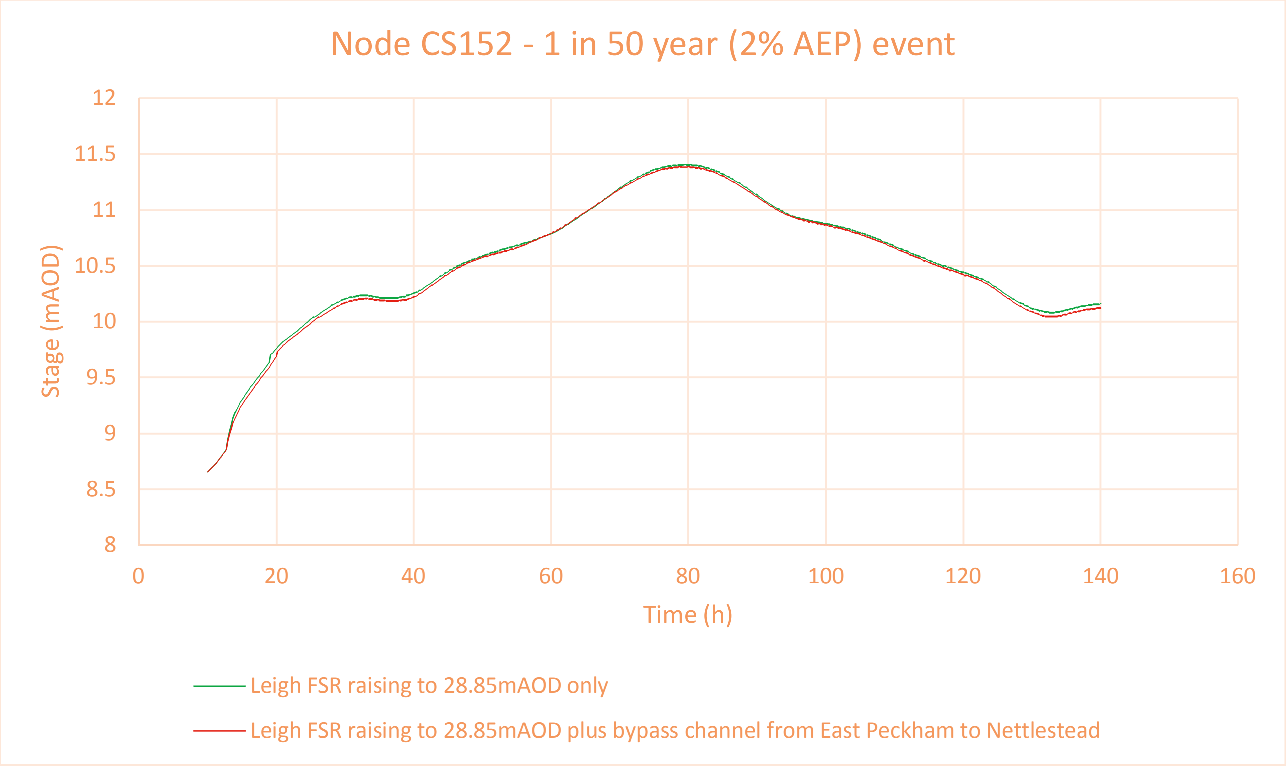

Figure 19b Modelled water levels at model node CS152 downstream of Twyford Bridge adjacent to The Lees for a 2% (1 in 50 year) AEP event as modelled for East Peckham, with and without the proposed bypass channel.

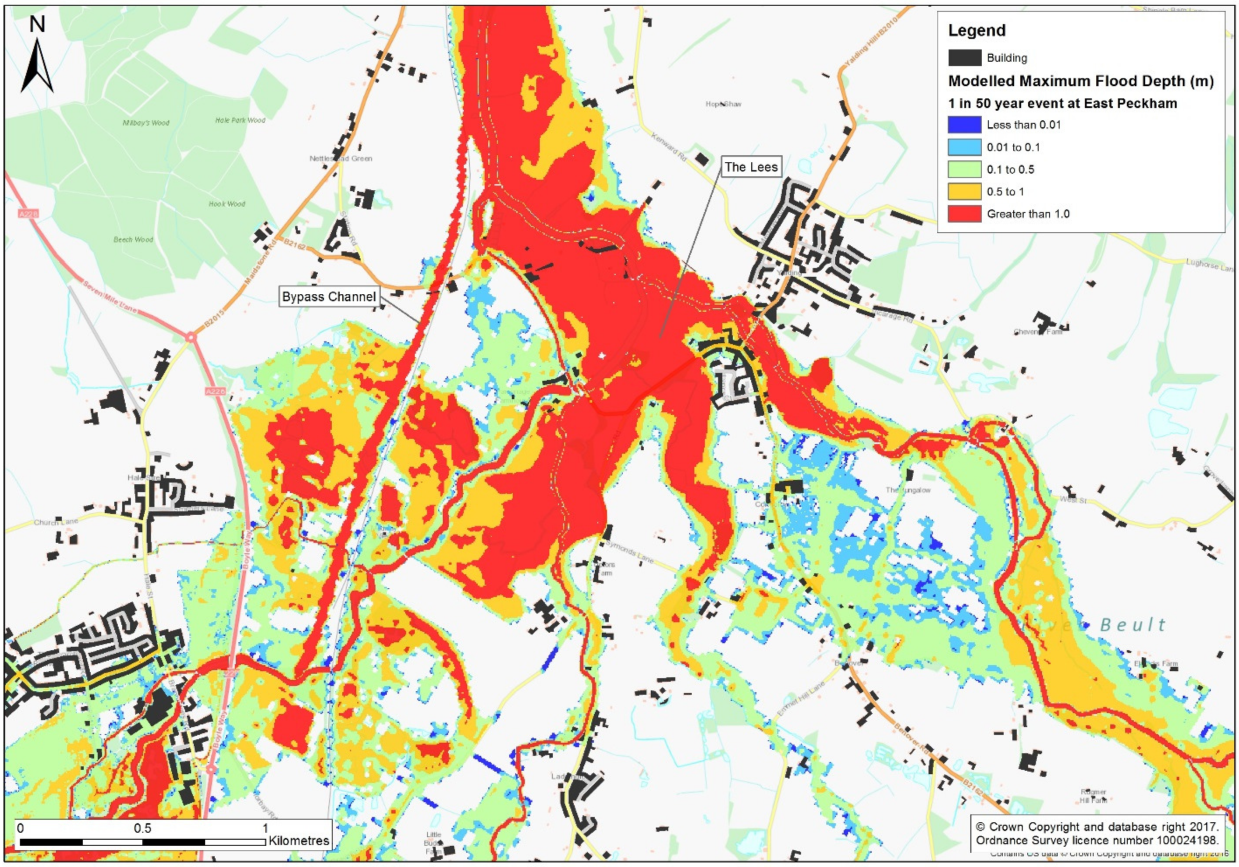

Figure 20 Modelled maximum flood depths for a 2% (1 in 50 year) AEP event as modelled for East Peckham, with the bypass channel in place.

2.4.2 Yalding Southern Bypass

One possible option is to formalise the IDB drain between Collier Street and Yalding as a bypass route and enlarge the channel with a bund along the right bank. This would involve significant excavation and construction, including bridges under Benover Road, Forge Lane, Emmet Hill Lane, Symonds Lane and Lees Road. Flows along the existing course of the Beult could be restricted to reduce the risk of damage to Town Bridge and the out-of-bank flows upstream of the bridge.

This would potentially leave Yalding still at risk from flood water backing up from the Medway along the Beult downstream of Town Bridge. This could be further addressed by a second control structure across the Beult adjacent to The Lees crossing downstream of The Tatt.

Such a scheme is likely to be very costly. It would also need to be combined with a version of the embankments and walls option to extend flood protection to Collier Street and Hunton, which would be unlikely to derive any benefit from the bypass route alone. For this reason we have not investigated this further.

2.5 Local Embankments

2.5.1 Collier Street – options on the Lesser Teise

The flooding in Collier Street has been identified in historic flood events as coming from the Lesser Teise. There is some slightly higher ground around Claygate which forms a barrier to overland flow from the western course of the River Teise towards Collier Street. Arcadis have been advised by local residents that the flooding in this area arises from three points (see **Figure 21**):

EXIT 1. out-of-bank flow east of Brook Farm at approximately NGR 573215 145400, which becomes channelled along Green Lane and affects Green Lane and Haviker Street;
EXIT 2. overland flow from approximately NGR 572410 147100 in a south-westerly direction towards Spitzbrook Cottages; and
EXIT 3. backing-up from the River Beult just downstream of its confluence with the Lesser Teise at NGR 571430 148320, along an Upper Medway Internal Drainage Board (UMIDB) drainage channel, affecting Den Cottages.

The hydraulic model also indicates some overland flow passing under the railway culverts indicated in **Figures 22a** and **24a**. This then flows north-westerly to the west of Brook Farm and into the area south of Green Lane, thence to Haviker Street. How these sources are dealt with in the model is detailed below.

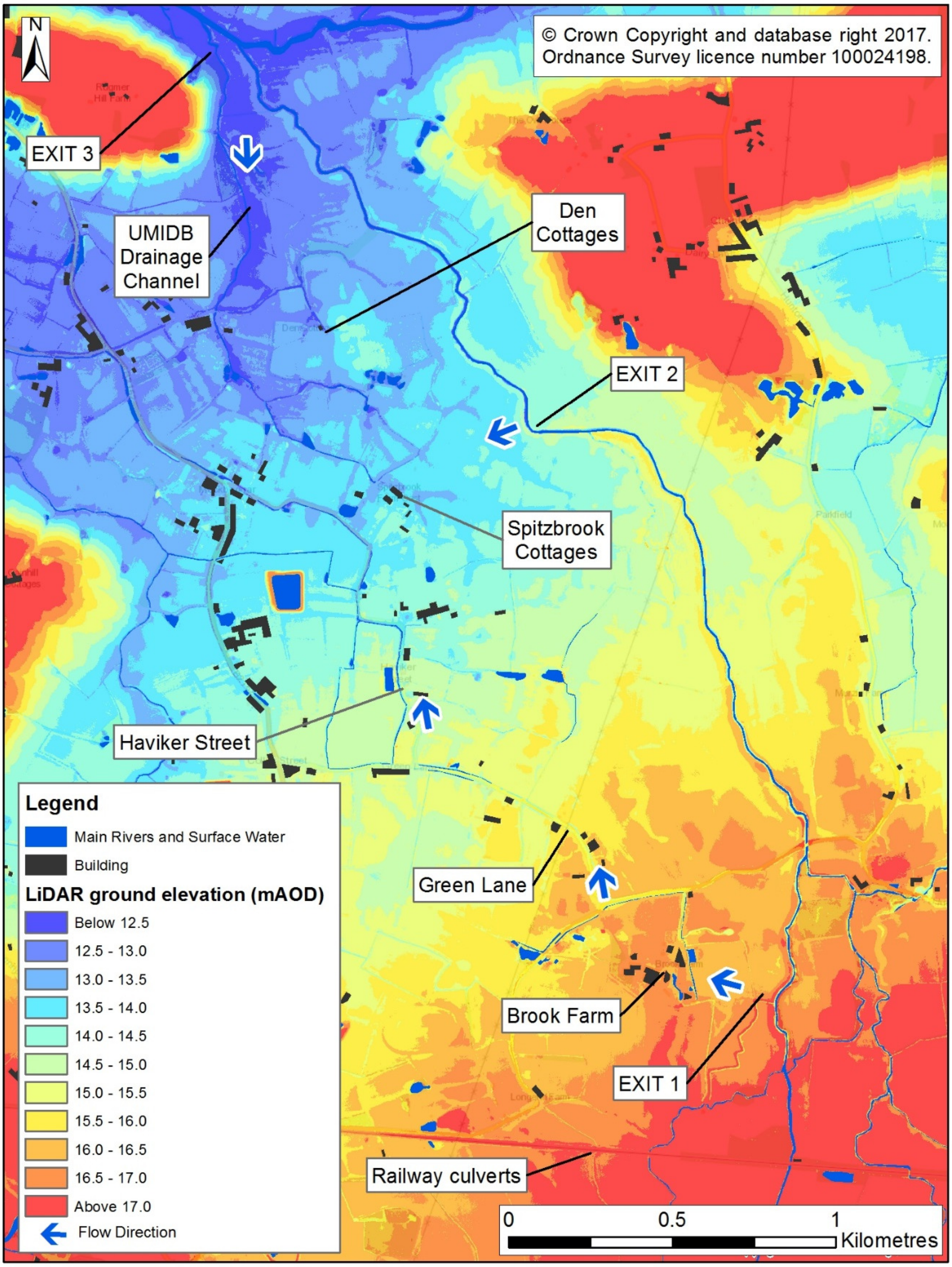

Figure 20 LiDAR Ground elevation plan showing the Lesser Teise downstream of the Paddock Wood to Marden railway line and observed overland flow routes.

EXIT 1

There is an informal flood bund along the left (west) bank of the Lesser Teise at Brook Farm, although this is understood to be in poor condition. This has not been specifically modelled in the hydraulic model to date. We have been asked to formalise this structure within the model to test if this would reduce flood risk to Green Lane and Haviker Street areas. An embankment 1m above current left bank crest level has been inserted into the model from the railway embankment to a point 200m downstream of Green Lane. In a 1% (1 in 100 year) AEP event (as modelled for Stonebridge) this embankment prevents overland flow past Brook Farm affecting Green Lane, although bypassing still occurs via several ditches culverted under the railway line between NGR 572797 144860 (420m west of the Lesser Teise bridge and 1,550m west of Marden railway station) and NGR 571390 144966 (1,150m east of the River Teise bridge and 4,170m east of Paddock Wood railway station). This bypass flow enters Green Lane opposite Haviker Street.

EXIT 2

Analysis of ground profiles using LiDAR indicates that the overland flow at Spitzbrook may be exacerbated by the Lesser Teise running downhill in a westerly direction and then curving 90 degrees to the north in what appears to be a slightly perched channel with the ground falling away slightly to the west. Therefore water is more likely to come out of bank at the corner, and would be unlikely to return to the channel once out of bank. At this location the model does not indicate any overland flow, although water is shown to come out of bank on the left bank downstream of here. To address this in the modelling a bund has been inserted from 10m upstream of the 90 degree bend all the way down to just beyond the confluence with the River Beult. The bund has been made a minimum of 1m above existing ground level, although it is required to be higher than this nearer to the Beult confluence and this will be addressed below.

EXIT 3

The baseline model run demonstrates clearly how water backs up the UMIDB drainage channel from just downstream of the confluence of the Beult and the Lesser Teise, and then passes into Benover Road and flows into Yalding along the roadway, past Symonds Lane. This route also sees water backing up from Yalding along Benover Road. The model output indicates peak water depth at the confluence of the UMIDB drain and the Beult, in a 1% (1 in 100 year) AEP event, to be 1.4m, and the ground elevation at this point (measured using LiDAR) is 12.3mAOD so the bund crest height is fixed in the model at a minimum of 13.8mAOD. We have inserted a bund along the left bank of the Lesser Teise into the model, as described under ‘Exit 2’ above. This extends down to the area of high ground on the left bank of the Beult immediately downstream of the UMIDB drain confluence. We have inserted one-way flow valves in the model at the confluence to prevent water backing up the UMIDB drain, but still allow it to flow out into the Beult except when levels in the Beult exceed the drain level.

Once the bunds at all three flood flow exits were included in the model, and overland flow through the culverts under the railway line restricted by throttling to one quarter of their cross-sectional area, the model was run again. This demonstrated that throttling flow through the culverts under the railway was ineffective as the railway embankment was being overtopped. To counter this we made a further change to the model, by extending the 1m high embankment along the left (west) bank of the Lesser Teise upstream from the railway embankment. The model was then run for both the 2% (1 in 50 year) and 1% (1 in 100 year) flood events, as modelled at Stonebridge.

Figure 22a shows the baseline flood extent (with depths indicated) for a 2% (1 in 50 year) AEP flood event as modelled at Stonebridge, **Figure 22b** the flood extent with the bunds and one-way flap valves included (at Exit 3) for the same event and **Figure 22c** shows the difference in flood depths, indicating where improvement is observed and where flooding is exacerbated as a result of reduced area of floodplain available.

Figure 22c also shows the locations of properties affected by the presence of the left bank bunds. In a 2% (1 in 50 year) AEP flood event there would be 173 properties with reduced risk of flooding, mostly in Collier Street and Benover, and 302 properties with no discernible change in flood risk within model tolerances. However, there are 193 properties with increased flood risk. These are located in Marden, Tilden, Hunton, Yalding, Wateringbury and East Farleigh. The worst affected area is Meades Close, Marden, with flood depths increased by up to 0.4m (and in four cases above this). The more downstream locations are generally affected less – of the properties affected by a peak water level increased by greater than 0.1m only four are in Hunton and one in Yalding whilst 53 are located in Marden and Tilden. Note these properties may be affected less once detailed threshold surveys are taken into consideration. As mentioned above, only selected properties have been surveyed.

Figures 23a and **23b** shows the difference in peak flood water level at node LT32BU (Spits Bridge on Green Lane) and at node B8U on the River Beult just upstream of Town Bridge. **Figure 23a** shows that the presence of bunds on the left bank increases peak water level within the Lesser Teise by greater than 0.4m, which supports the flood extents in **Figure 22c**.

The modelling indicates that the bunds on the Lesser Teise would be effective in significantly reducing property flooding in Collier Street in a 2% (1 in 50 year) AEP flood. They would also remove the flow route into the south end of Yalding through Benover. However, by constraining flow in the Lesser Teise this both increases flooding on the right bank and also accelerates flow downstream, leading to marginally higher peak water levels further down the catchment.

There is a case for undertaking further investigation, including additional model runs, with the bunds set back from the left bank closer to Collier Street, and with short bunds at Marden to protect the properties there. Marden, being a concentrated urban area, is more easily defended than for spread-out communities such as Collier Street. This may be a more optimal solution, although the properties at Tilden are widespread and not so easily protected. Tilden is also at risk of flooding from both directions – from the Lesser Teise to the south-west and also from the Beult to the north-east.

A further proposal from the JPFG is to enlarge and clear the existing ditch from Green Lane at NGR 572420 145940 to the Lesser Teise. This could help to drain the overtopped flood water once it is in Green Lane. If a setback bund was constructed along the left bank of this ditch instead of along the Lesser Teise this would leave a larger area of floodplain for storage. This is elaborated on in section 2.5.3 below. During a site visit in February 2017 it was observed that this ditch, and a second ditch to the north-west, included sections which had recently been cleared by riparian owners, and sections which featured accumulations of vegetation.

It should be noted however that there is a risk that clearing these ditches could potentially open up a flow route for water backing up from the Lesser Teise, or entering the Lesser Teise catchment by overland flow from the Beult through Tilden.

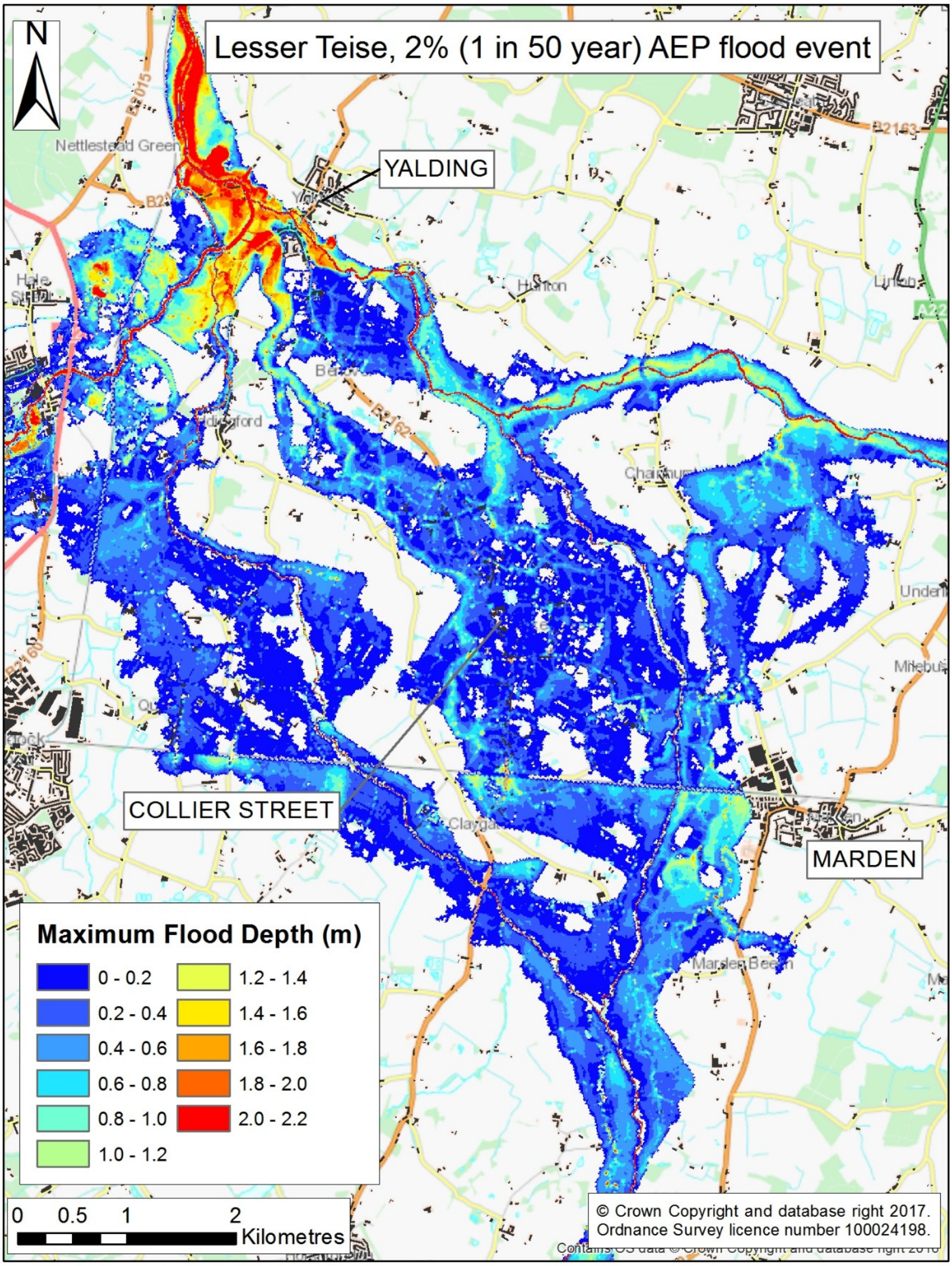

Figure 22a Maximum flood extent for a 2% (1 in 50 year) AEP flood event (as modelled for Stonebridge), baseline condition.

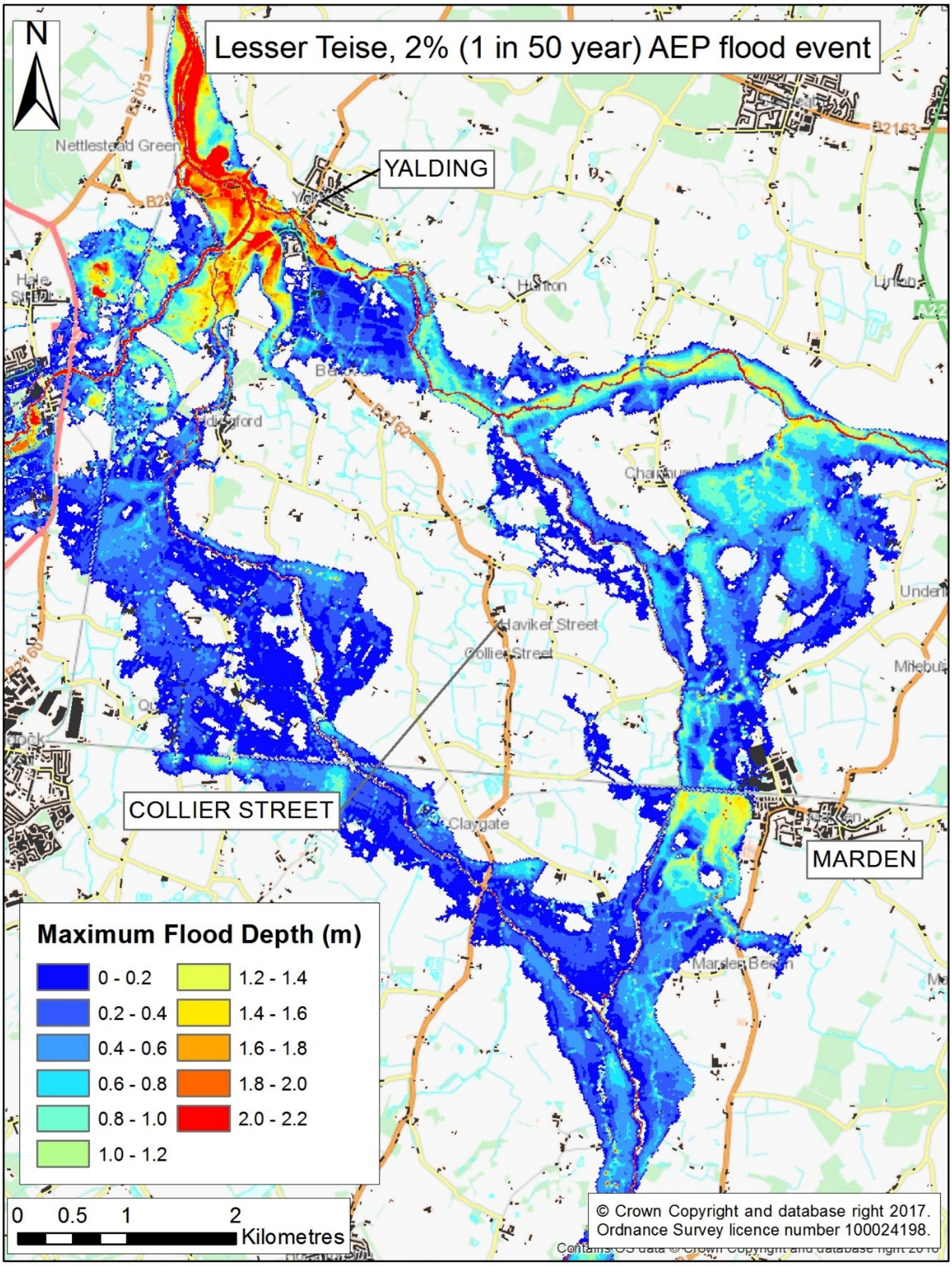

Figure 22b Maximum flood extent for a 2% (1 in 50 year) AEP flood event (as modelled for Stonebridge), improved left bank bunds on the Lesser Teise.

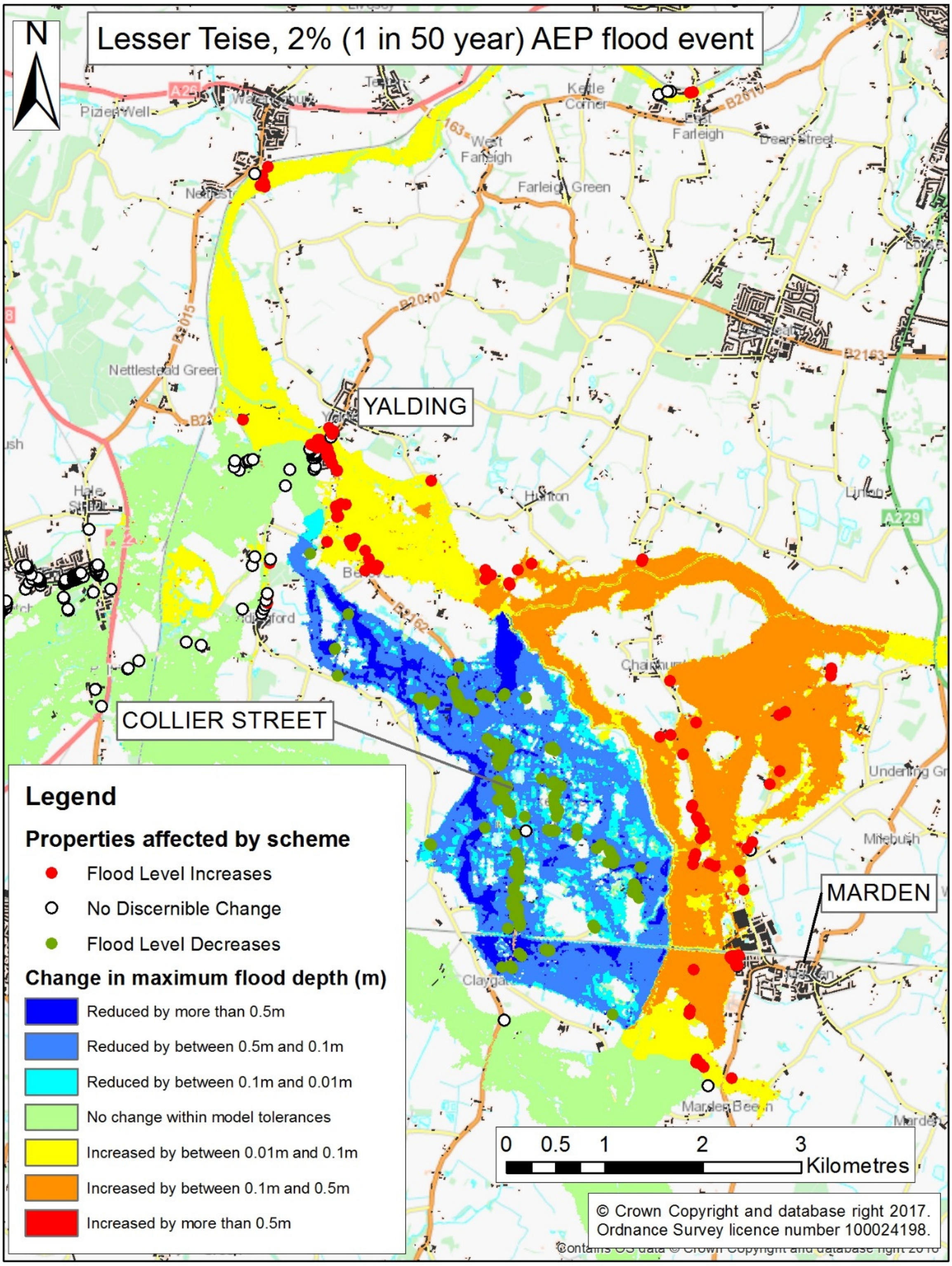

Figure 22c Difference in flood elevations for a 2% (1 in 50 year) AEP flood event (as modelled for Stonebridge), improved left bank bunds on the Lesser Teise compared to baseline condition. Includes properties showing a change in flood risk.

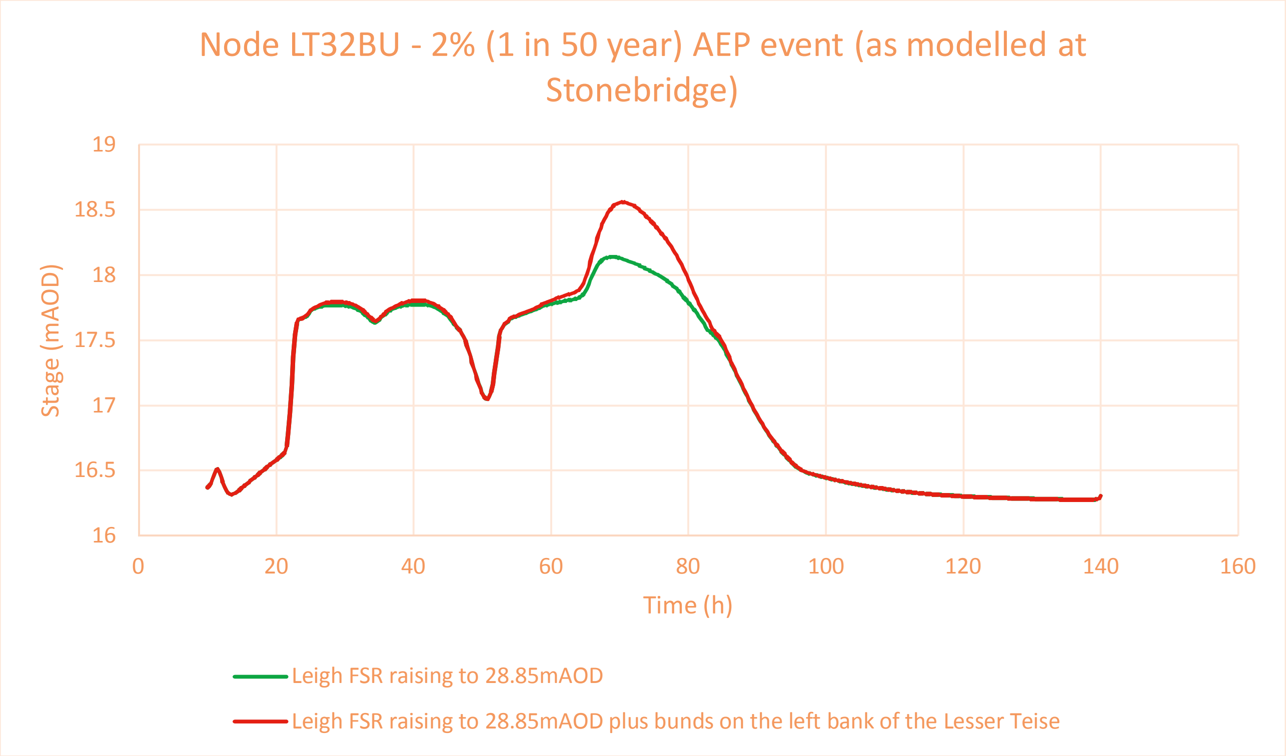

Figure 23a Difference in peak flood level for a 2% (1 in 50 year) AEP flood event (as modelled for Stonebridge), at node LT32BU at Green Lane bridge, improved left bank bunds on the Lesser Teise compared to baseline condition. The presence of the defences along the Lesser Teise increases peak flood level by 420mm.

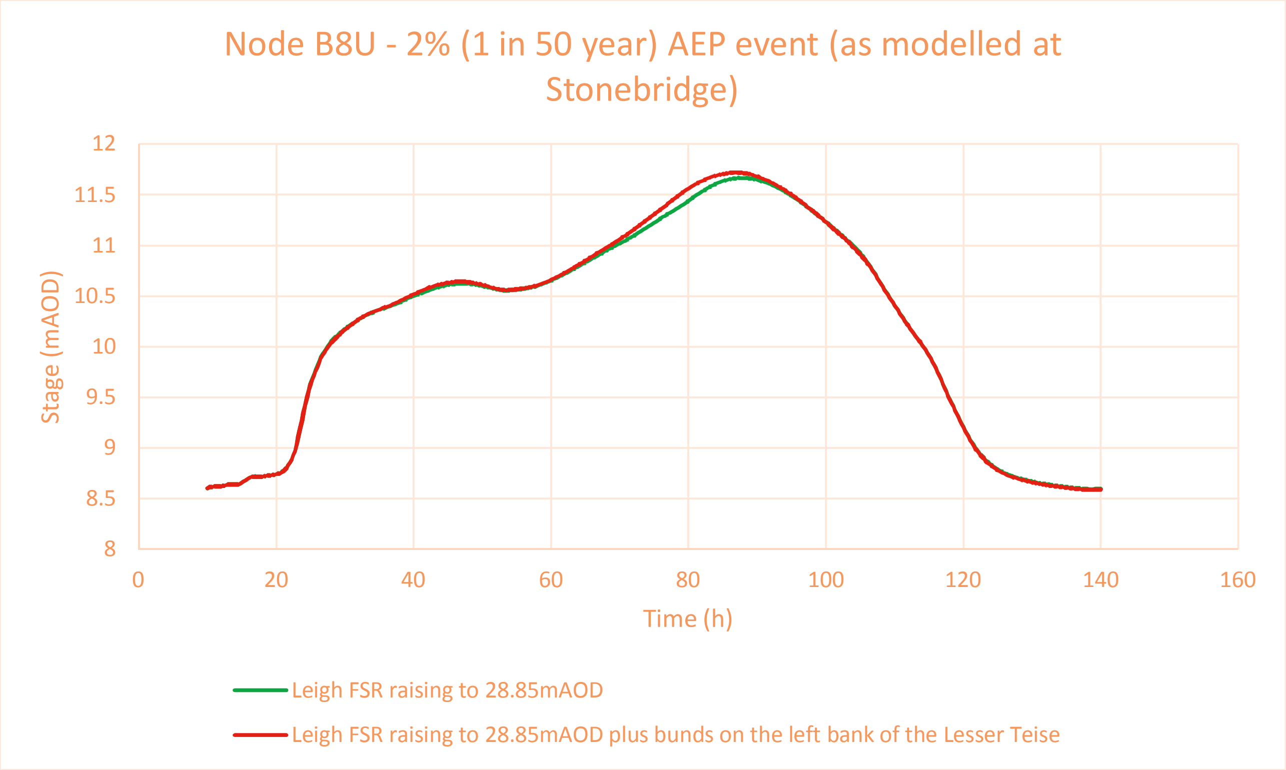

Figure 23b Difference in peak flood level for a 2% (1 in 50 year) AEP flood event (as modelled for Stonebridge), at node B8U immediately upstream of Town Bridge at Yalding, improved left bank bunds on the Lesser Teise compared to baseline condition. The presence of the defences along the Lesser Teise increases peak flood level by 53mm.

The 1% (1 in 100 year) flood event as modelled at Stonebridge was also used to test the left bank bunds option as above, and the results are given in **Figures 24** to **25**.

Even in a 1% (1 in 100 year) AEP event, although the railway would be overtopped, the flow of water overland from the south is considerably reduced (**Figure 24b**) and could probably be constrained locally using sand bags and barriers to train flow away from the lowest-lying properties that might remain at risk.

Considerably greater numbers of properties would be adversely affected by the presence of the bunds than would be affected in a 2% (1 in 50 year) AEP flood (**Figure 24c**). In a 1% (1 in 100 year) event 190 properties would experience a reduction in flood risk, 401 would see no discernible change within model tolerances, and 376 properties would experience increased peak flood depths of greater than 0.01m. Of those 376, 66 (all in Marden and Tilden) see peak water levels increased by greater than 0.1m. Areas not subject to any change in flood risk in a 2% (1 in 50 year) event which do experience worse flood risk in larger floods include some properties in Laddingford.

Given the increase in numbers of properties affected downstream, we suggest there might be a limit on how much protection can be offered by bunds along the Lesser Teise. 2% (1 in 50 year) AEP protection might be possible, with changes to the layout of the bunds to avoid increasing flood risk elsewhere. However, bunds capable of defending properties to a 1% (1 in 100 year) AEP standard would probably be certain to cause detriment somewhere due to the volume of water passing through the catchment and the presence of some properties in every area flood water could be diverted to or through.

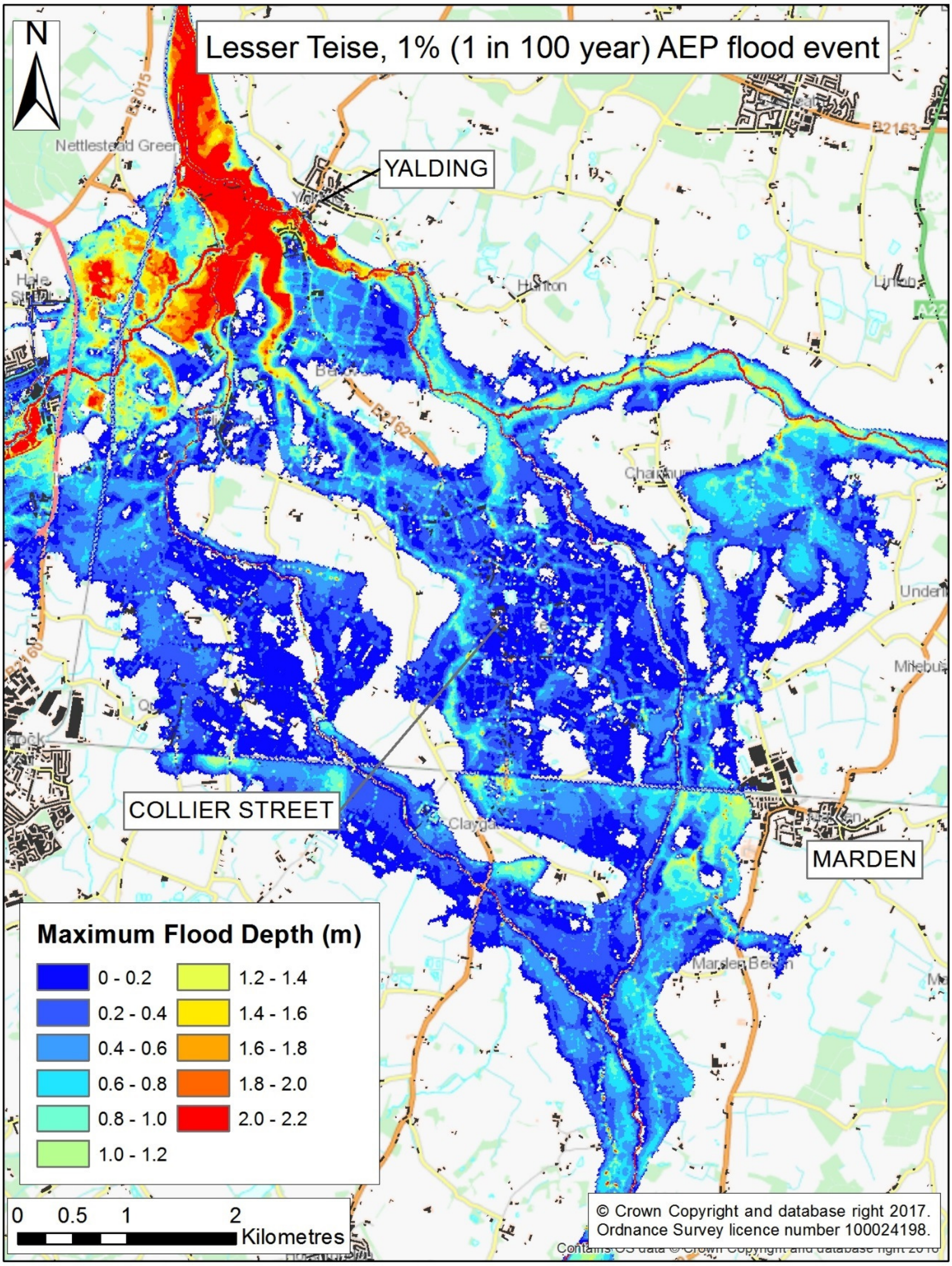

Figure 24a Maximum flood extent for a 1% (1 in 100 year) AEP flood event (as modelled for Stonebridge), baseline condition.

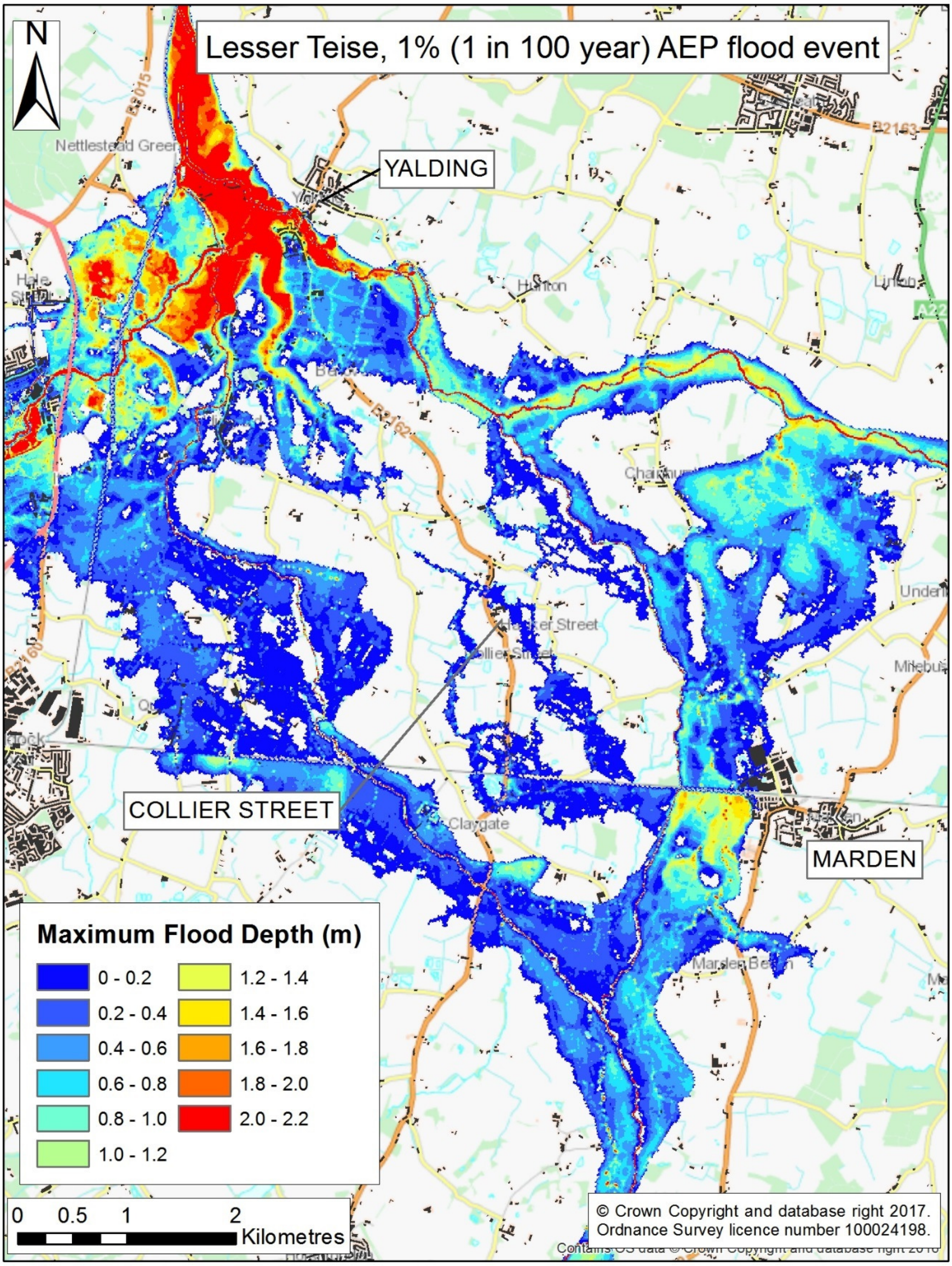

Figure 24b Maximum flood extent for a 1% (1 in 100 year) AEP flood event (as modelled for Stonebridge), improved left bank bunds on the Lesser Teise.

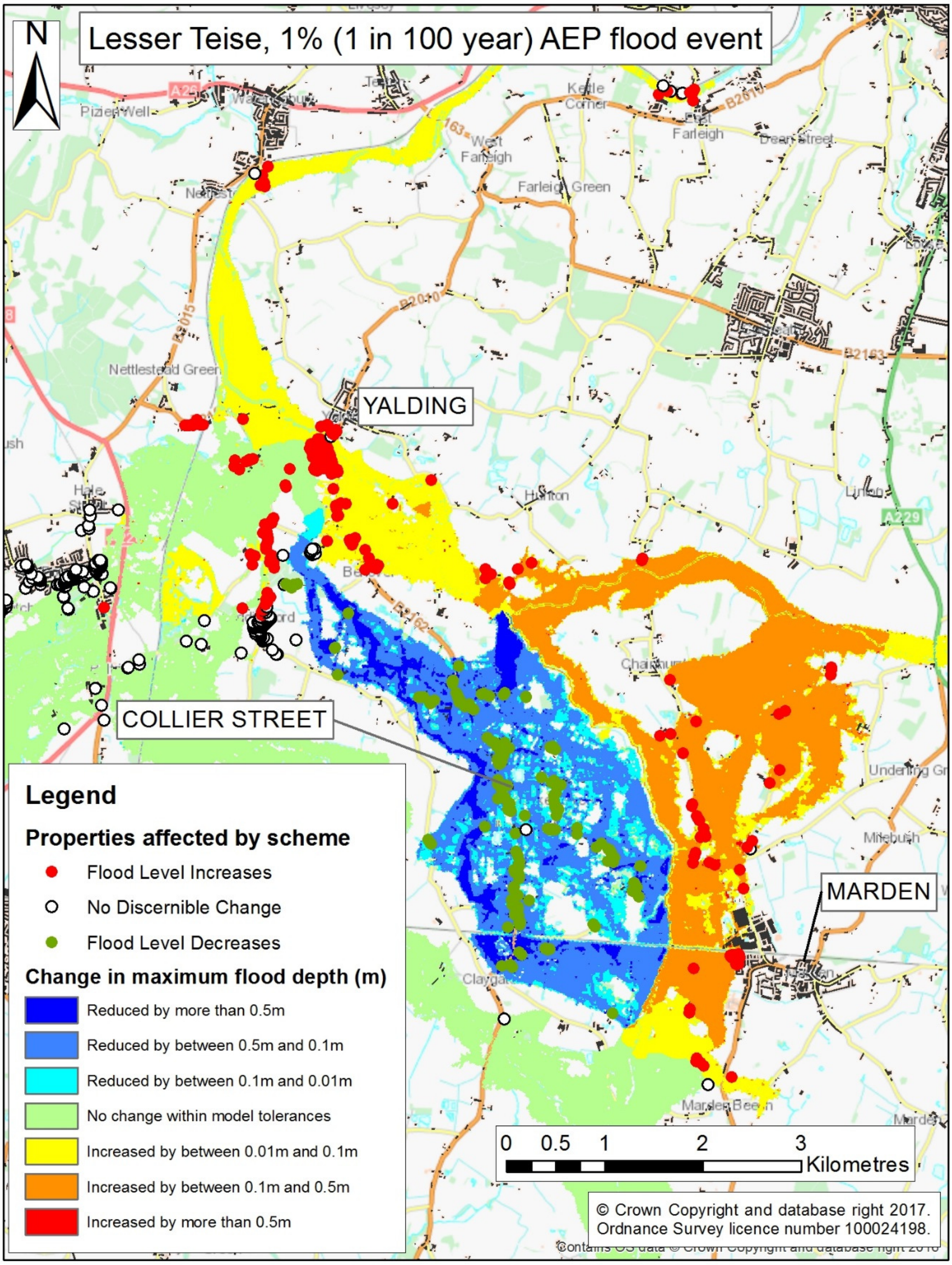

Figure 24c Difference in flood elevations for a 1% (1 in 100 year) AEP flood event (as modelled for Stonebridge), improved left bank bunds on the Lesser Teise compared to baseline condition. Includes properties showing a change in flood risk.

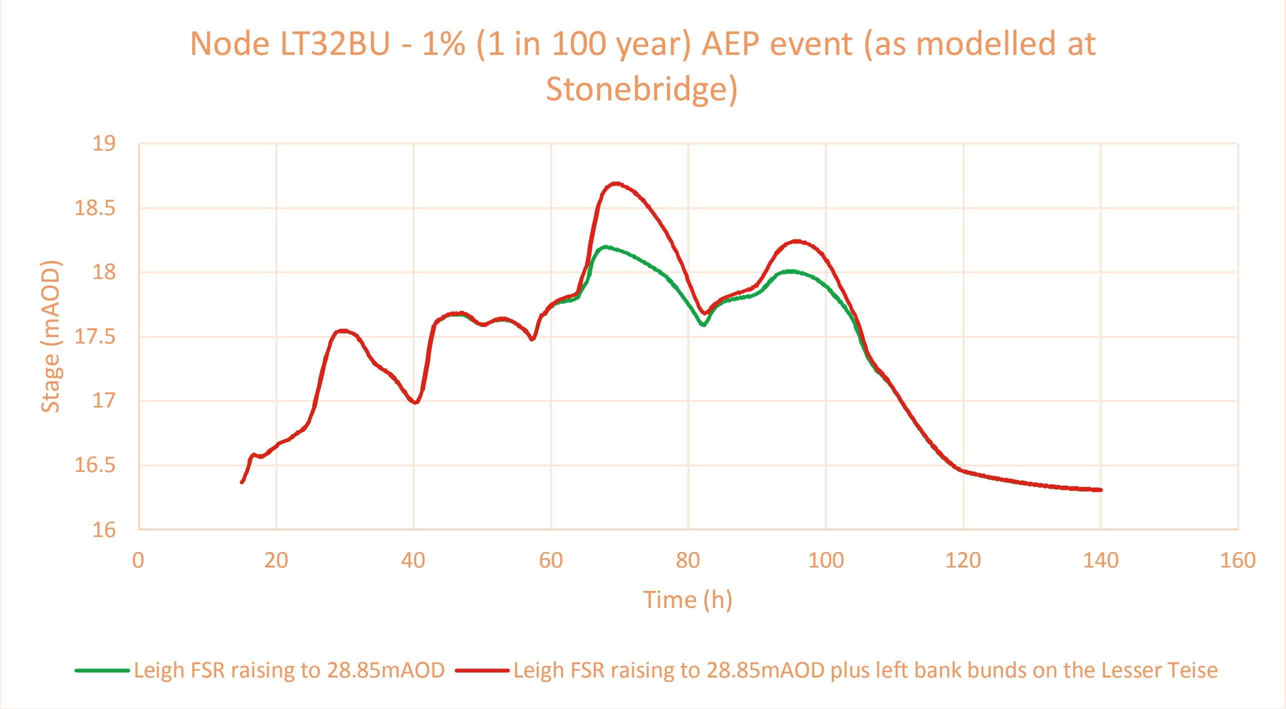

Figure 25a Difference in peak flood level for a 1% (1 in 100 year) AEP flood event (as modelled for Stonebridge), at node LT32BU at Green Lane bridge, improved left bank bunds on the Lesser Teise compared to baseline condition. The presence of the defences along the Lesser Teise increases peak flood level by 493mm.

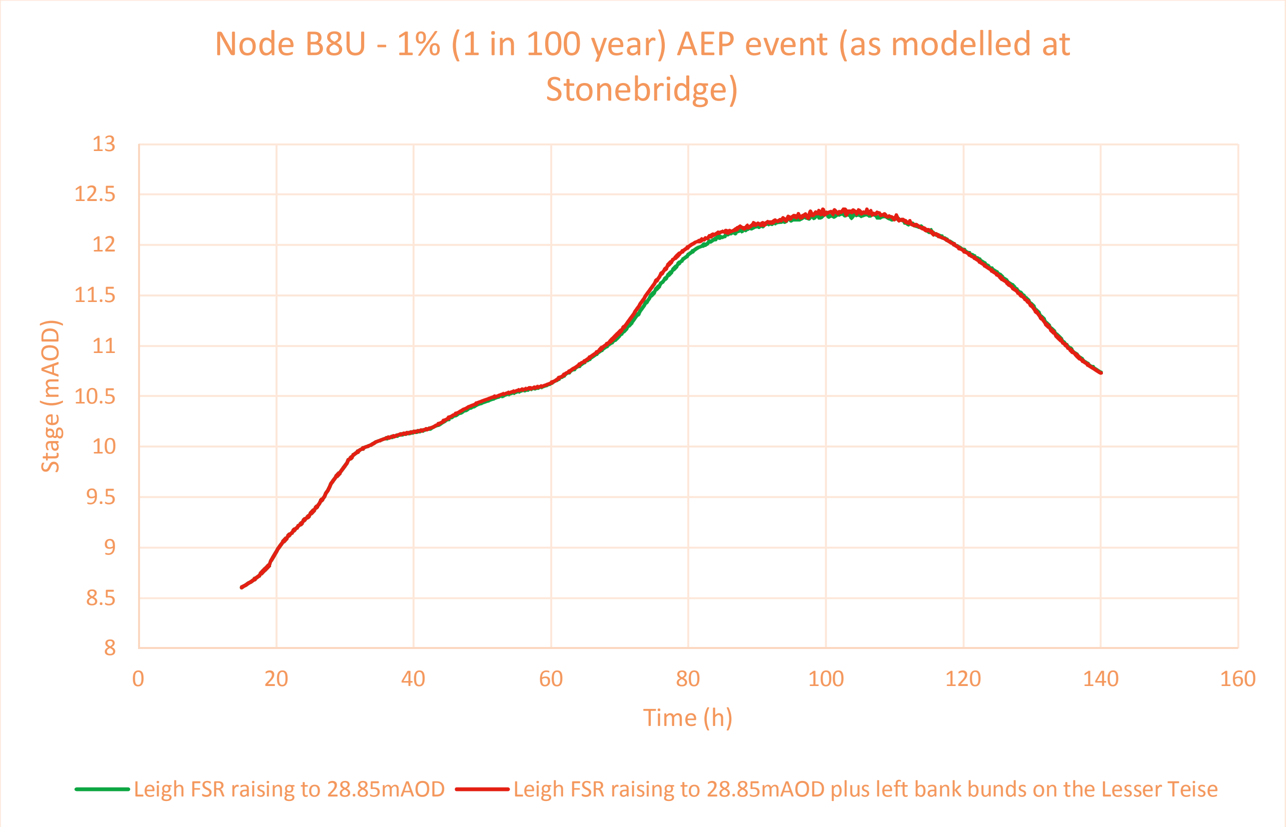

Figure 25b Difference in peak flood level for a 1% (1 in 100 year) AEP flood event (as modelled for Stonebridge), at node B8U immediately upstream of Town Bridge at Yalding, improved left bank bunds on the Lesser Teise compared to baseline condition. The presence of the defences along the Lesser Teise increases peak flood level by 30mm.

2.5.2 Yalding - Upstream on the Beult

Flooding out of bank on the Beult occurs at three key locations which lead to property flooding:

- On the right bank at Hunton, in the vicinity of Water Lane (near Node B28 in **Figure 26**);
- On the left bank immediately downstream of the confluence with the Lesser Teise (already considered in relation to a Teise-dominated flood event in 2.5.1 above); and
- On the left bank in the vicinity of Mill Lane.

There is also out-of-bank flow through the low-lying area around Tilden, forming an island at Chainhurst.

See **Figure 26** for locations.

We have run a 2% (1 in 50 year) AEP flood event (as modelled for Smarden) to estimate the depth of flooding out of bank and then inserted raised banks in the key areas that the model indicates are at risk. This includes the UMIDB drain joining the Beult at node B28, mentioned in section 2.5.1 above (with the use of one-way valves to allow this area to drain into the Beult but not to back up). The model includes all the bunds in section 2.5.1, plus additional ones at Mill Lane (left bank on the Beult) and at Hunton (right bank on the Beult). The results are shown in **Figure 27a, b** and **c** which show a significant reduction in flood extent at Collier Street, Benover and the south end of Yalding, and some improvement at Hunton.

The model output indicates 212 properties in Collier Street, Benover, the south end of Yalding and Hunton showing an improvement in flood risk of between 0.01m and 0.8m, 269 properties across the catchment showing no discernible change within model tolerances and 152 showing a worsening of flood risk. Of these, 66 experience an increase in flood level of greater than 0.05m, and all but 6 of these are in Marden and Tilden. The flood level in Yalding is increased by up to 0.05m and the flooding mechanism at Yalding is reduced to mainly backing-up from The Lees or any flow paths immediately upstream of Town Bridge. The currently-observed flow routes from the south, via either Collier Street or Mill Lane through Benover, would be stopped.

Although the threshold survey information provided by the Environment Agency is incomplete, the data that exists has been interrogated with regard to those properties showing detriment. In total, 80 properties have surveyed thresholds. Of these, 43 which showed detriment and 4 which showed no discernible change have thresholds above the peak water level for a 2% (1 in 50 year) flood event. 1 property which showed improvement, 13 which showed no discernible change and 19 which showed detriment have thresholds below peak water level.

There is a case for developing this option further, in conjunction with the Environment Agency proposal for walls at Yalding. As with the option considered in section 2.5.1 above, if the bunds on the Lesser Teise were set back closer to Collier Street in order to allow retention of more floodplain, and protection was provided at Marden, together with a detailed threshold survey to confirm whether the properties around Tilden are actually at risk (they might be elevated above the local ground level), then it may be possible to provide a reasonable standard of protection to a significant number of properties in the Weald Basin. However, it will be necessary to ensure that any properties that do remain at increased risk of flooding are provided with adequate mitigation measures. This is explored further in Section 2.5.3 below.

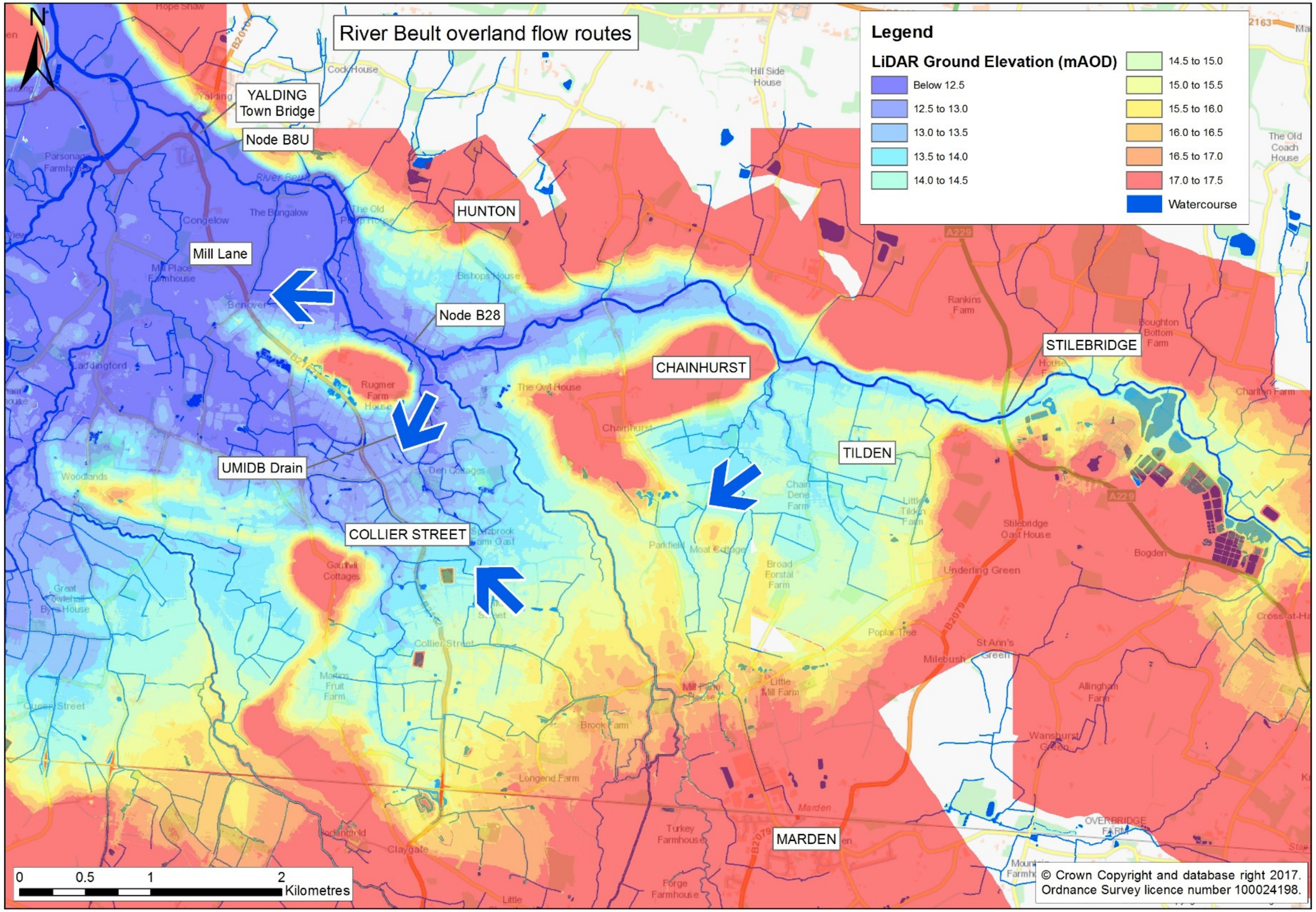

Figure 26 Location plan showing the Beult between Stilebridge and Yalding and indicated overland flow routes obtained from the hydraulic model.

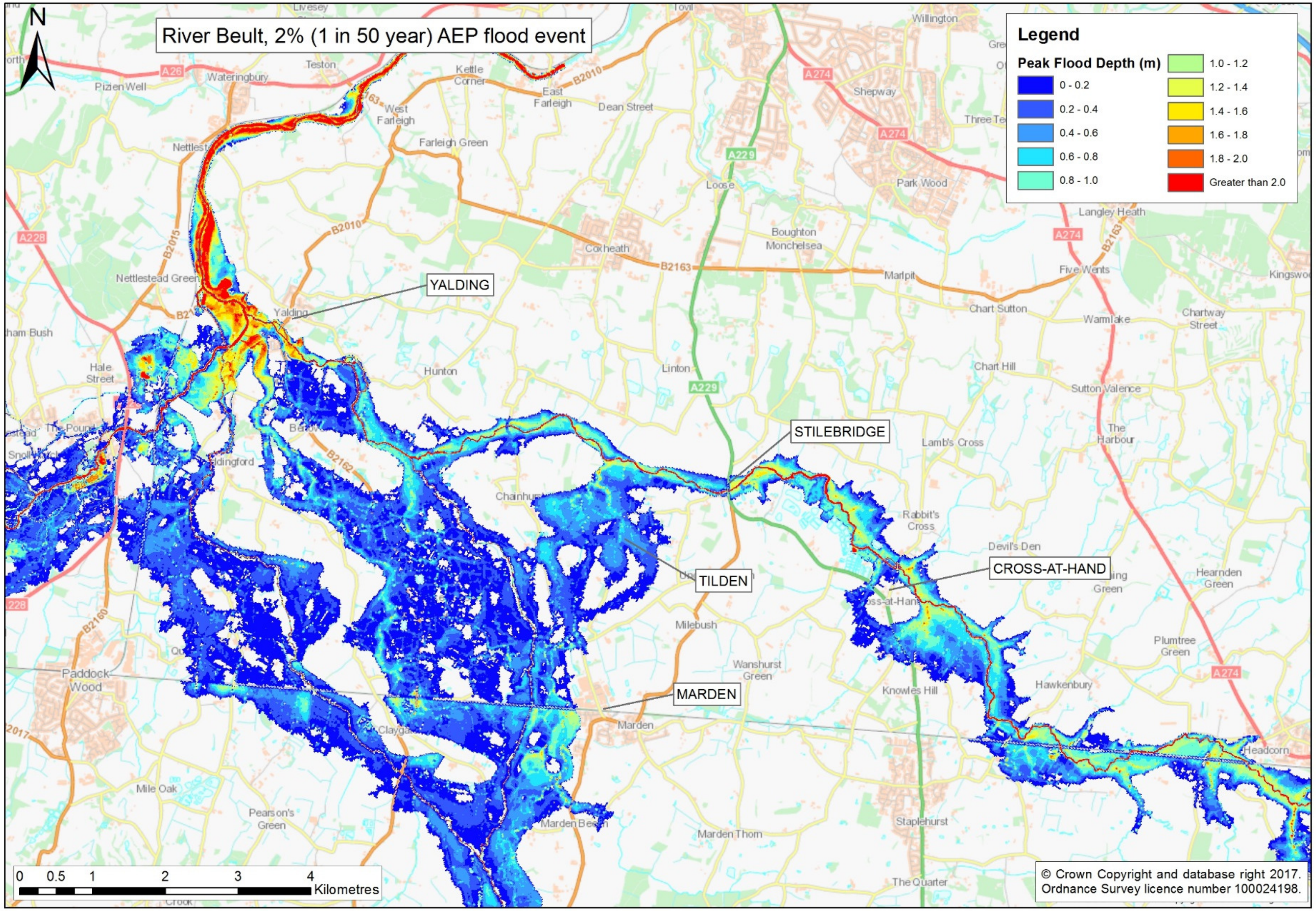

Figure 27a Maximum flood extent for a 2% (1 in 50) AEP flood event (as modelled for Smarden), baseline condition.

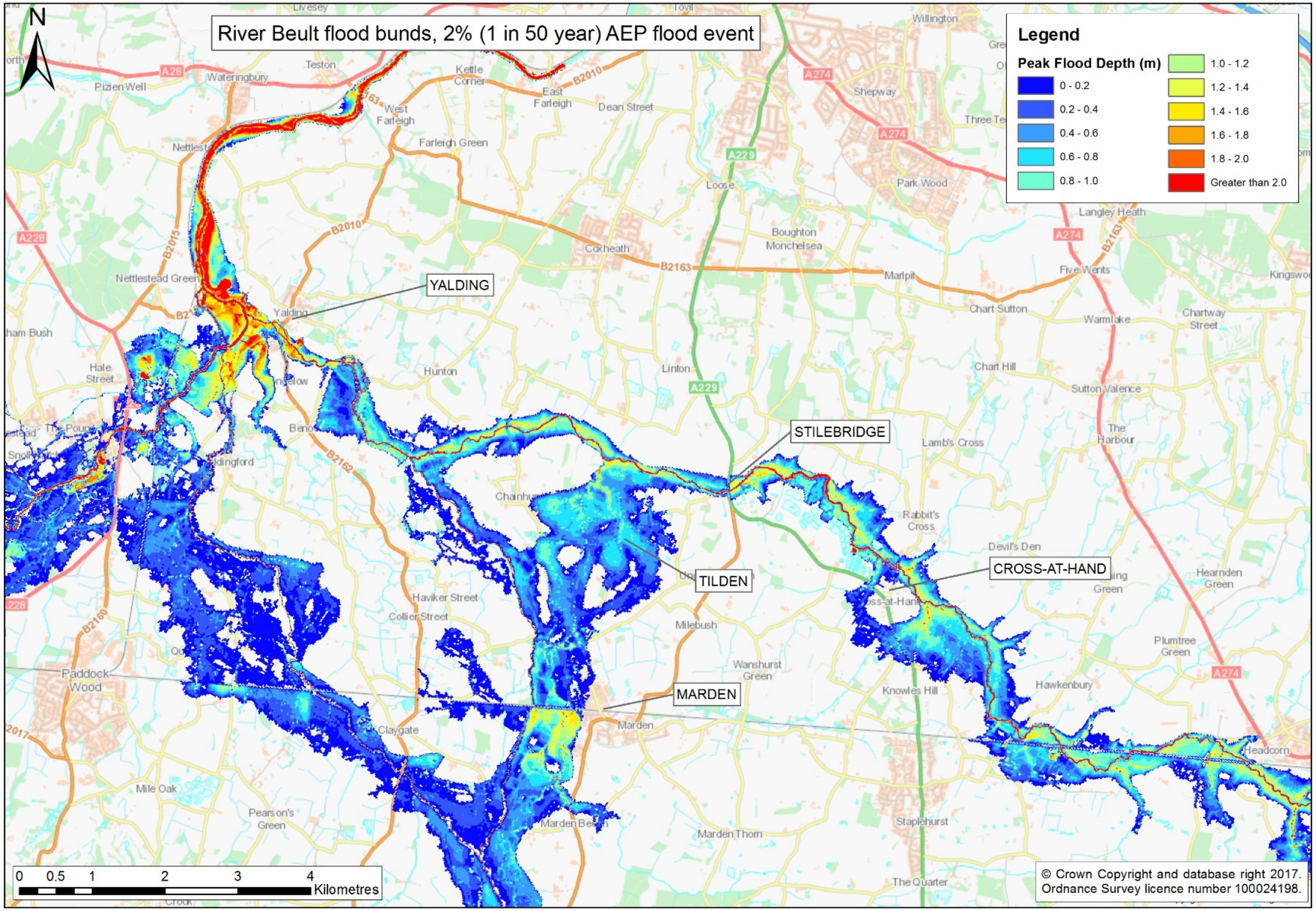

Figure 27b Maximum flood extent for a 2% (1 in 50) AEP flood event (as modelled for Smarden), bunds at Hunton, by the Lesser Teise confluence and at Mill Lane.

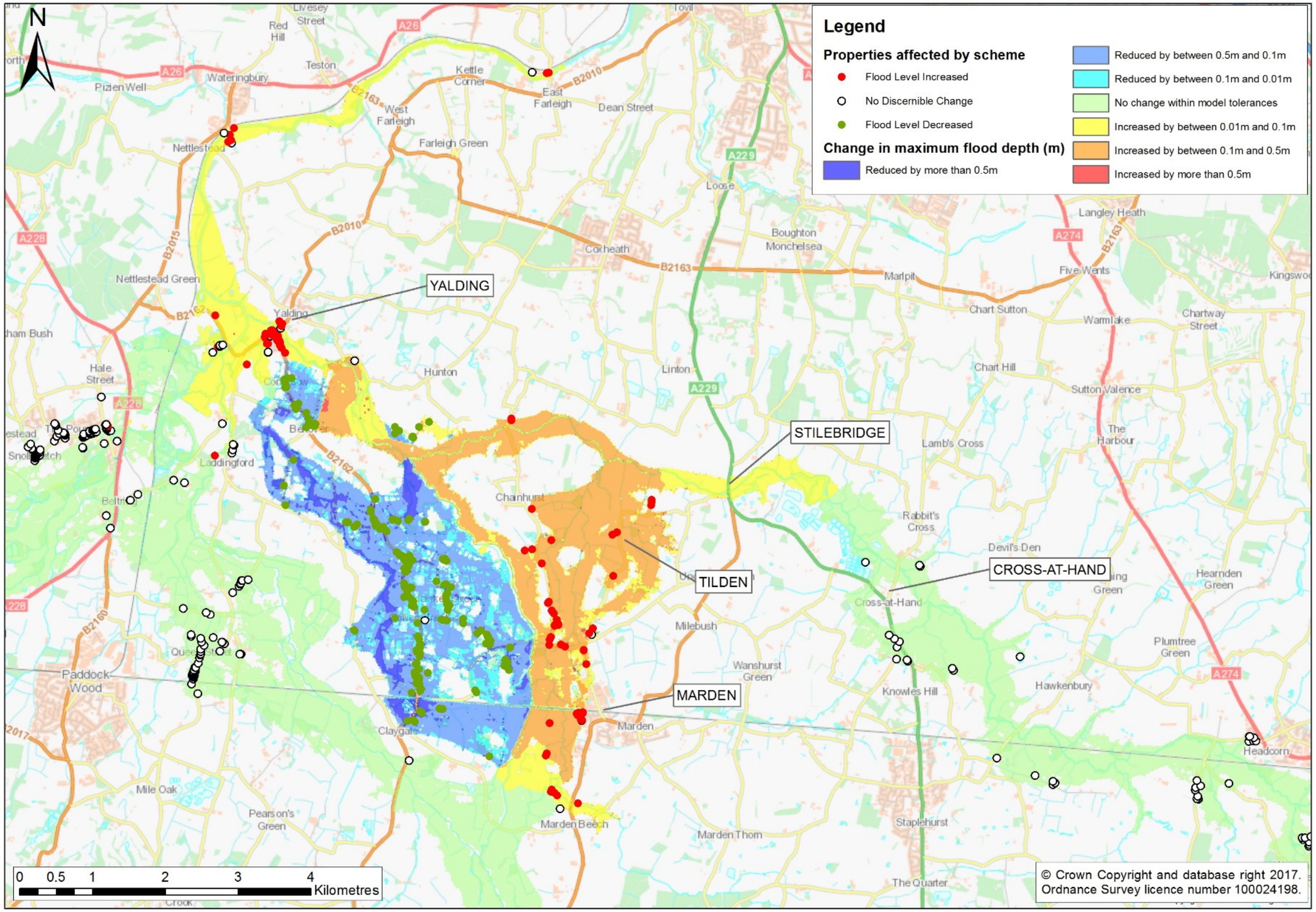

Figure 27c Difference in flood elevations for a 2% (1 in 50) AEP flood event (as modelled for Smarden), bunds at Hunton, by the Lesser Teise confluence and at Mill Lane compared to baseline condition.

2.5.3 Refined Alignment – Embankments and Walls

Following the initial work on this study, it was considered that refining the alignment of upstream embankments, coupled with the earlier Environment Agency proposals for walls in Yalding, might be worth considering. Although the options explored in sections 2.5.1 and 2.5.2 above do improve protection for many properties, they are also showing detriment to a significant number. Maximising the available floodplain, while providing relatively low-cost shallow embankments closer to the properties in Collier Street, could be a way forward. Therefore a revised alignment for defences to protect Collier Street and Yalding, together with small sections of embankment on the right bank of the River Beult at Hunton and downstream of Town Bridge in Yalding, and some protection to groups of properties at Marden have been modelled. The proposed alignments are shown in **Figure 28a**.

Benefits of this approach include reducing the risk of water backing up along the drainage ditches east of Haviker Street as a source of flooding, as the embankment would be between the houses and the ditches (as opposed to in 2.5.1 and 2.5.2 where the embankments are alongside the Lesser Teise).

However, there are significant environmental issues associated with this option. These include the visual impact on and potential flood water loadings on the Town Bridge in Yalding, which is a historic listed structure.

For this option we have opted to assess not against the 2% (1 in 50 year) AEP flood event, but against the 1.33% (1 in 75 year) AEP flood event instead (see **Table 1** for the events). This is due to the requirements for DEFRA Flood Defence Grant in Aid (FDGiA) funding which require a flood alleviation scheme to demonstrate the number of properties moved from a 'Very Significant' or 'Less Significant' risk of flooding to a 'Moderate' or 'Low' risk of flooding. The threshold for this change in risk is the 1.33% (1 in 75 year) AEP flood event, so if this Standard of Protection can be demonstrated then DEFRA funding can be triggered (for further information see "*Calculate Grant in Aid funding for flood and coastal erosion risk management projects - Guidance for risk management authorities. Version 1 updated February 2014* " https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/297377/LIT_9142_dd8bbe.pdf)

The baseline model runs of the 1.33% (1 in 75 year) AEP events demonstrated that the 1.33% AEP flood at Stonebridge (the '28DEC68331400' event – see **Table 1**) creates more flood extent and depth at every location than does the 1.33% AEP flood at Smarden. Therefore the Stonebridge event is used to represent the 1.33% AEP event for both the Beult and the Teise in this section.

The sections of embankment which have been tested in the model are as indicated in **Table 4** below. These have been identified using the basemap condition of only raising the Leigh FSR to 28.85mAOD crest level to determine the extent and maximum depth of flooding at each location, for 1.33% (1 in 75 year) AEP flood events for each of the rivers Medway, Beult and Teise and taking the worst case extent for each embankment.

Having run the model once, we identified several points where overspill was occurring in a 1.33% (1 in 75 year) AEP event, so a second run was made with the embankment crest levels raised in those areas to avoid overtopping. This addressed the spill but revealed that water was being directed towards Spenny Lane and was increasing risk to eight properties there. Therefore a final run was made with an additional short section of embankment (section 9 in Table 4) to provide protection to the Spenny Lane properties. This configuration of embankments is shown in **Figure 28b**.

Figure 29a (and the enlargements within **Figure 30**) shows the difference in peak flood level for a 1.33% (1 in 75 year) AEP flood event as modelled at Stonebridge, and indicates the locations of properties affected by the presence of the embankments (a breakdown of these is given in **Table 5** and the full list of these is given in **Appendix B**). **Figure 29b** (and further enlargements within **Figure 30**) shows the difference for a 1.33% (1 in 75 year) AEP flood event as modelled at East Peckham. In general the Stonebridge event causes greater flooding, although the area around The Lees is affected to a greater extent for a flood predominately focussed on the Medway, which is to be expected.

Figures 31a to **g** show the stage (level) hydrographs at selected nodes for the 1.33% (1 in 75 year) AEP flood as modelled at Stonebridge with and without the embankments. It can be seen that the change in flood level at Stilebridge (node STIL01_0377) and at Marden (node LT47) is not discernible, showing that the realigned embankment has removed the issue of potentially causing detriment at Tilden and Marden. There is also no discernible difference in levels on the western channel of the River Teise (node T35BU), and only the most minor change on the Lesser Teise upstream of the confluence with the Beult (node LT10D). However, at the Beult confluence (node B28) and downstream to Town Bridge (node B8U) there is a significant increase in peak water level, and a corresponding reduction in peak water level downstream of Town Bridge (node CS157). For comparison, **Figures 32a** and **b** show the nodes either side of Town Bridge for the 1.33% (1 in 75 year) AEP flood event as modelled for the Medway at East Peckham (node CS121). This shows similar, but lesser changes in peak water level.

In **Table 5** there is also an indication of how many properties still at risk of flooding might be suitable for additional Property Level Protection (PLP). The criteria used for this is a modelled flood depth not exceeding 600mm (which is the maximum normally available with PLP due to the risk of severe structural loading on property walls above this level), and a building type that appears appropriate. Modern (including some Victorian and more recent) buildings with solid foundations and damp courses are suitable for PLP to be tied into. Traditional timber post construction buildings with compacted earth foundations, of which there are many in the Weald Basin, would not be suitable and alternative forms of PLP may need to be explored. These would include measures such as deep cut-off walls around the building to effectively create a damp course at the upper boundary of the Wealden Clay beneath the property. The numbers listed as suitable for PLP in **Table 5** assume presence of a damp course and modern construction.

It should be noted that many of the properties listed as potentially requiring additional PLP would not be suitable for PLP alone without the refined alignment embankments, as the water depth would be too great for a PLP system to be of any use.

There are 54 properties identified as being at increased flood risk as a result of the proposed embankments, and 1 property with reduced flood risk that would still be at risk of flooding in a 1.33% (1 in 75 year) AEP event, which either appear to be of traditional build and unlikely to be suitable for PLP, or in a few cases would be suitable but would be subject to greater depths of flooding than the 600mm PLP is normally used for.

Figures 31f and **32a** also demonstrate that the upstream water level impacting on the historic Town Bridge would be increased if the refined embankments option is constructed. This may require some structural work to the bridge, which could be problematic given the bridge's listed status.

Although it has not proven possible to find an option that can provide complete protection for the extended Weald Basin communities, this is the most realistic possibility for providing reasonable protection to the community as a whole and so is taken forward for economic analysis in Section 3. It should be emphasised that, as this option still results in detriment to some properties, and the environmental impacts associated with proximity to Town Bridge, it would still not be technically viable as it stands. There may be elements of this package that could be technically viable if the economics are acceptable, and further refinements of the alignments could be made to try to find a more fully technically viable solution.

Table 4 Sections of embankment modelled

Section	Location	Length of embankment / wall	Maximum height of embankment / wall	Embankment crest level
1a	South of Lyngs Close between Collier Street Brook and Benover Road	310m	0.5m	12.2mAOD
1b	Forming rear boundaries to properties in Lyngs Close	200m wall	2.8m	12.2mAOD
1c	Between The Lees and Yalding, crossing Lees Road, then round to north of Acott Fields	385m	2.8m with a one-way valve to allow drainage away from Yalding at The Lees, and a sealing gate across Lees Road	12.2mAOD

Section	Location	Length of embankment / wall	Maximum height of embankment / wall	Embankment crest level
1d	Downstream of Town Bridge on the left bank	80m	Sheet pile wall with crest 3.8m above current river bank	12.2mAOD
2a	Right bank of River Beult at The Tatt	280m	Sheet pile wall with crest up to 3.8m above current bank level	12.2mAOD
2b	Right bank of River Beult upstream of Town Bridge, tying into to Churchyard wall	50m	0.8m	12.2mAOD
3a	In back gardens along left bank upstream of Town Bridge	65m	Crest up to 4.7m above existing bank level, or could be set back to reduce height	12.4mAOD at Town Bridge rising to 12.42mAOD by The George
3b	Left bank upstream of Town Bridge	470m	3.1m through existing gardens and behind surgery	12.42mAOD at The George rising to 12.5mAOD south of no. 4 Benover Road
4a	Continuation of 3 along east side of Benover Road Congelow Farm	320m	1.2m	12.5mAOD south of no. 4 Benover Road rising to 12.7mAOD at Congelow Farm
4b	Continuation of 4a	1020m	1.0m, including raising a short section of Mill Lane where the embankment crosses the lane, and blocking up two ditches	12.7mAOD at Congelow Farm to 12.9mAOD at Old Granary Nursery
5a	North of Haviker Street, from near Sparrows Cottage to Den Lane	450m	1.0m with a one-way valve where the alignment crosses a UMIDB drain	13.8mAOD
5b	Running along north side of Den Lane	175m	1.75m	13.8mAOD
5c	Continuing along north side of Den Lane to Den Cottages	195m	1.6m	13.8mAOD
5d	South of Den Cottages	65m	0.5m	14.3mAOD
5e	East of Haviker Street	360m	1.5m	14.3mAOD

Section	Location	Length of embankment / wall	Maximum height of embankment / wall	Embankment crest level
5f	East of Brandenbury Farm	990m	1.0m	14.3mAOD from north of Spitzbrook rising to 15.6mAOD at Green Lane
5g	North of Green Lane and east of Haviker Street	40m	1.25m	15.6mAOD
5h	South of Collier Street Church	715m	1.0m	15.9mAOD
5i	West and north of School House	145m	1.5m	15.9mAOD
5j	Between School House and Granary Fields	275m	2.0m	15.9mAOD
5k	West of Granary Fields	220m	2.4m	15.9mAOD
5l	Crossing Collier Street Brook north of Old Moat Farm	35m	1.0m including 300mm diameter culvert to throttle flows	15.9mAOD
6	West of Meades Close, Marden	385m	1.3m	18.9mAOD
7	West of Wheelbarrow Park Industrial Estate, Marden	80m	1.2m	18.2mAOD
8a	Water Lane, Hunton	1150m	1.5m	13.4mAOD at the west end rising to 14.1mAOD at the east end
8b	At Bishop's Lane, Hunton	300m	0.6m with 1 small ditch infilled and fitted with a 150mm culvert and flap valve	14.1mAOD
9	Spenny Lane, Collier Street	730m	1.8m	15.9mAOD

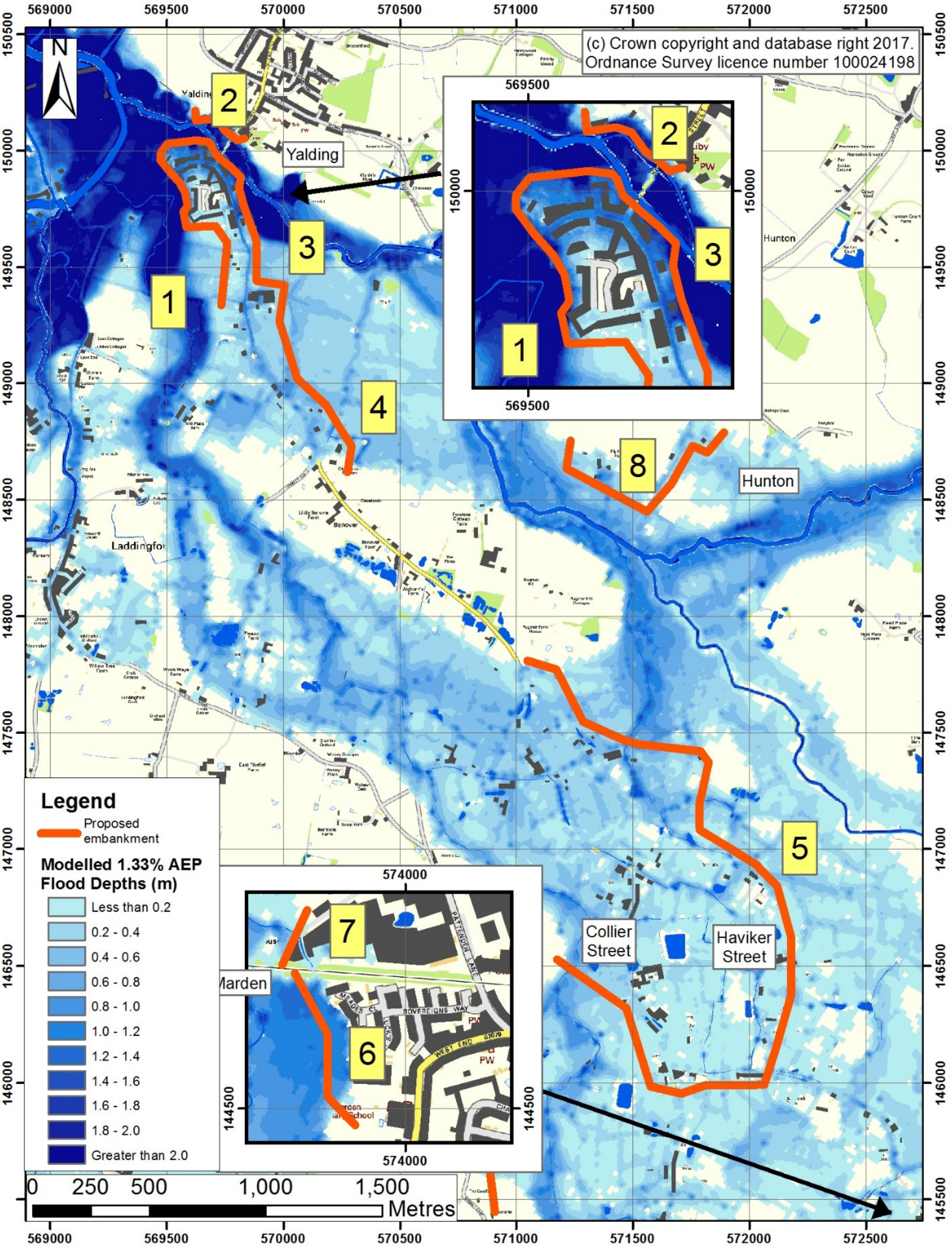

Figure 28a Locations of embankment sections modelled (refer to Table 4 for section numbers). The area shaded blue is a composite flood extent for the 1.33% (1 in 75 year) AEP flood events as modelled for East Peckham, Smarden and Stonebridge. Baseline condition – only the Leigh FSR raised to 28.85mAOD crest level.

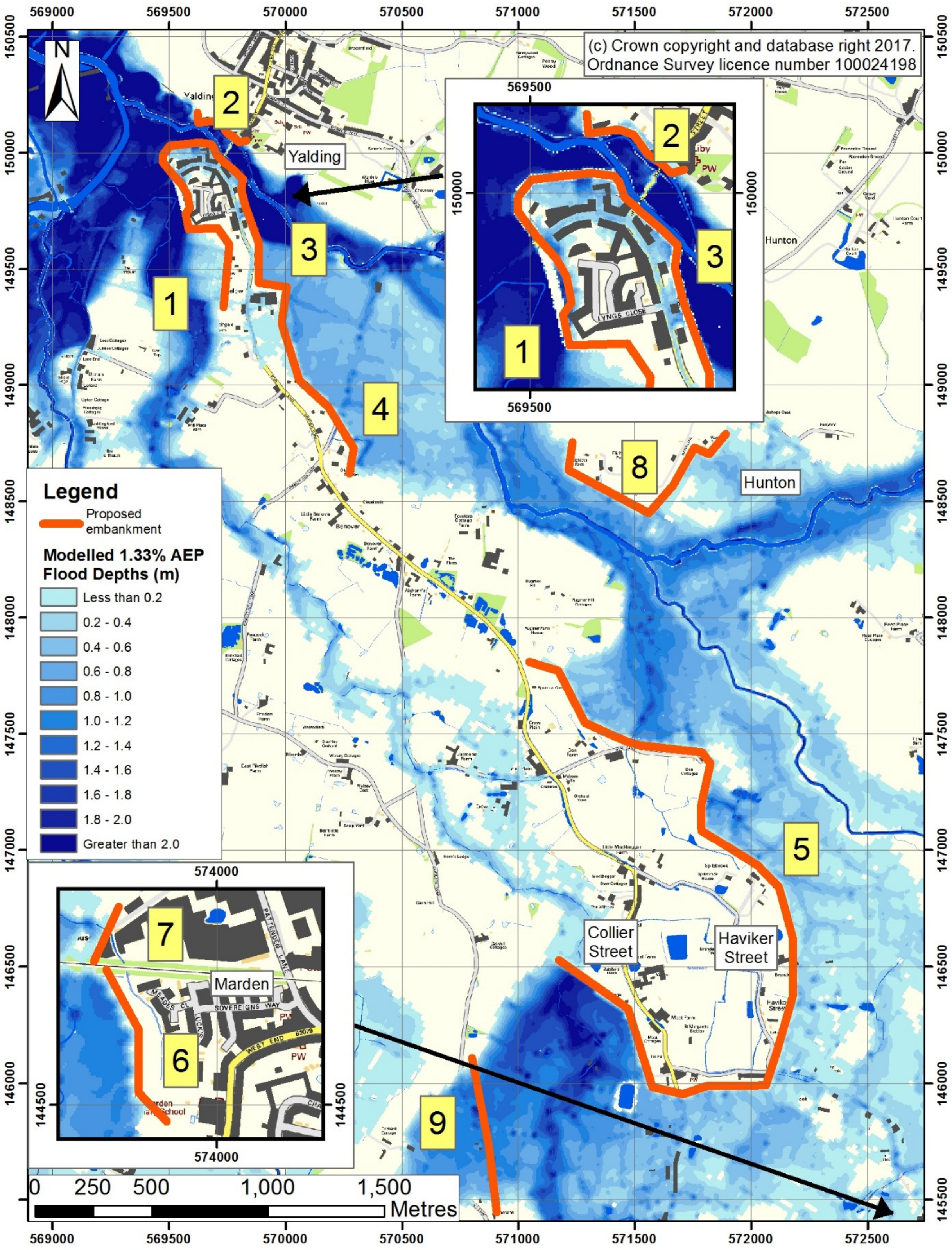

Figure 28b Locations of embankment sections modelled, with additional embankment at Spenny Lane (section 9) (refer to Table 4 for section numbers). The area shaded blue is a composite flood extent for the 1.33% (1 in 75 year) AEP flood events as modelled for East Peckham, Smarden and Stonebridge. Modelled with embankments in place – compare to Figure 26a for differences in flood extent and depth.

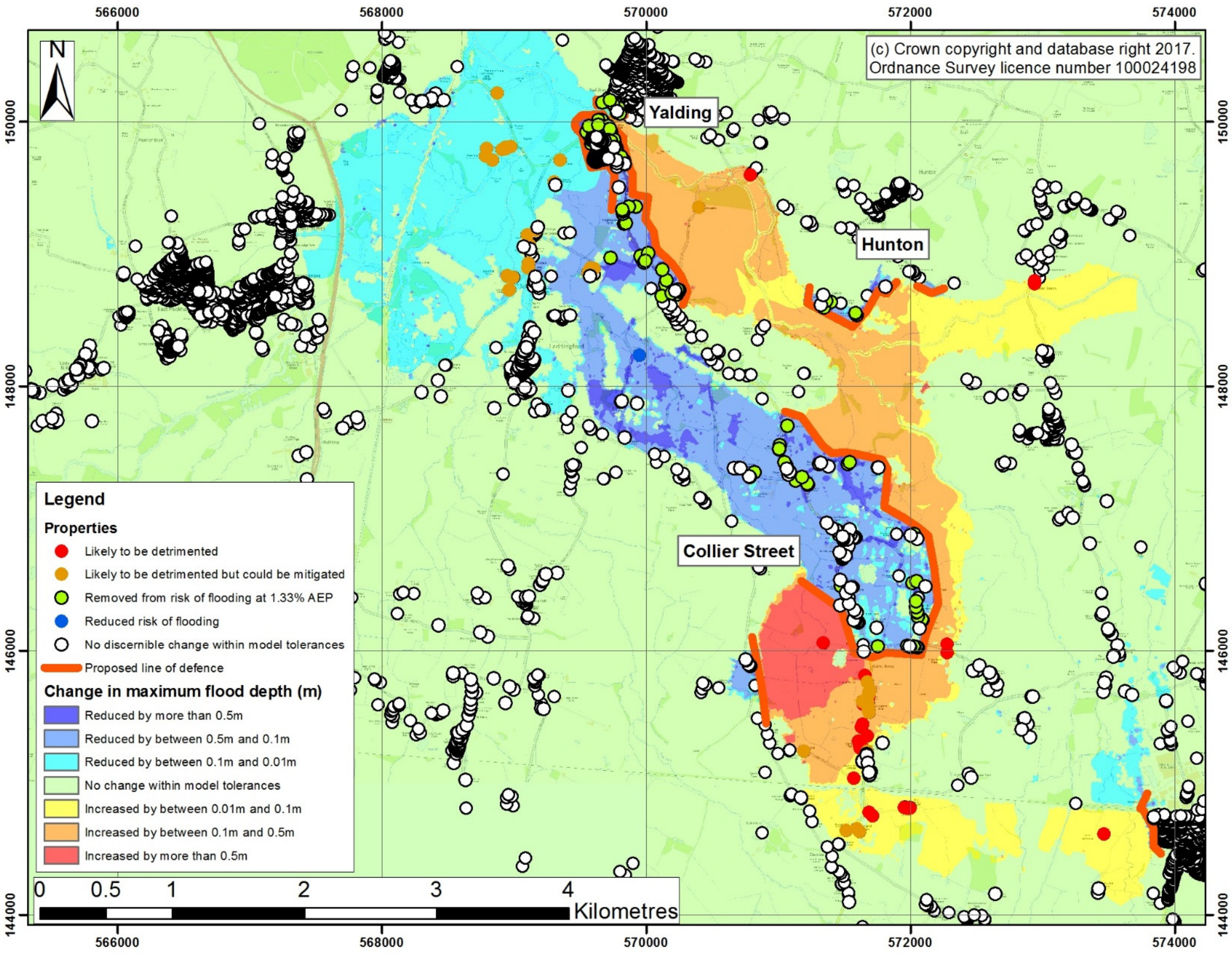

Figure 29a Difference in peak flood levels for a 1.33% (1 in 75 year) AEP flood as modelled at Stonebridge, with the refined embankment alignments as shown compared to the baseline of raising the Leigh FSR embankment to 28.85mAOD crest level

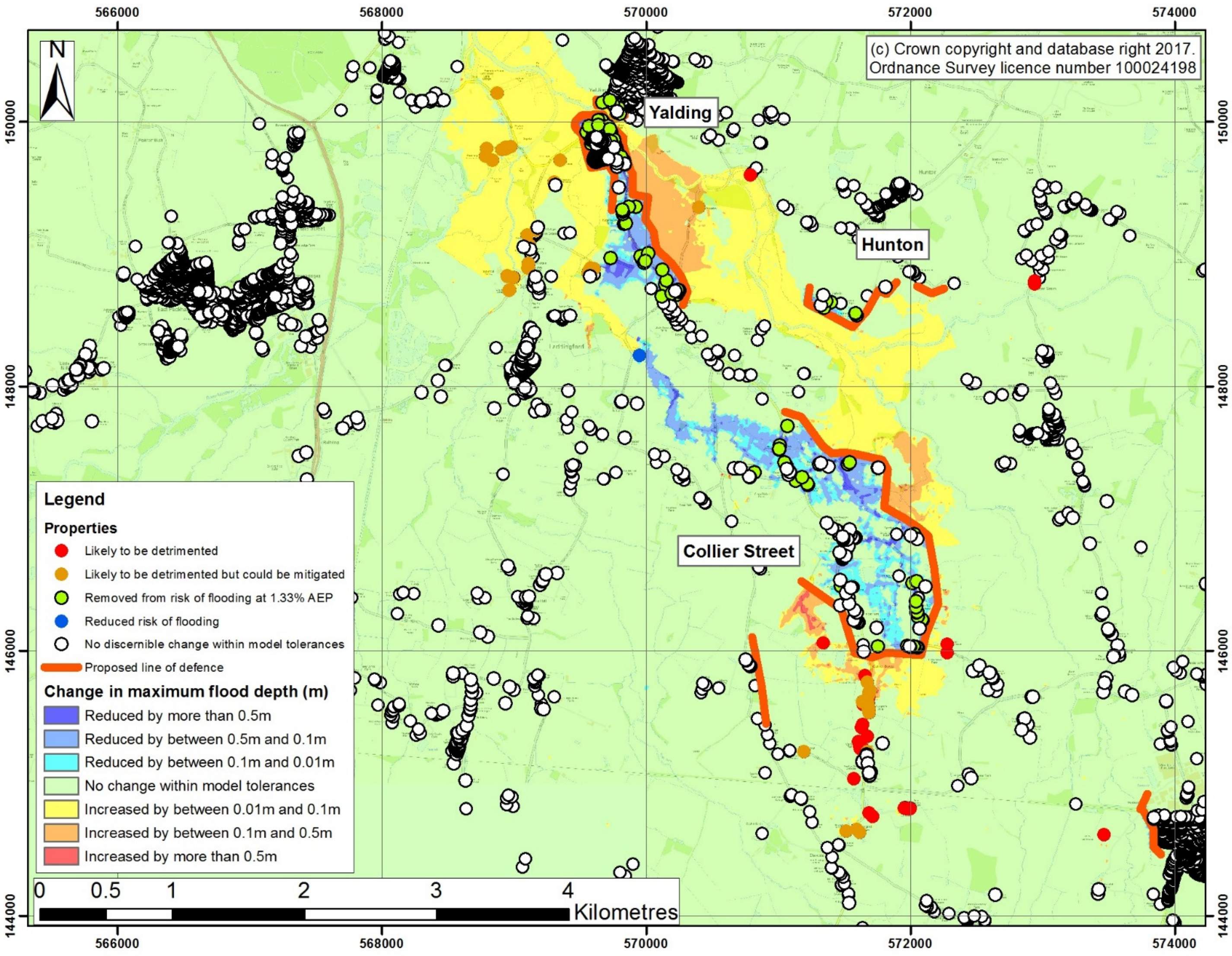

Figure 29b Difference in peak flood levels for a 1.33% (1 in 75 year) AEP flood as modelled at East Peckham, with the refined embankment alignments as shown compared to the baseline of raising the Leigh FSR embankment to 28.85mAOD crest level

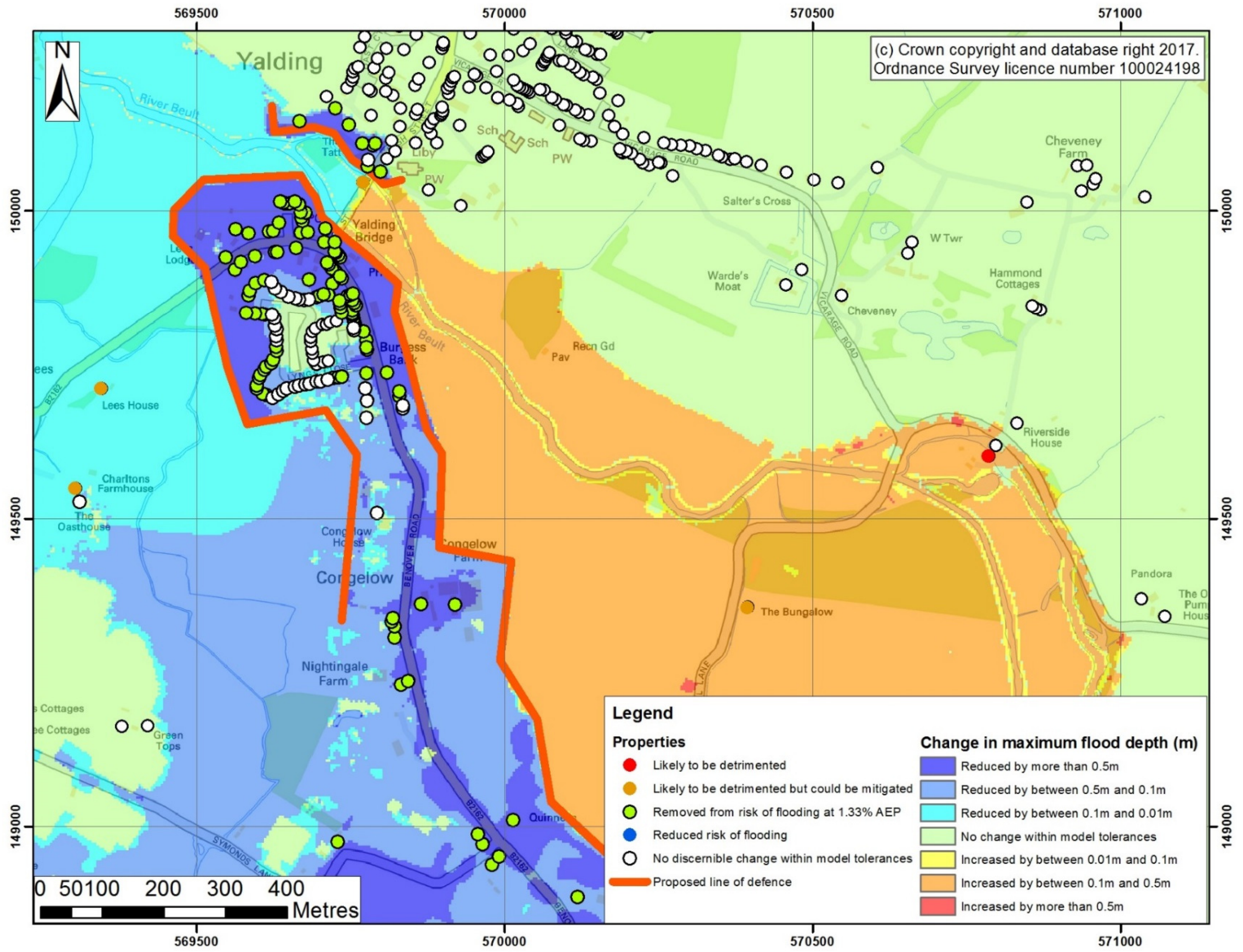

Figure 30a Enlargement of Figure 29a, Yalding area

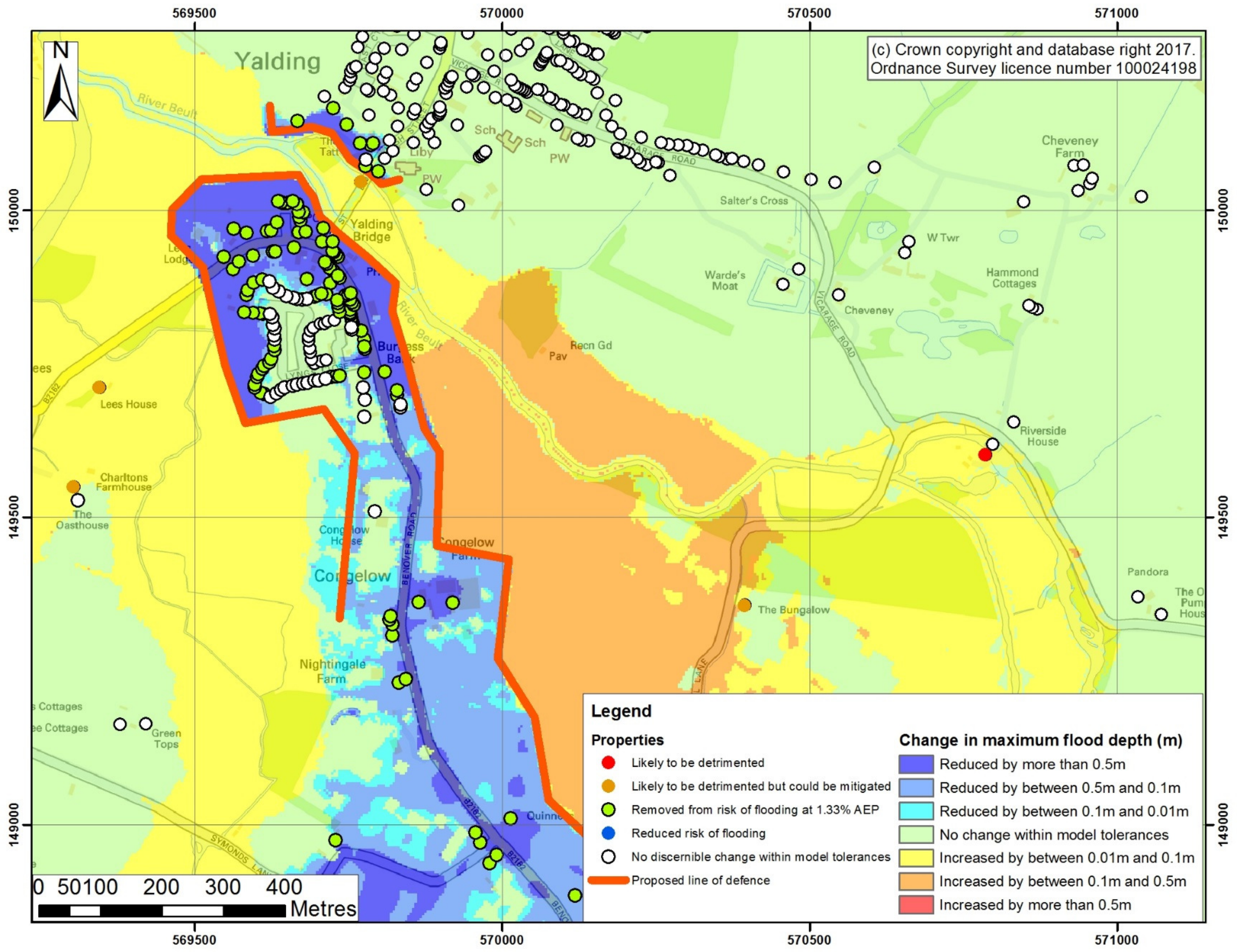

Figure 30b Enlargement of Figure 29b, Yalding area

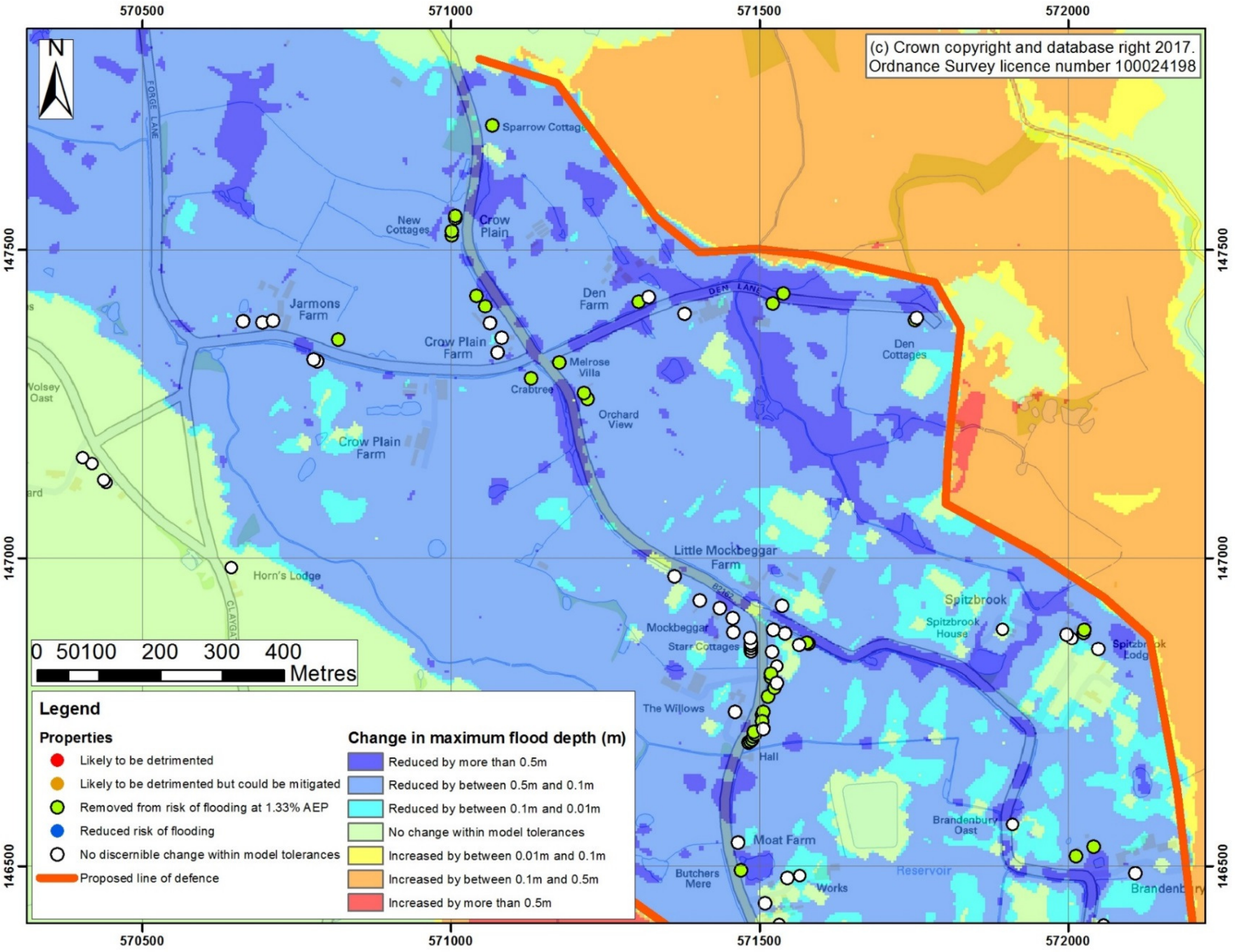

Figure 30c Enlargement of Figure 29a, Collier Street North area

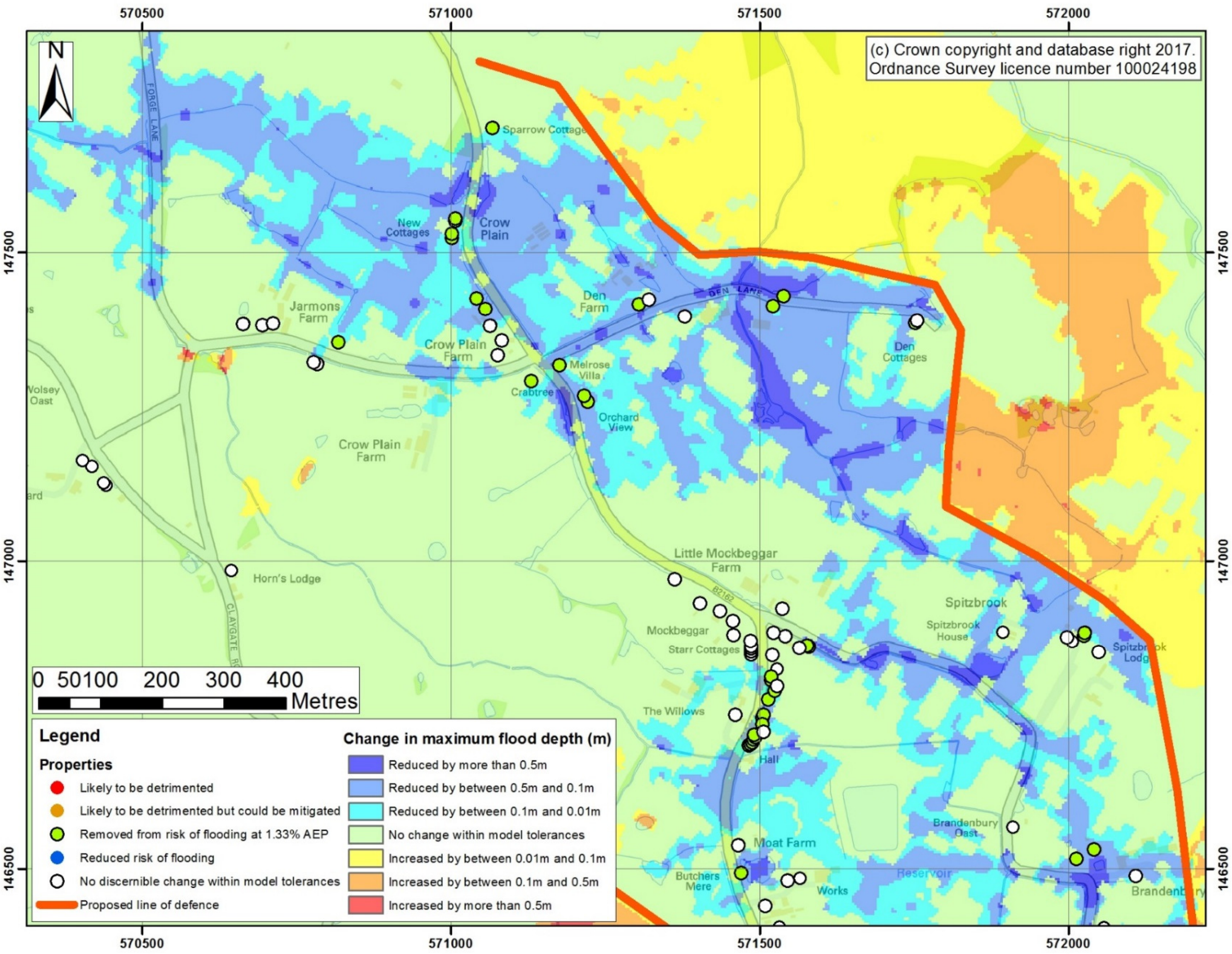

Figure 30d Enlargement of Figure 29b, Collier Street North area

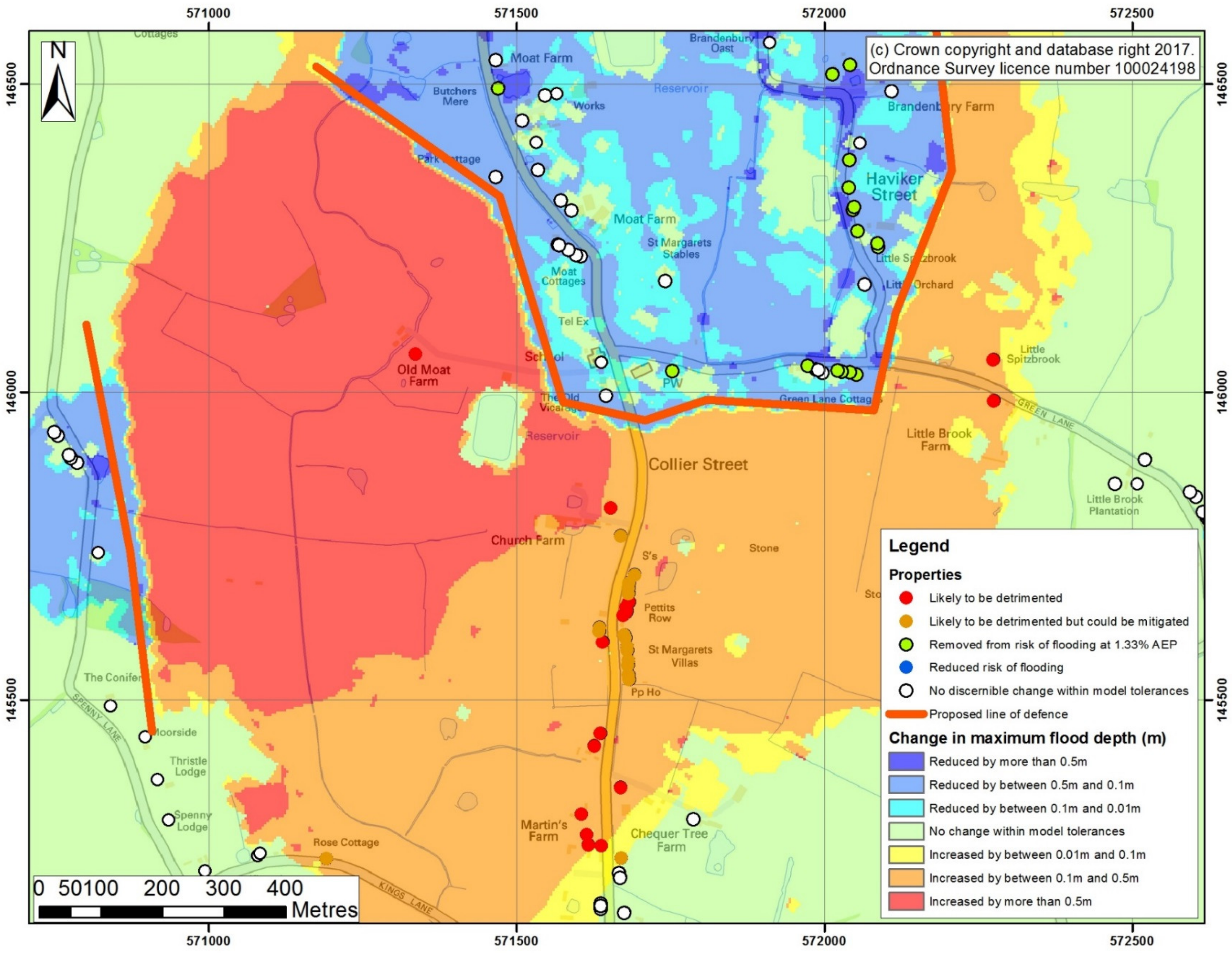

Figure 30e Enlargement of Figure 29a, Collier Street South area

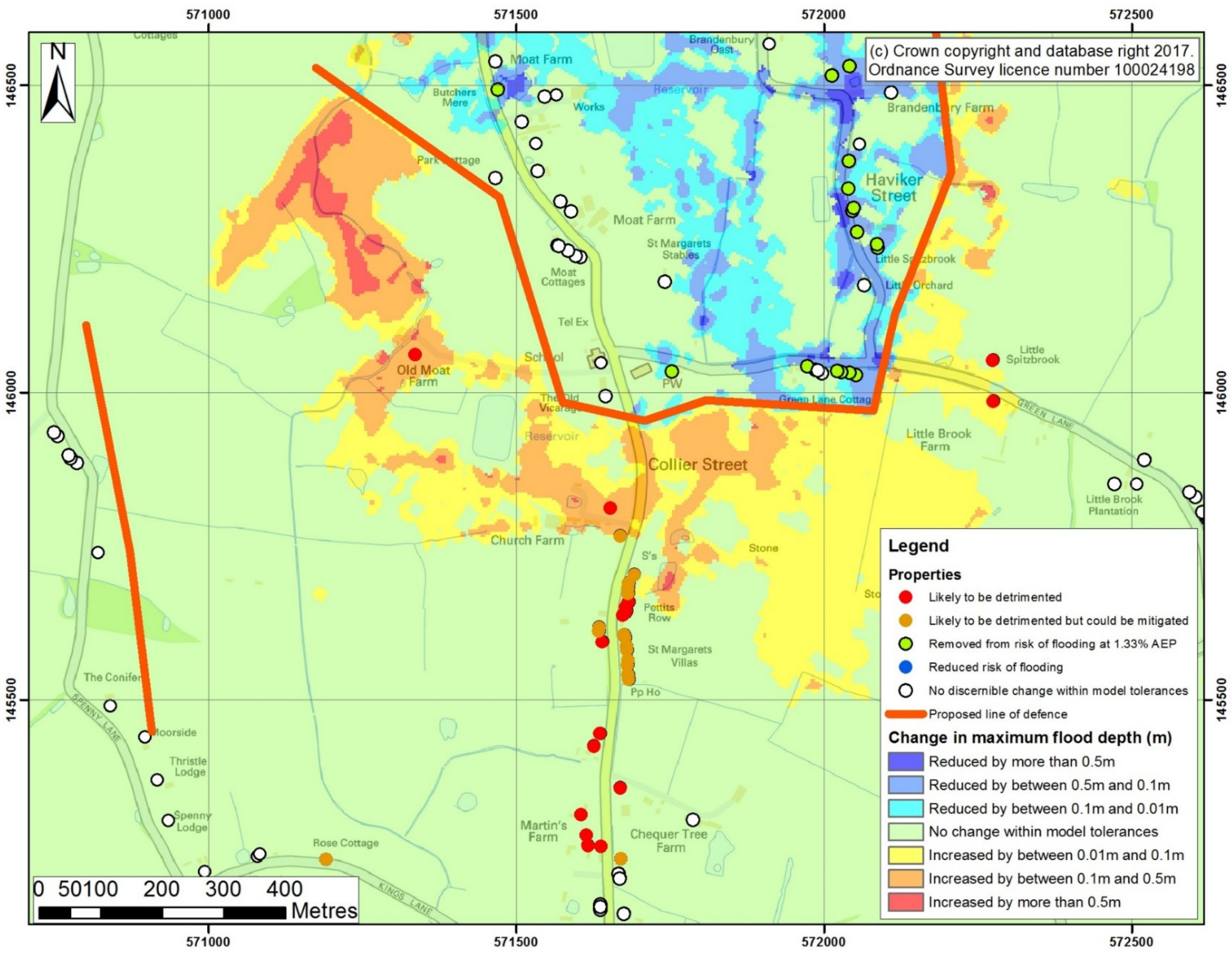

Figure 30f Enlargement of Figure 29b, Collier Street South area

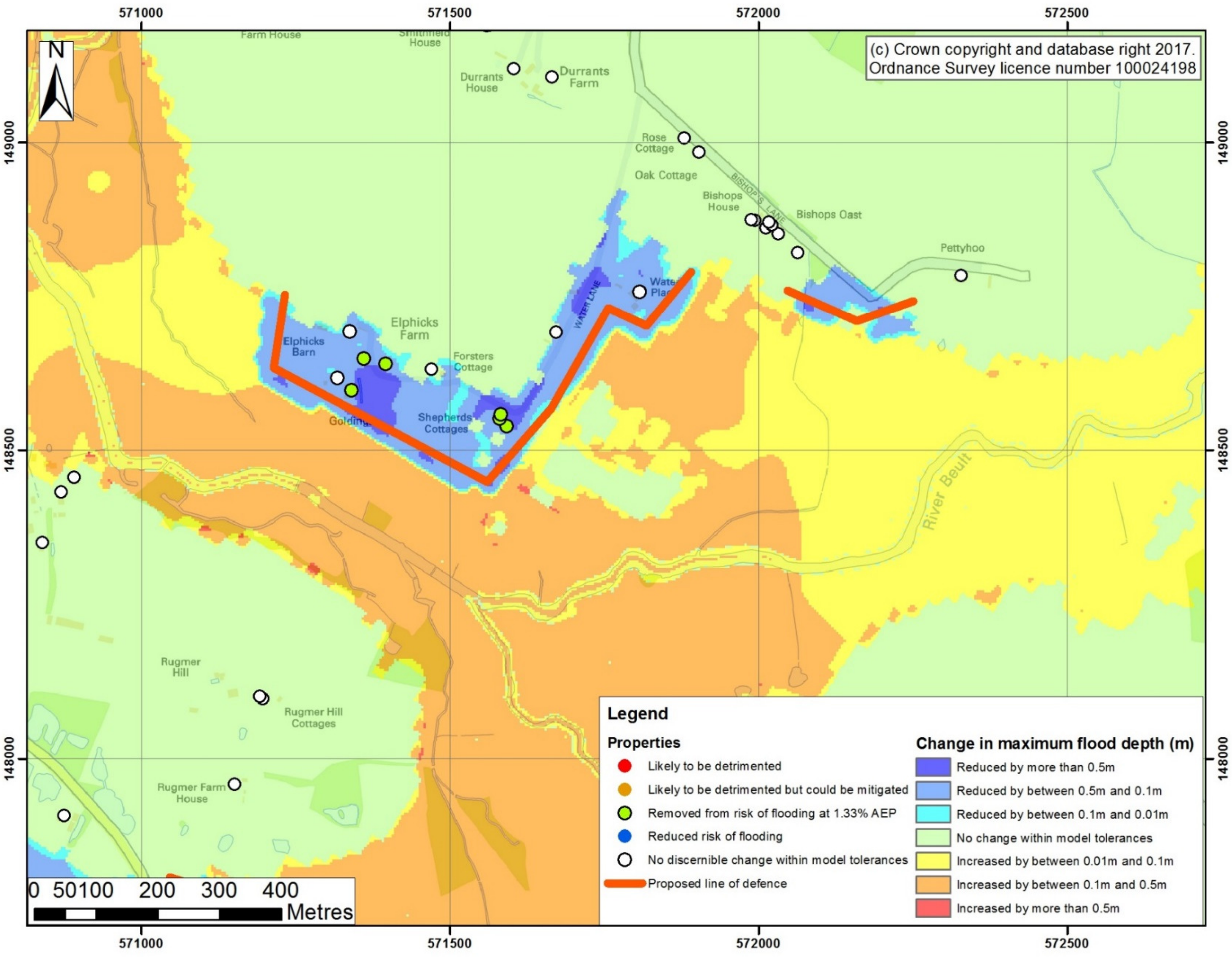

Figure 30g Enlargement of Figure 29a, Hunton area

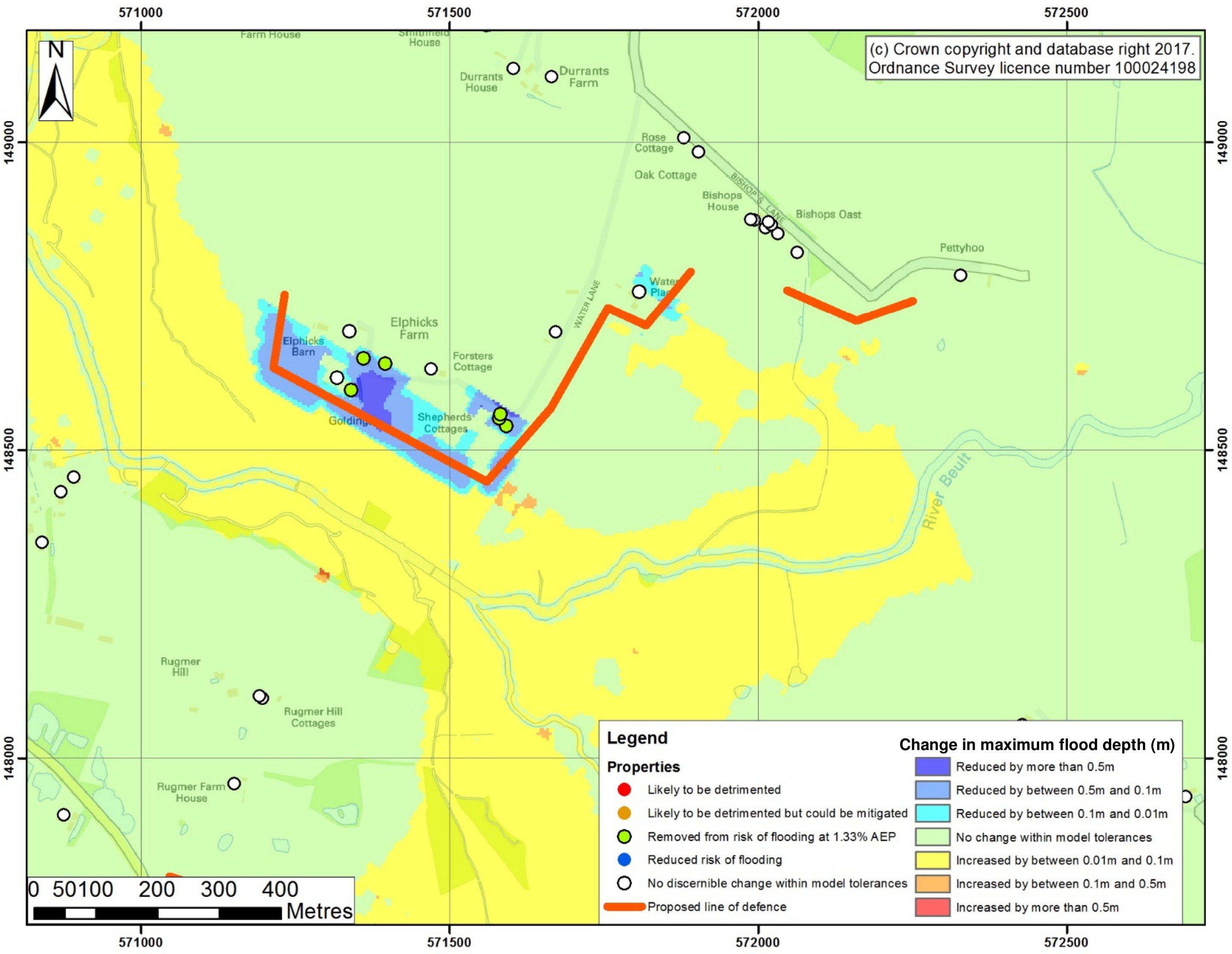

Figure 30h Enlargement of Figure 29b, Hunton area

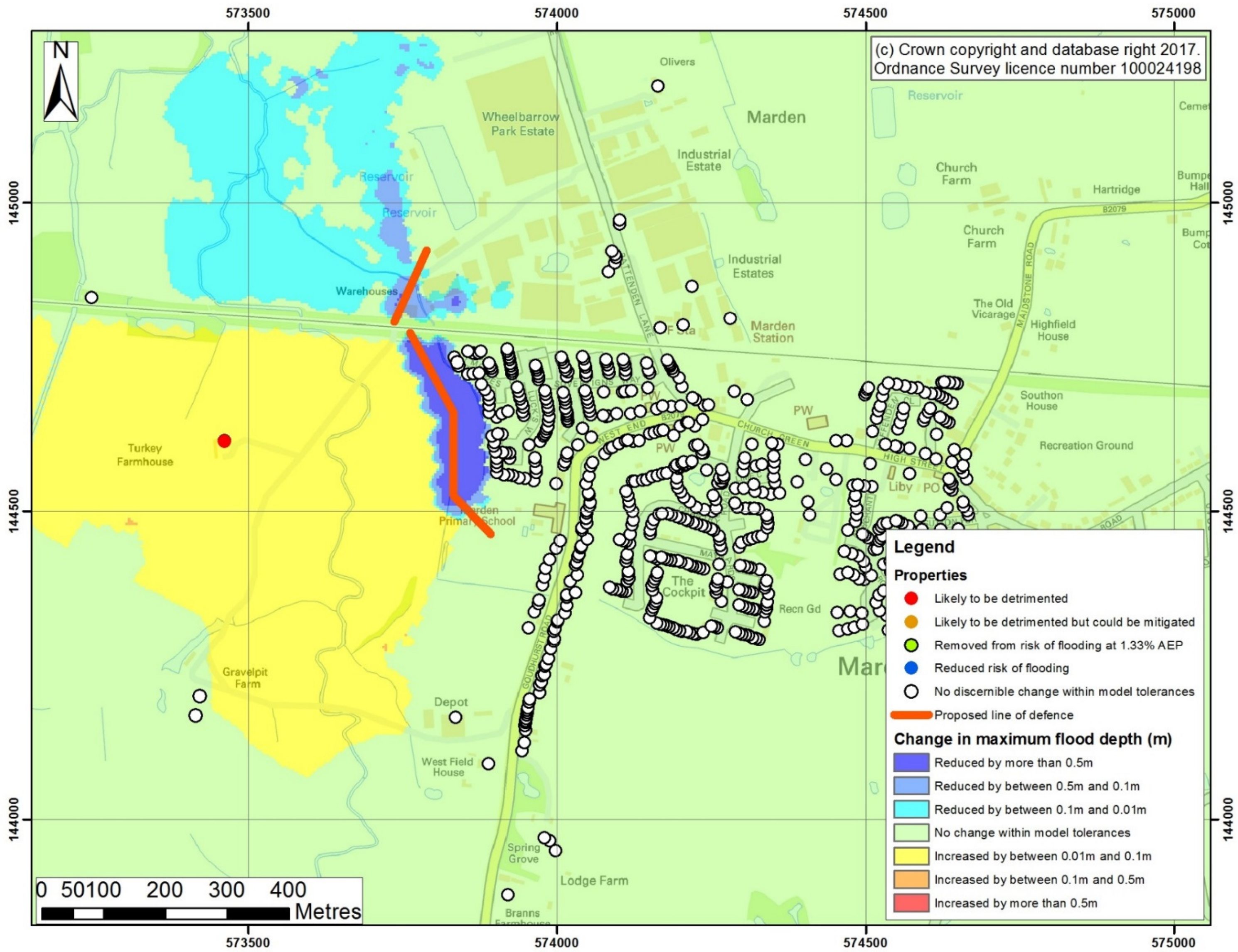

Figure 30i Enlargement of Figure 29a, Marden area

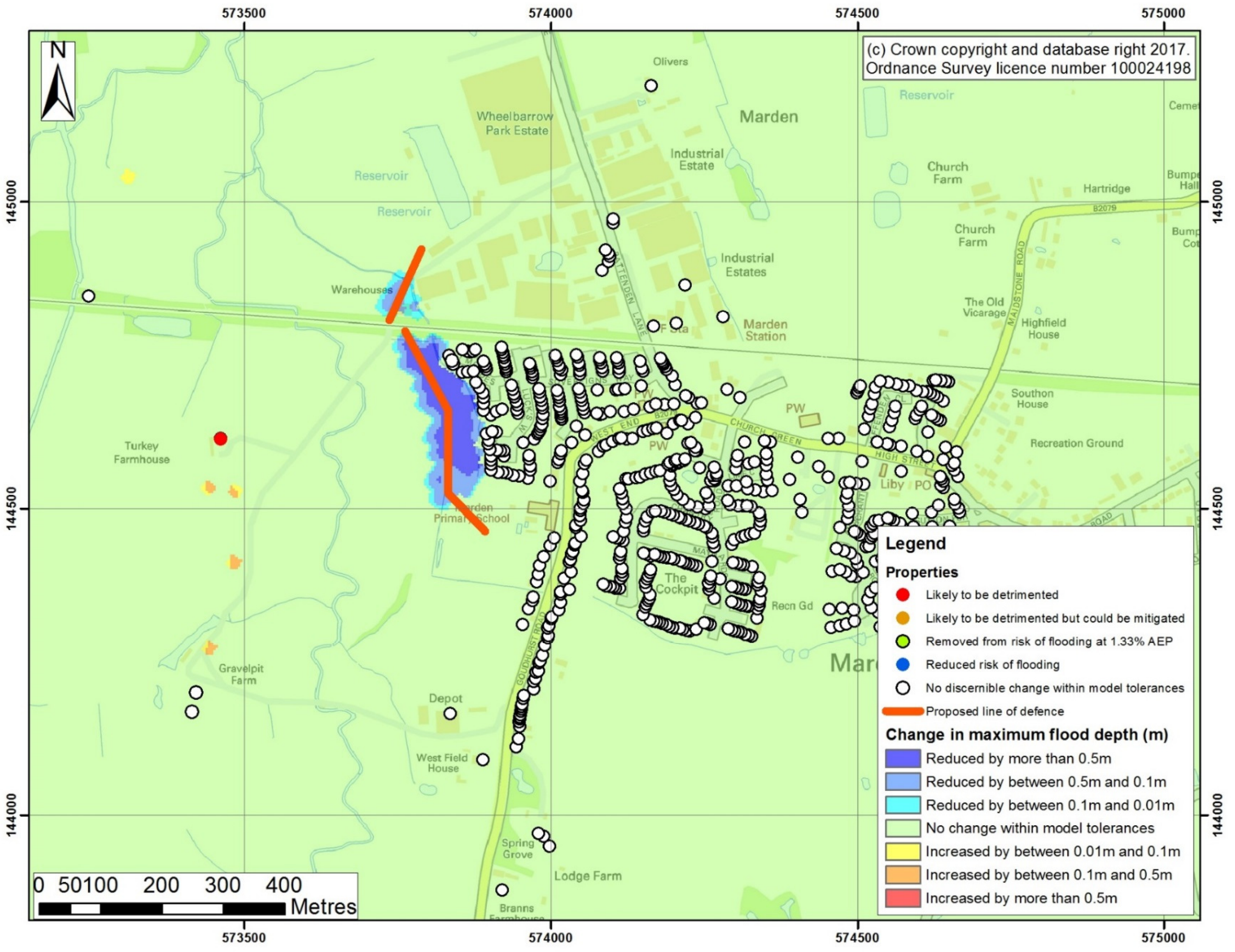

Figure 30j Enlargement of Figure 29b, Marden area

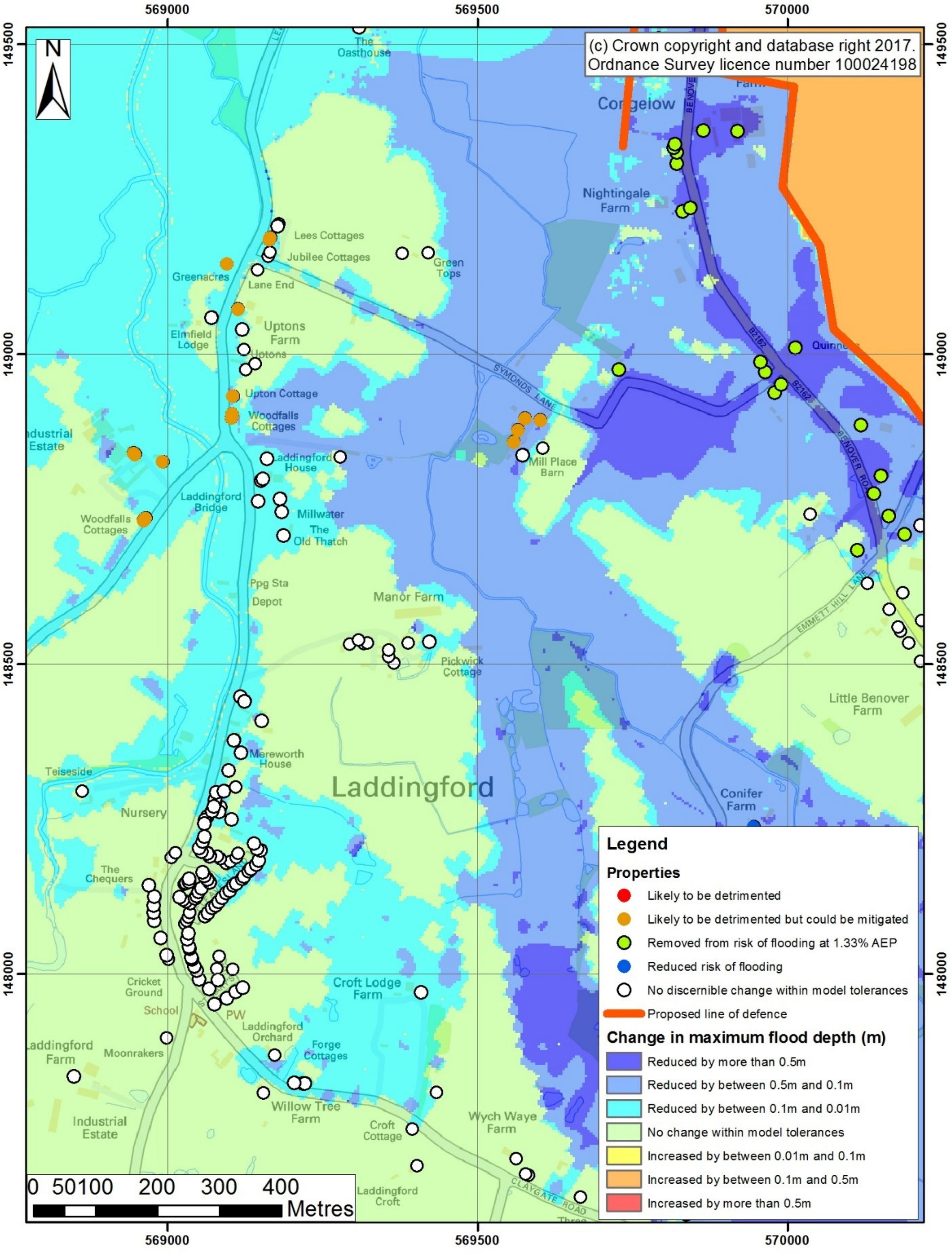

Figure 30k Enlargement of Figure 29a, Laddingford area

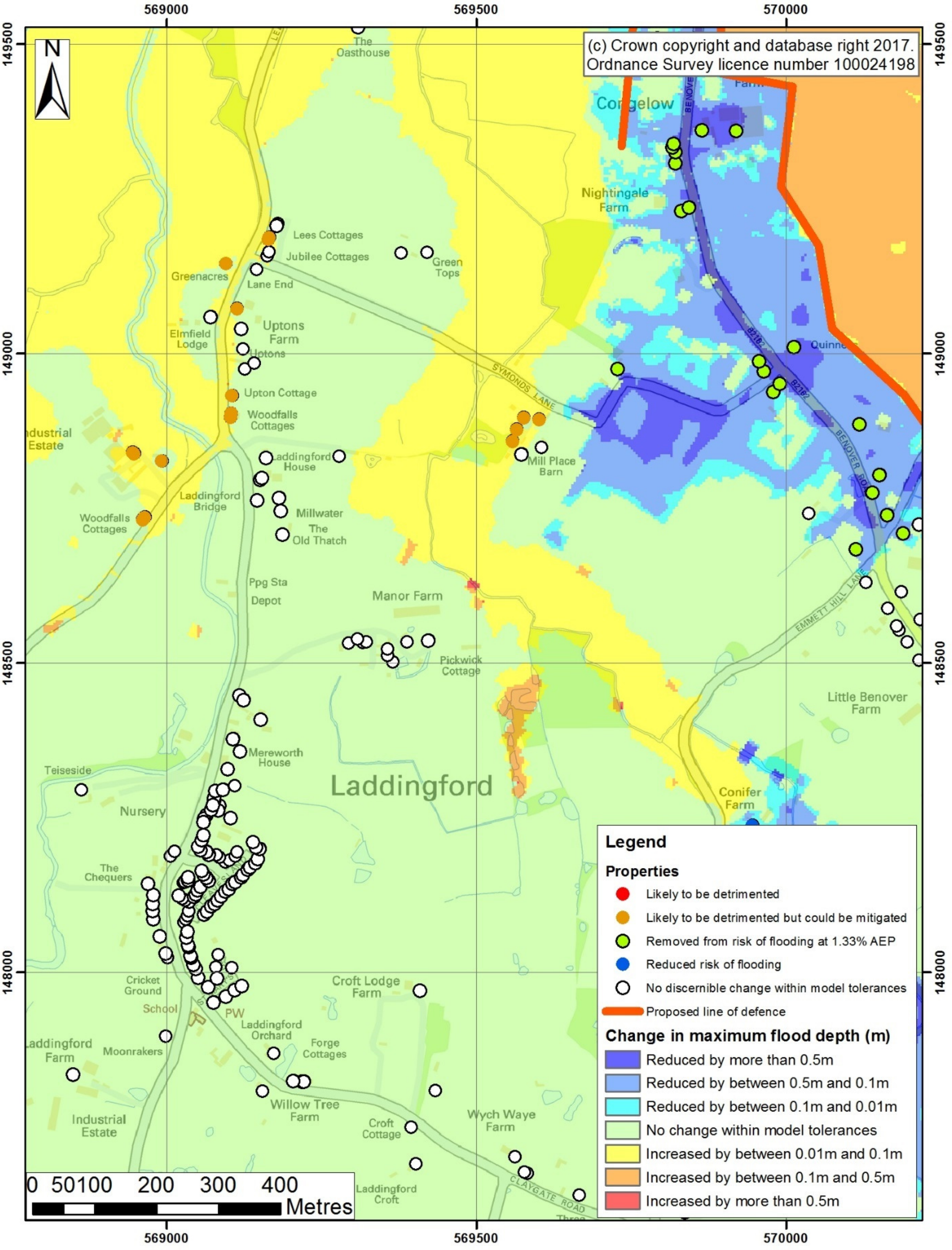

Figure 30l Enlargement of Figure 29b, Laddingford area

Table 5 Change in flood risk due to the proposed scheme

Effect on properties	*Number of properties affected*	*Number of properties that could be protected with the scheme plus additional PLP*
Removed completely from 1.33% (1 in 75 year) AEP flood risk from the Medway, Beult or Teise	*263*	
Reduced peak water levels but continues to be at risk of flooding from a 1.33% (1 in 75 year) AEP flood from one or more river sources	*76*	*75*
No discernible change in flood risk within the model tolerances (+/- 10mm water depth)	*463*	
Increase in flood risk in a 1.33% (1 in 75 year) AEP flood event	*89*	*35*

* Note PLP protection may not be eligible for funding for the 89 properties adversely affected by the scheme. There would be a need to include a value for compensation to any properties adversely affected, and this has not been determined within this study.

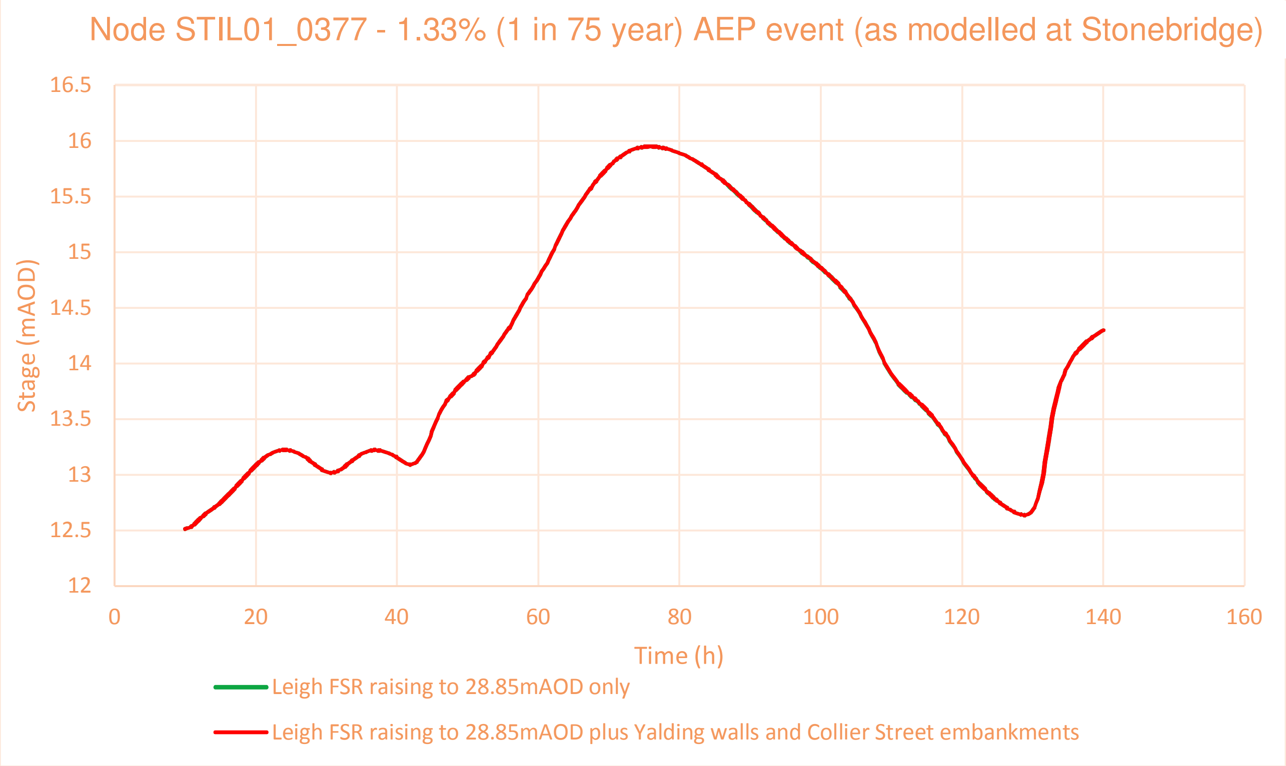

Figure 31a Difference in peak flood level for a 1.33% (1 in 75 year) AEP flood event (as modelled for Stonebridge), at node STIL01_0377 at Stilebridge, refined embankment alignments compared to baseline condition. There is no discernible difference at Stilebridge.

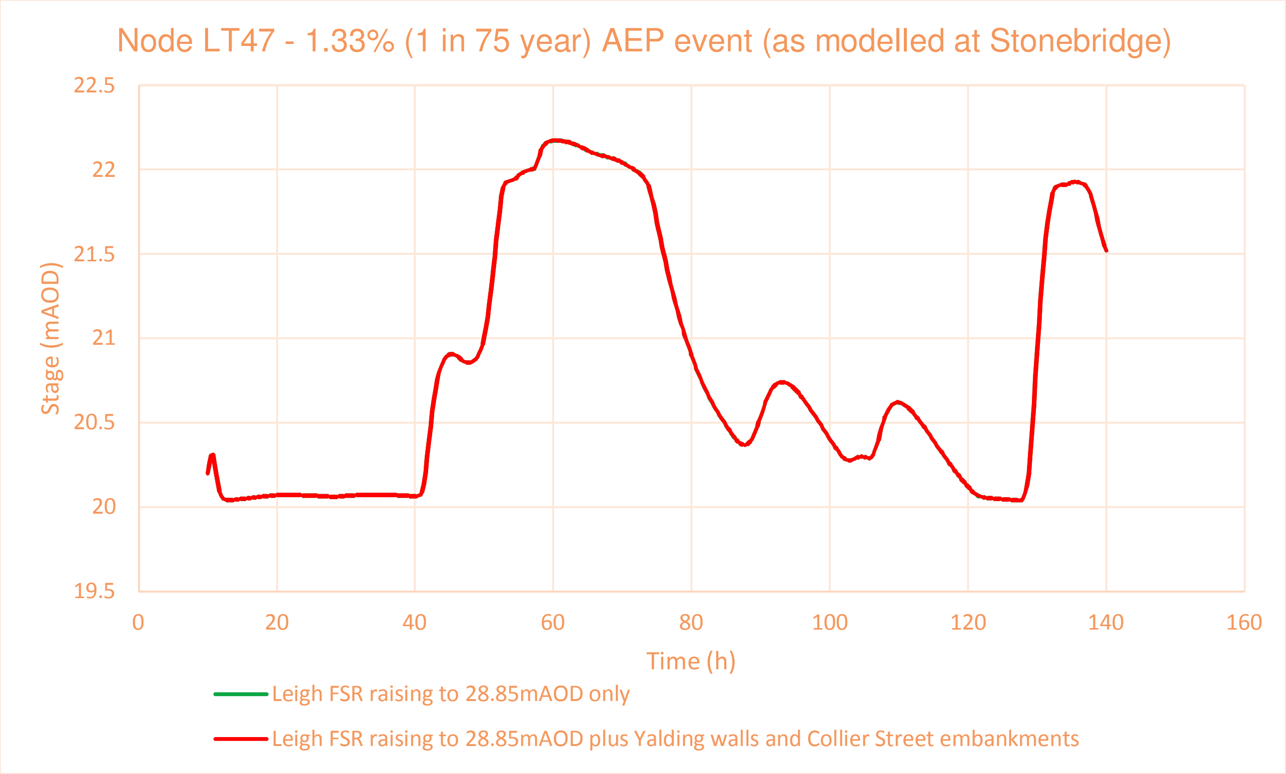

Figure 31b Difference in peak flood level for a 1.33% (1 in 75 year) AEP flood event (as modelled for Stonebridge), at node LT47 at the divergence of the Teise and Lesser Teise near Marden, refined embankment alignments compared to baseline condition. There is no discernible difference here.

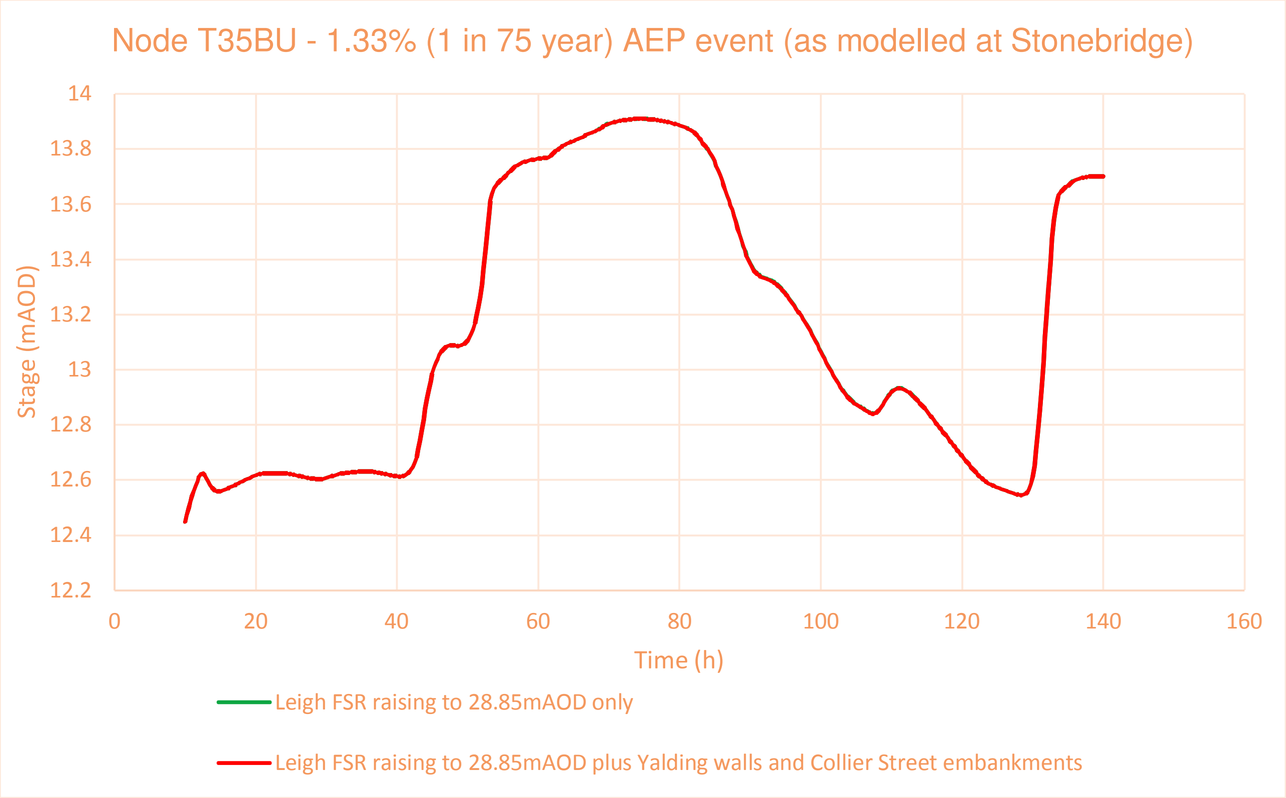

Figure 31c Difference in peak flood level for a 1.33% (1 in 75 year) AEP flood event (as modelled for Stonebridge), at node T35BU on the River Teise downstream of the divergence of the Lesser Teise, refined embankment alignments compared to baseline condition. There is no discernible difference here.

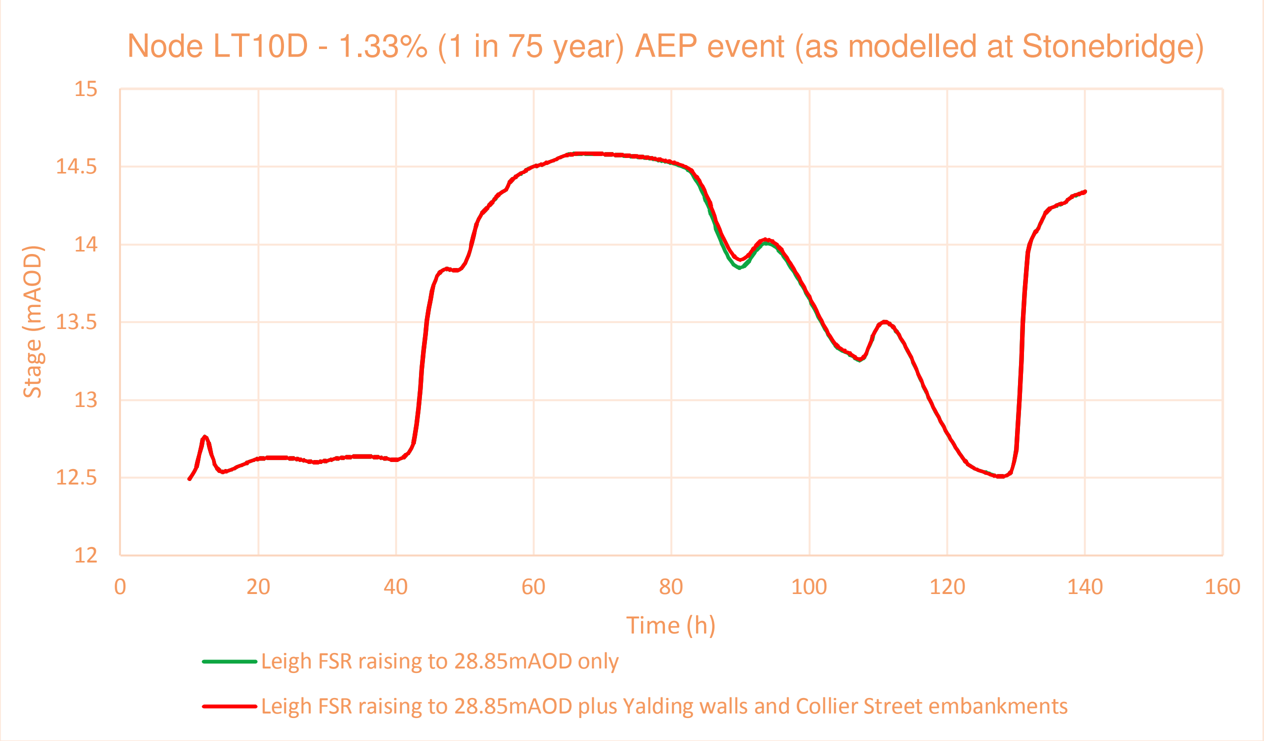

Figure 31d Difference in peak flood level for a 1.33% (1 in 75 year) AEP flood event (as modelled for Stonebridge), at node LT10D on the Lesser Teise near Den Cottages, refined embankment alignments compared to baseline condition. There is only a very minor change in peak water levels here at around 90 hours.

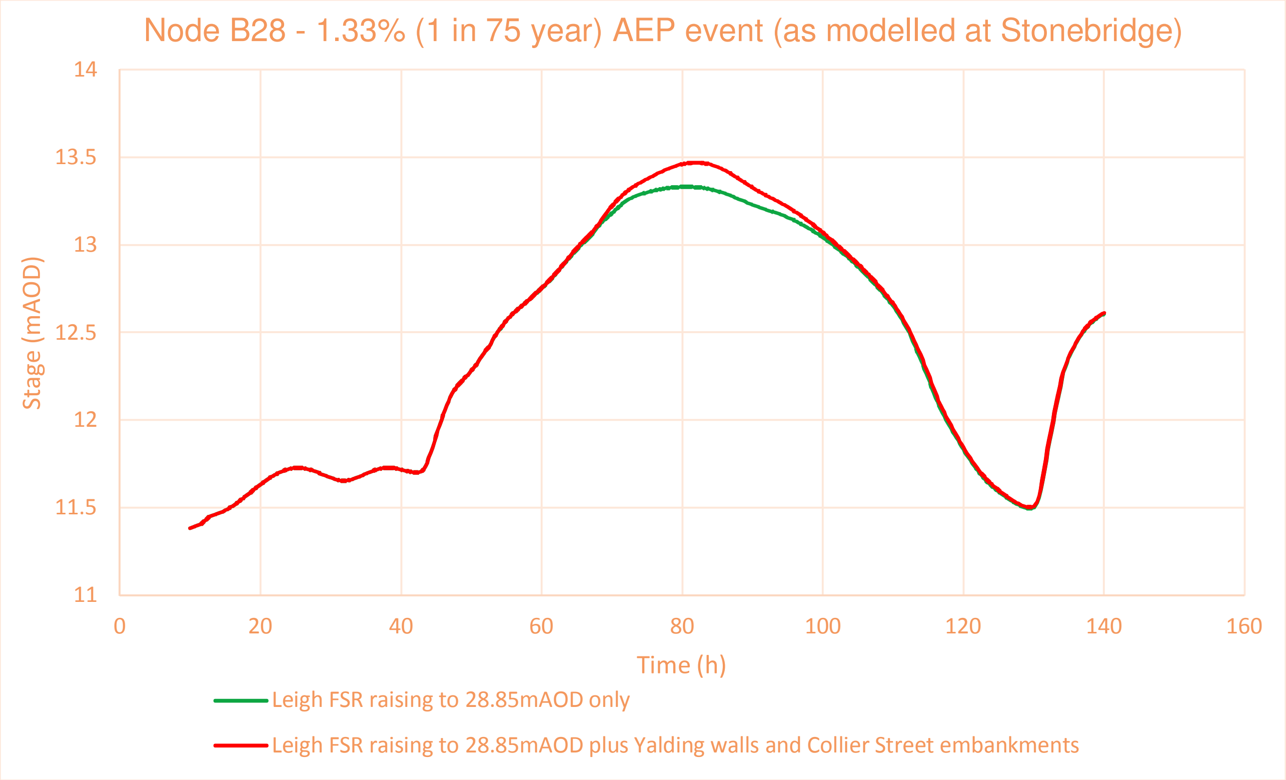

Figure 31e Difference in peak flood level for a 1.33% (1 in 75 year) AEP flood event (as modelled for Stonebridge), at node B28 immediately downstream of the confluence between the Lesser Teise and the River Beult, refined embankment alignments compared to baseline condition. The peak water level has increased by 137mm with the embankments in place.

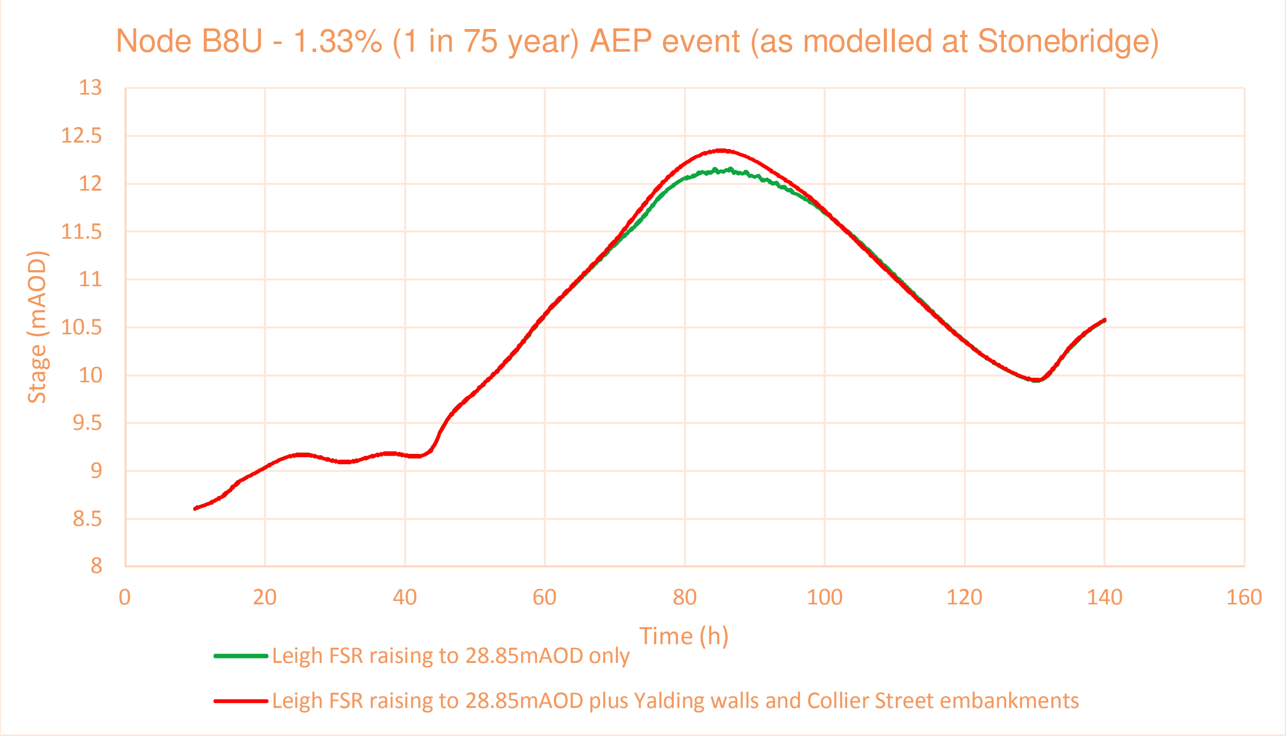

Figure 31f Difference in peak flood level for a 1.33% (1 in 75 year) AEP flood event (as modelled for Stonebridge), at node B8U immediately upstream of the Town Bridge at Yalding, refined embankment alignments compared to baseline condition. The peak water level has increased by 190mm with the embankments in place.

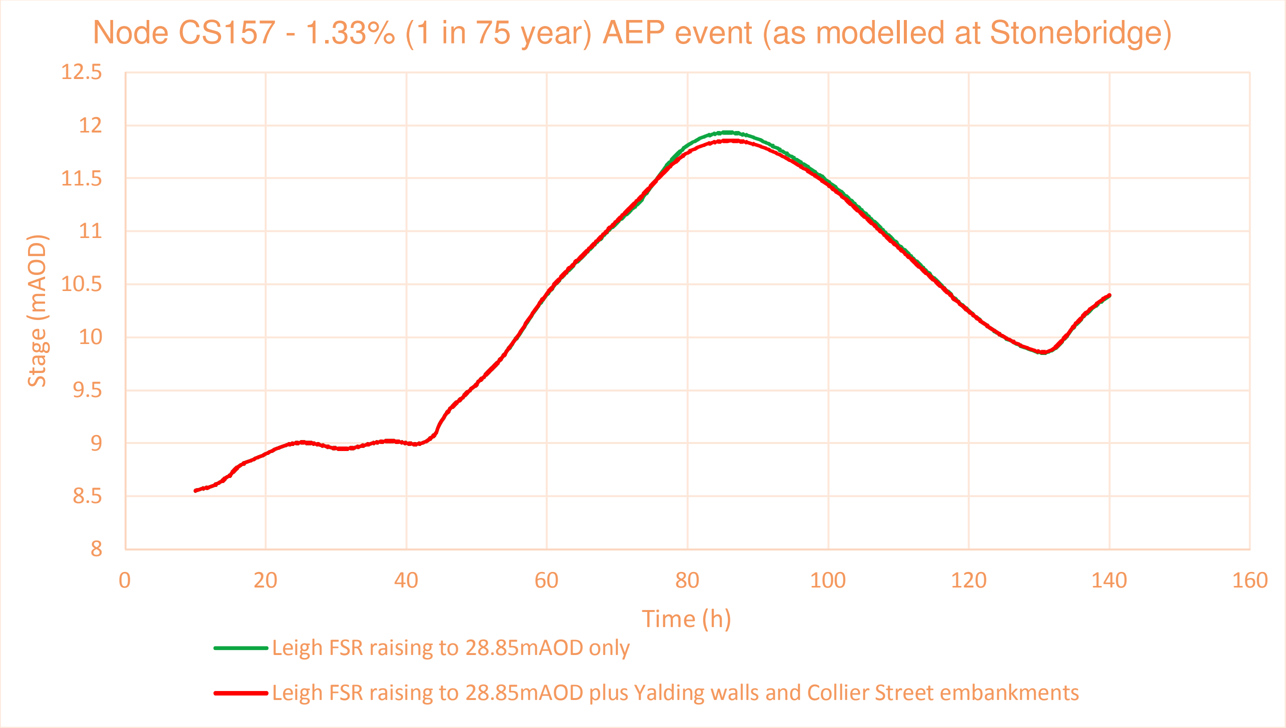

Figure 31g Difference in peak flood level for a 1.33% (1 in 75 year) AEP flood event (as modelled for Stonebridge), at node CS157 immediately downstream of the confluence between the River Medway and the River Beult, refined embankment alignments compared to baseline condition. The peak water level has decreased by 77mm with the embankments in place.

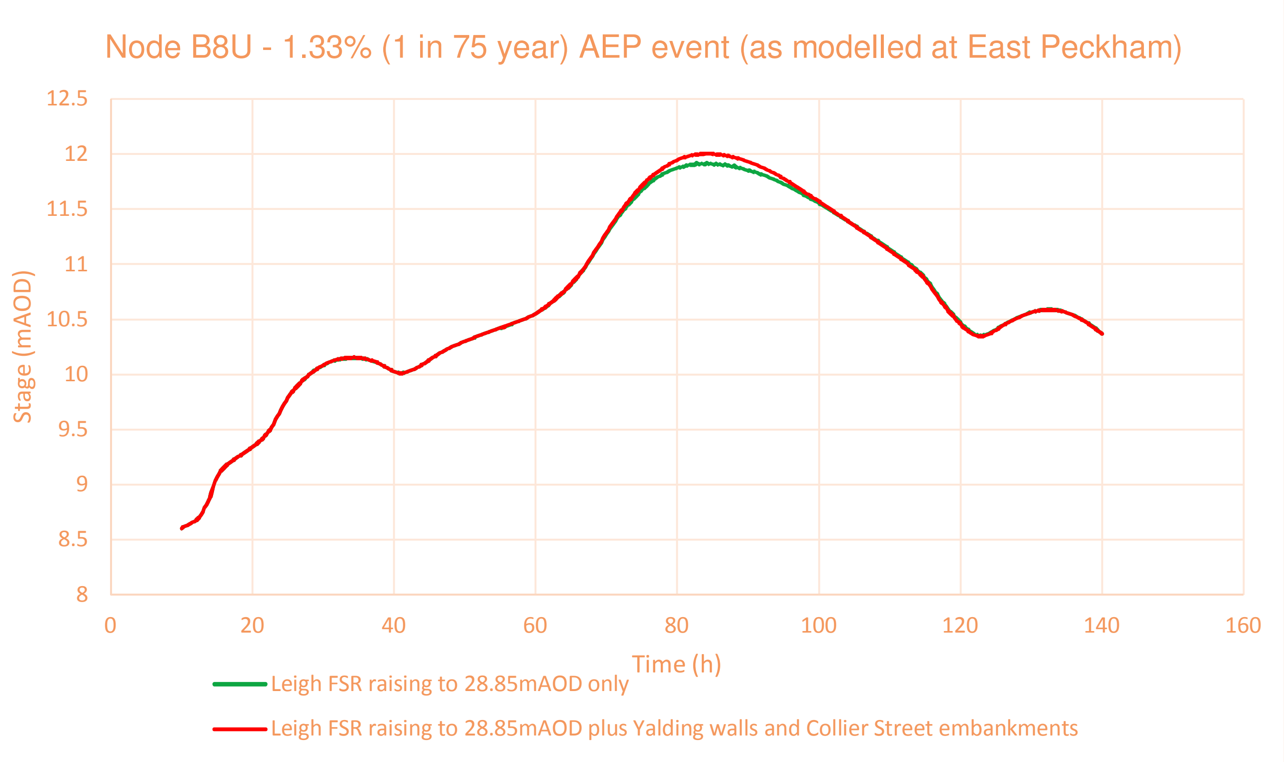

Figure 32a Difference in peak flood level for a 1.33% (1 in 75 year) AEP flood event (as modelled for East Peckham), at node B8U immediately upstream of the Town Bridge at Yalding, refined embankment alignments compared to baseline condition. The peak water level has increased by 80mm with the embankments in place.

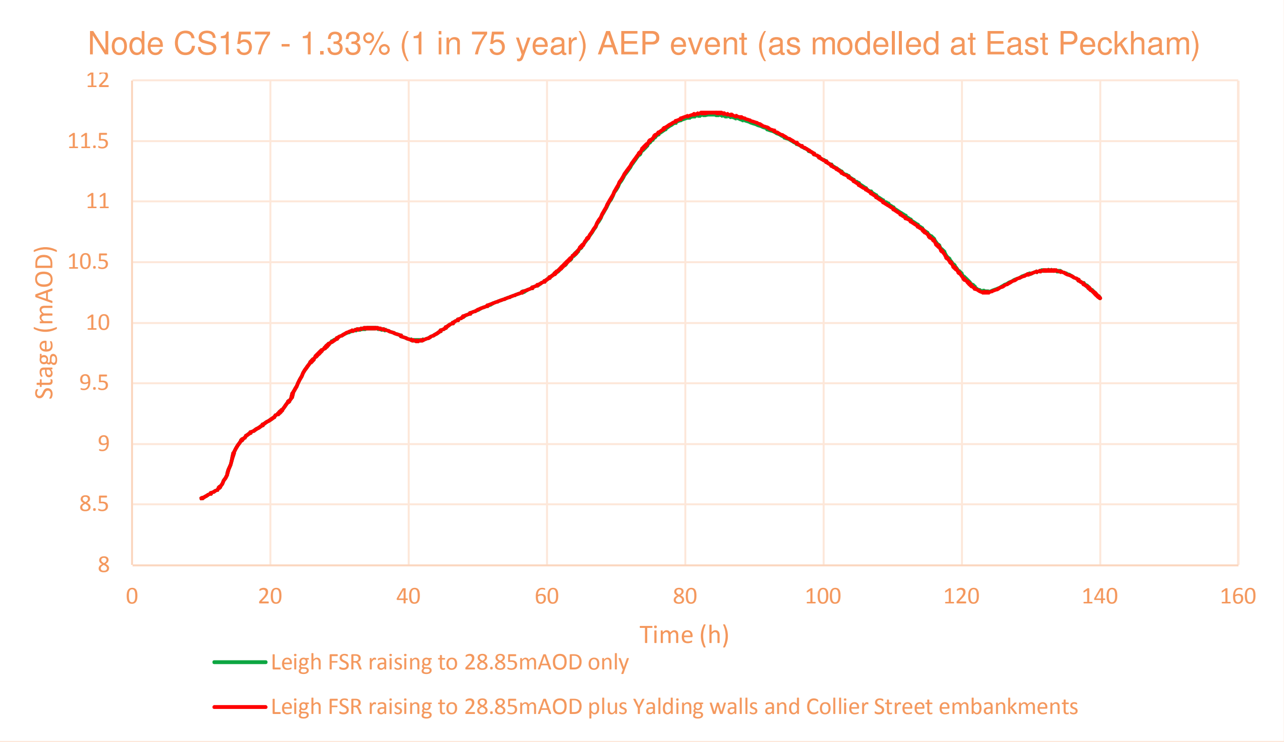

Figure 32b Difference in peak flood level for a 1.33% (1 in 75 year) AEP flood event (as modelled for East Peckham), at node CS157 immediately downstream of the confluence between the River Medway and the River Beult, refined embankment alignments compared to baseline condition. The peak water level has decreased by 17mm with the embankments in place.

2.6 Other Options

2.6.1 Upstream Afforestation on the Beult

The hydraulic model was modified to test the effect of increasing woodland cover by increasing surface roughness in the 2D model, and increasing the groundwater infiltration rate in line with guidance provided in the ISIS hydraulic modelling instructions. The area selected for planting in the model comprised an area of the valley floor between Smarden and 2km downstream of Headcorn. This represents an area of 5.8 km^2, and is shown in **Figure 33**.

In **Figure 34** the maximum flood extent and depth is shown for the 2% (1 in 50 year) flood event as modelled at Smarden. Flooding continues to extend across Tilden, Collier Street, Hunton, Benover and Yalding as before. **Figure 35a** shows the difference in flood level between the baseline (raised Leigh FSR only) and modelled (raised Leigh FSR plus the increased woodland cover) for a 2% (1 in 50 year) event at node B64U at Cross-at-Hand, and **Figure 35b** shows the same comparison at node B28 just downstream of the confluence with the Lesser Teise, near Hunton. The reduction in flood depth is 0.026m at Cross-at-Hand and 0.009m (within the model tolerance of 10mm) at Hunton.

It is also noticeable that, even at the early stages of the flood event there is very little discernible change in flood depth. This would imply that the increased woodland cover would also be relatively ineffective for smaller floods. While the concept of increased afforestation is valid, and has been demonstrated to work in catchments with large upstream rural areas where a significant part of the catchment (maybe 30% or more) can be planted, there are other factors in the Weald Basin which counter this. Among these is the fact that the underlying ground surface has a high clay content, so the areas not planted will still generate much faster runoff. If the entire catchment was planted as woodland there may be an appreciable effect, but this is not realistic. However, afforestation (increasing woodland) does have further advantages, including reducing soil runoff and therefore both improving water quality and reducing siltation rates in rivers downstream, so where opportunities exist this is a good policy to follow. There have been commercial willow plantations grown for biomass fuel, as this is a woody crop that is relatively fast-growing. Such opportunities could be looked at further, but the modelling evidence indicates that increasing woodland cover would have a negligible effect on flood risk for the communities at risk in the Weald Basin.

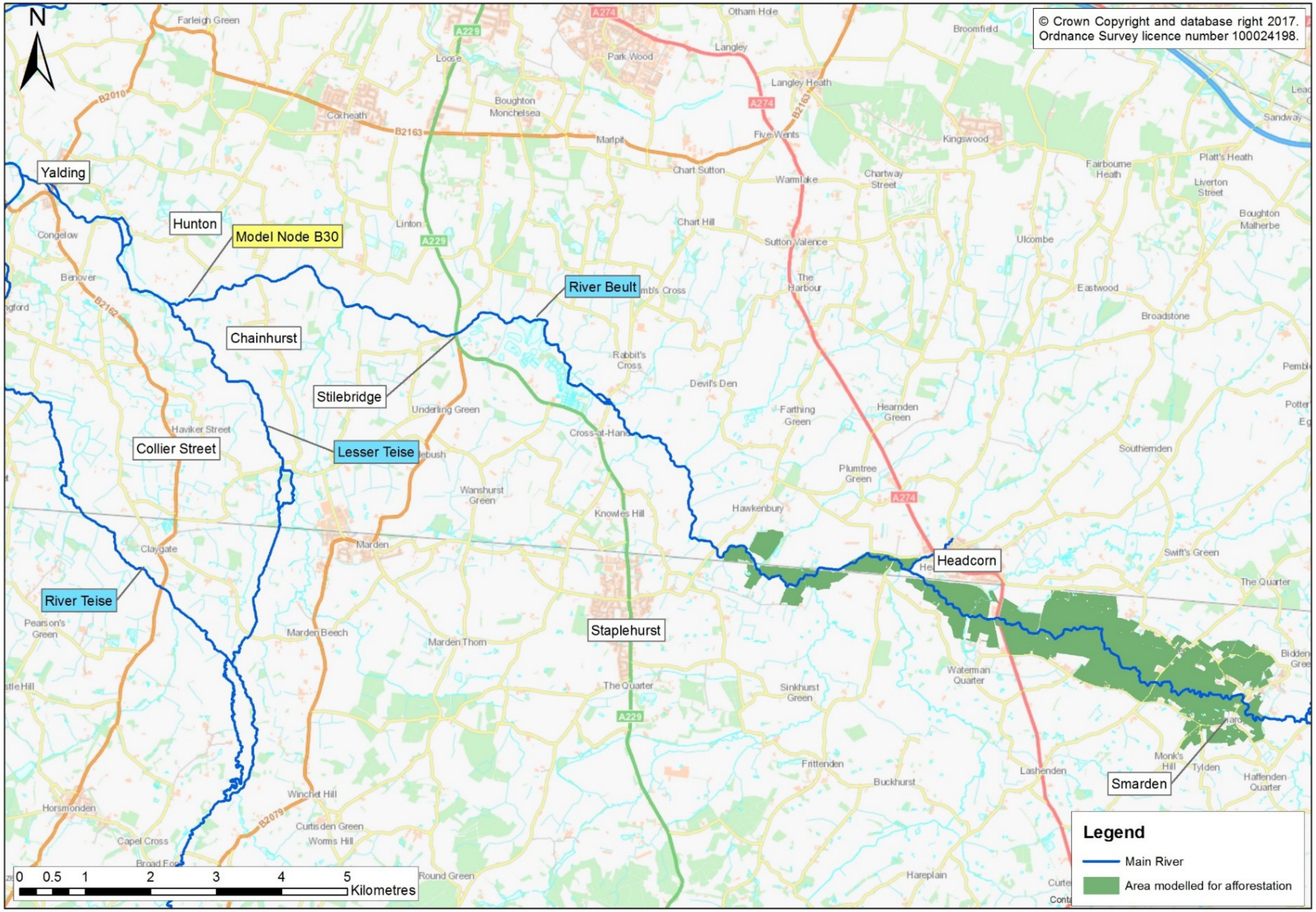

Figure 33 Area modelled for increased woodland cover in the hydraulic model.

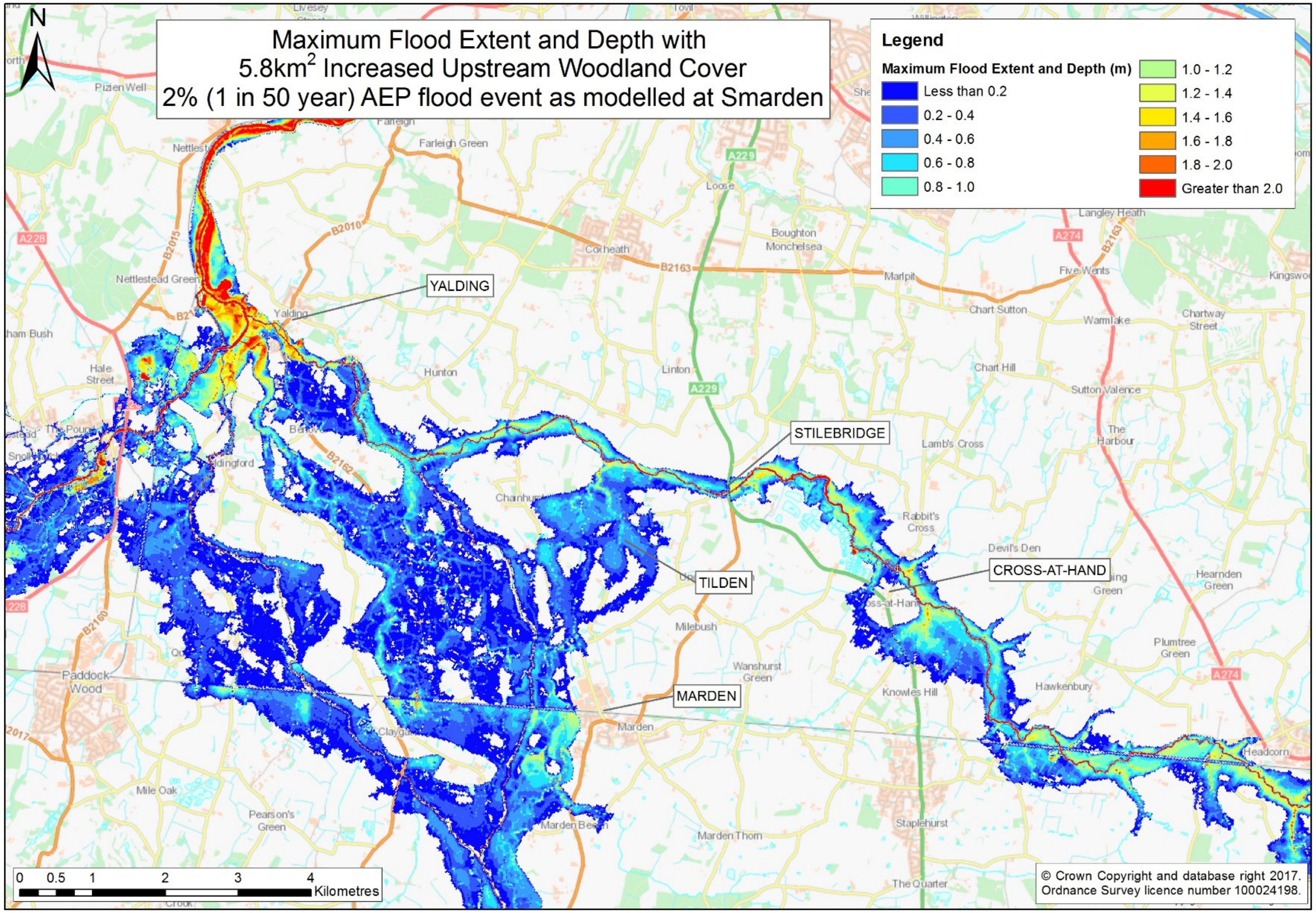

Figure 34 Modelled peak flood extent with increased woodland cover, 2% (1 in 50 year) AEP event as modelled at Smarden

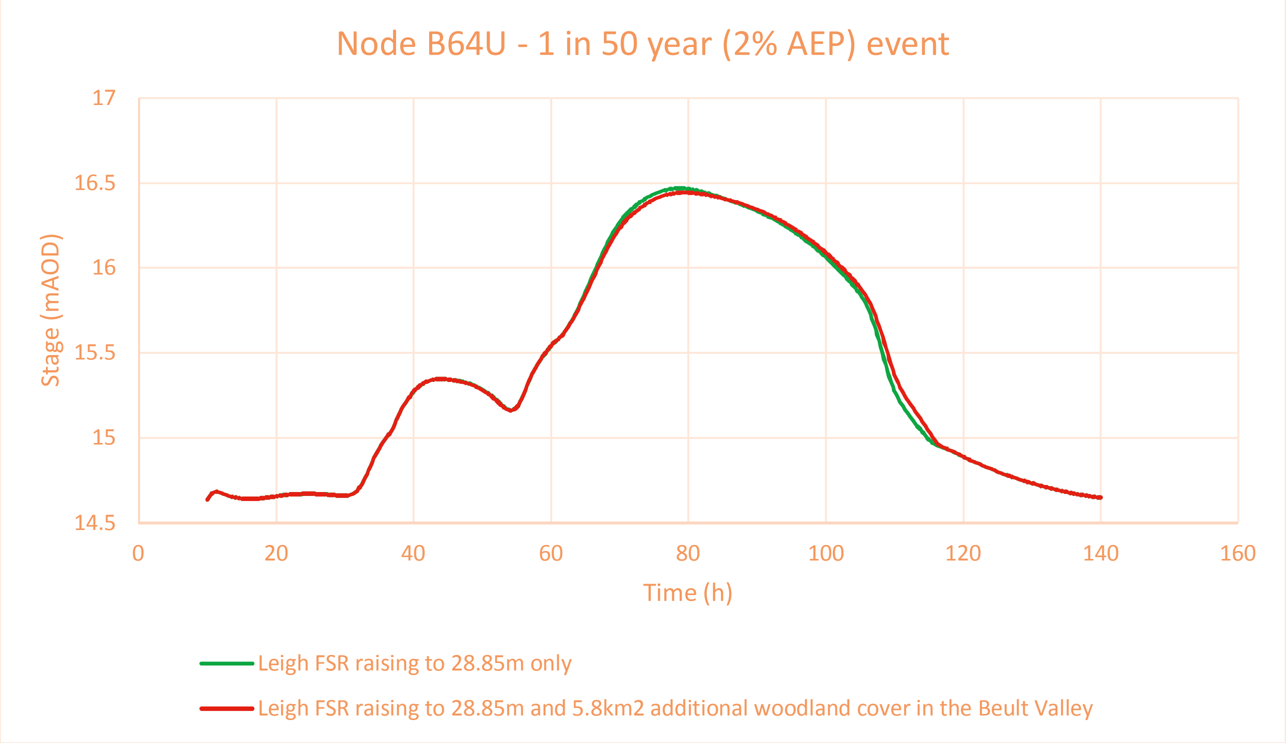

Figure 35a Comparison in peak flood levels for a 2% (1 in 50 year) AEP flood as modelled for Smarden, with existing conditions and with increased afforestation as per Figure 25, location node B64U at Cross-at-Hand. Peak water level is reduced by 24mm.

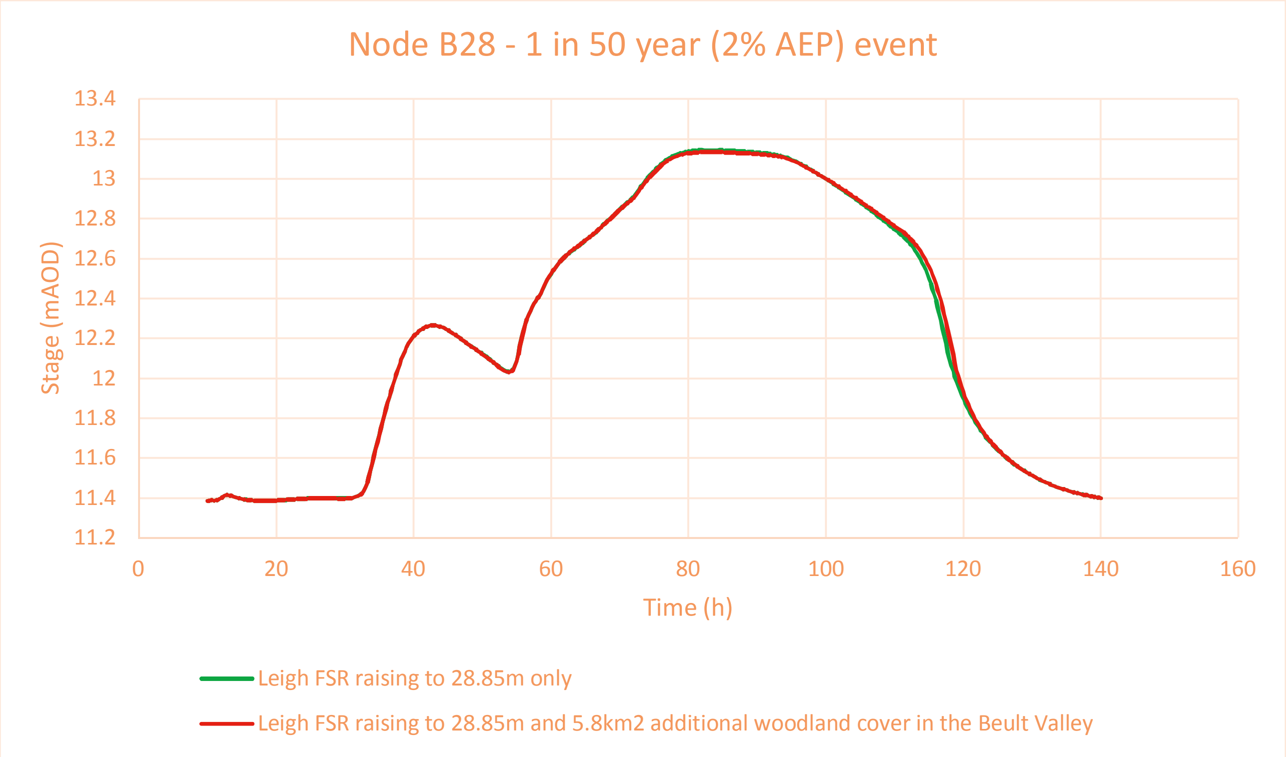

Figure 35b Comparison in peak flood levels for a 2% (1 in 50 year) AEP flood as modelled for Smarden, with existing conditions and with increased afforestation as per Figure 25, location node B28 at Hunton. The peak water level is reduced by 9mm, which is within the model tolerance of 10mm.

2.6.2 Upstream Meandering on the Beult

We have simulated an additional 1.1km of channel by adding meanders to the Beult floodplain (**Figure 36**). The model was run for the 2% (1 in 50 year) AEP flood event (as modelled for Smarden), and the change in water level was output for several nodes along the Beult (**Figures 37a** to **37c**). It is noted that there is a marginal reduction in peak water level for the first flood peak at Cross-at-Hand, close to the location of the meanders. However, there is negligible change for the much larger second peak. Also, as the flood progresses down the catchment even the small initial reduction diminishes from approximately 60mm at Cross-at-Hand to 30mm at the Lesser Teise confluence and less than 20mm at the Medway confluence. There is also no noticeable delay in arrival of the peak flood as a result of the longer channel length. Note the model precision is only +/- 10mm so a 20mm improvement is virtually immeasurable.

The reason for this is that, with larger floods, there is extensive out-of-bank floodplain flow in the Beult valley. Even if the water in the channel is taking longer to move downstream, there is sufficient out-of-bank flow to move the flood at approximately the same speed. However, it should be recalled that the model hydrology is designed to assume concurrent rainfall across the catchment. With a storm falling primarily over the eastern part of the Beult catchment it is possible the effect of meanders could be marginally better, but the improvement is unlikely to be significant.

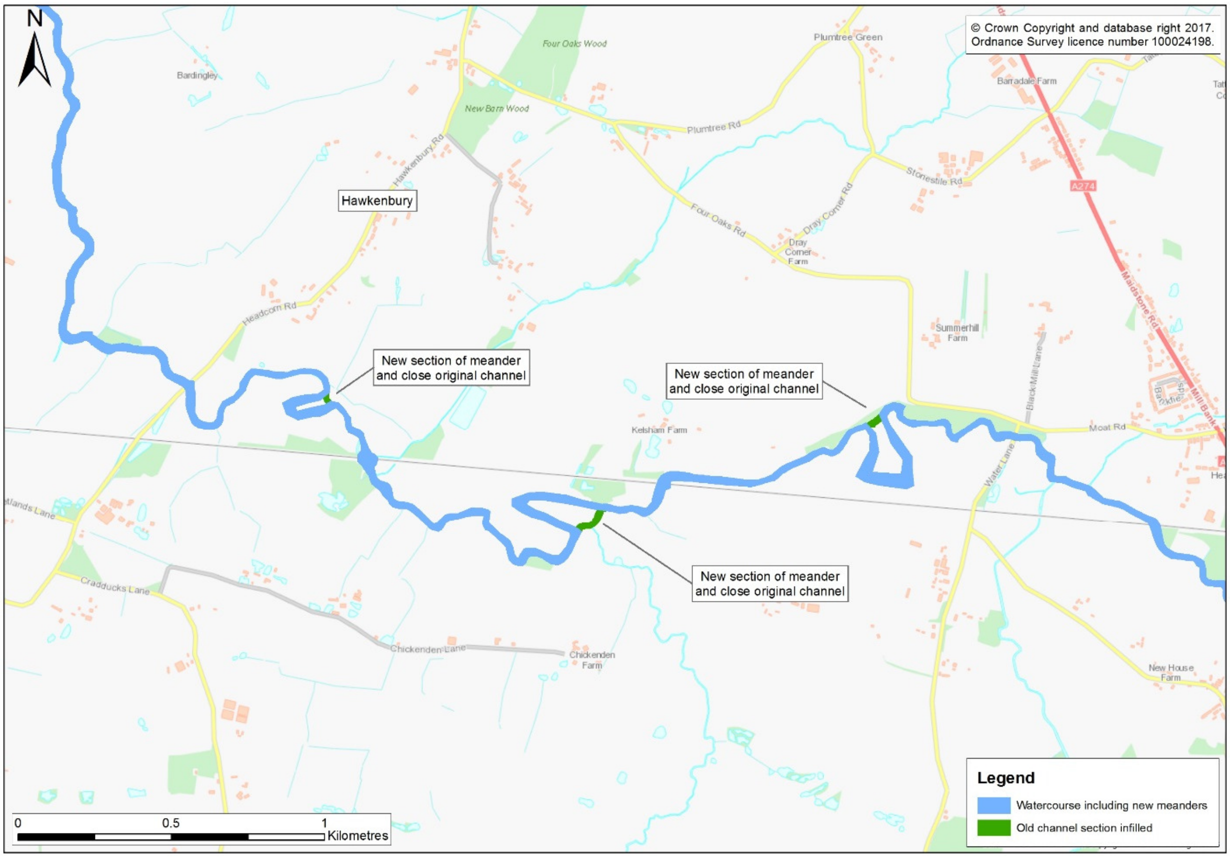

Figure 36 Locations of meanders added into the hydraulic model. These amount to increasing the channel length by 1.1km between Headcorn and Hawkenbury. These are only indicative locations and any actual meandering would have to be agreed with landowners.

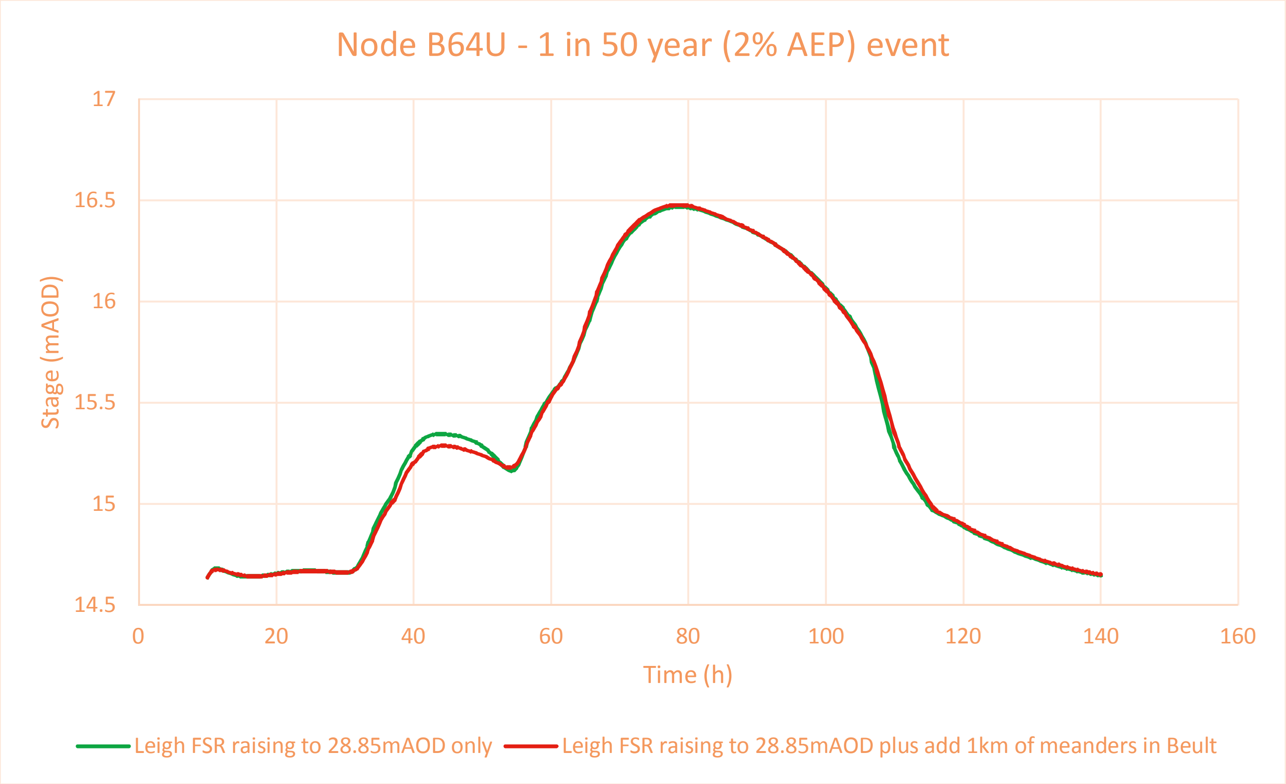

Figure 37a Modelled water levels at model node B64U upstream of the bridge at Cross-at-Hand for a 2% (1 in 50 year) AEP event as modelled for Smarden, with and without the additional 1.1km of meanders. Peak water level is reduced by 9mm, within the model tolerance of 10mm.

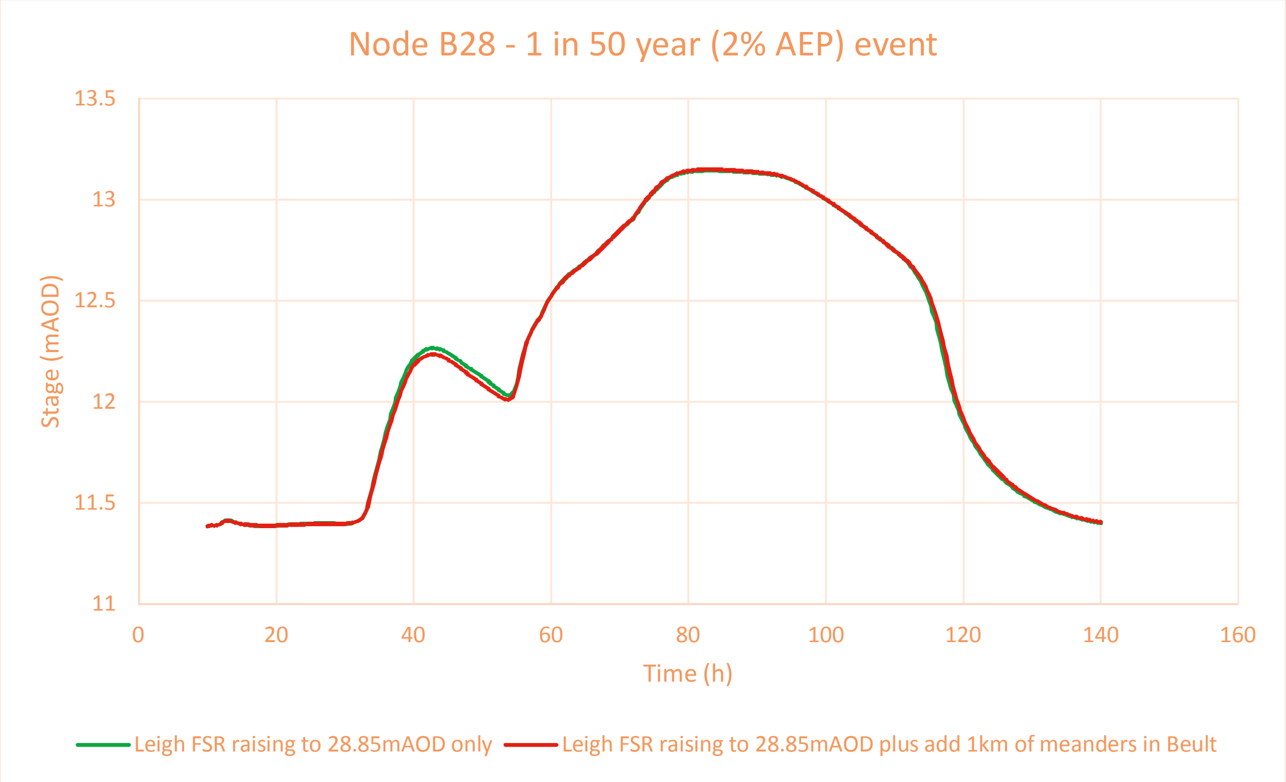

Figure 37b Modelled water levels at model node B28 just downstream of the confluence with the Lesser Teise for a 2% (1 in 50 year) AEP event as modelled for Smarden, with and without the additional 1.1km of meanders. Peak water level is reduced by 5mm.

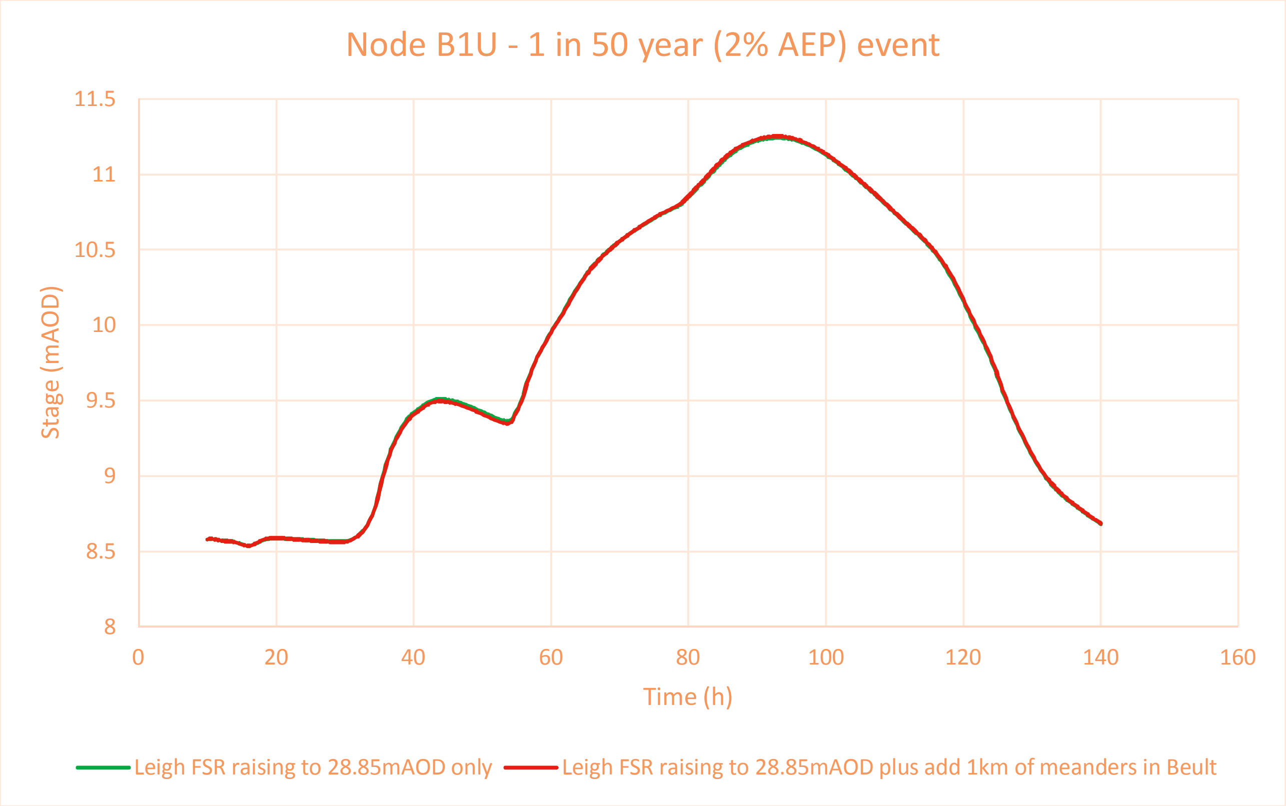

Figure 37c Modelled water levels at model node B1U immediately upstream of the confluence with the River Medway for a 2% (1 in 50 year) AEP event as modelled for Smarden, with and without the additional 1.1km of meanders. Peak water level is reduced by 10mm.

2.6.3 Upstream Afforestation on the Teise

The upstream extent of the hydraulic model is at Stonebridge. Therefore the model does not extend as far upstream from the Weald Basin communities along the Teise Valley as it does along the course of the Beult Valley. It would be possible to modify the hydrology (the upstream inflows) to simulate the effect of additional woodland cover but this would be much coarser than what can be assessed using the model in the Beult Valley where we have a full 2D floodplain model. Also the upstream Teise Valley is already quite heavily wooded and there is less potential for increasing the cover. As the model result for increasing woodland in the Beult Valley has produced negligible improvement in flood risk, and even in very large floods on the Teise the modelling indicates flows on the Beult to be dominant, it is highly unlikely that increasing woodland cover in the Teise Valley would provide significant improvement either. Therefore this option has not been modelled.

2.6.4 Upstream Meandering on the Teise

Upstream of Stonebridge the Teise Valley becomes narrower and more constrained by the upland topography of the High Weald, therefore the opportunities for increasing meandering become far fewer. As with the above option, the model does not extend upstream from Stonebridge and so this is not easily tested within the existing model. It would be possible to extend the model but that would be an expensive process and, given the indications of minimal improvement in flood risk as a result of the modelled upstream meandering on the River Beult we consider that such funding could be put to more appropriate use in funding direct local flood protection measures where these can be provided. Therefore this option has not been modelled.

2.6.5 Southern Water Bewl Abstraction at Kenward

The five Southern Water abstraction pumps at Kenward (location shown on **Figure 13**) can withdraw 2.89 m^3/s maximum flow from the River Medway just downstream of the confluence with the River Beult, and pump this back up the Teise valley to Bewl Water reservoir (see **Figure 1**). This has not been previously included in flood model runs. It should be noted that, in a flood event, Southern Water would not operate the pumps as flood water is generally more contaminated than the normal river flow and would require more expensive treatment. However, we have modelled the effect of the pumps being operated at full capacity from the outset of a 2% (1 in 50 year) AEP flood event as modelled for East Peckham, to identify a theoretical effect on a major flood.

The modelled results given in **Figure 38a** and **38b** demonstrate that maximum water depth is reduced by approximately 20-25mm at both The Lees and Hampstead Marina. The maximum flood depth would still be 11.38mAOD at The Lees and water would be above bank level of 10.1mAOD for over 100 hours. This is a very minor effect and would be unlikely to improve flood risk significantly at any of the properties identified as being at risk.

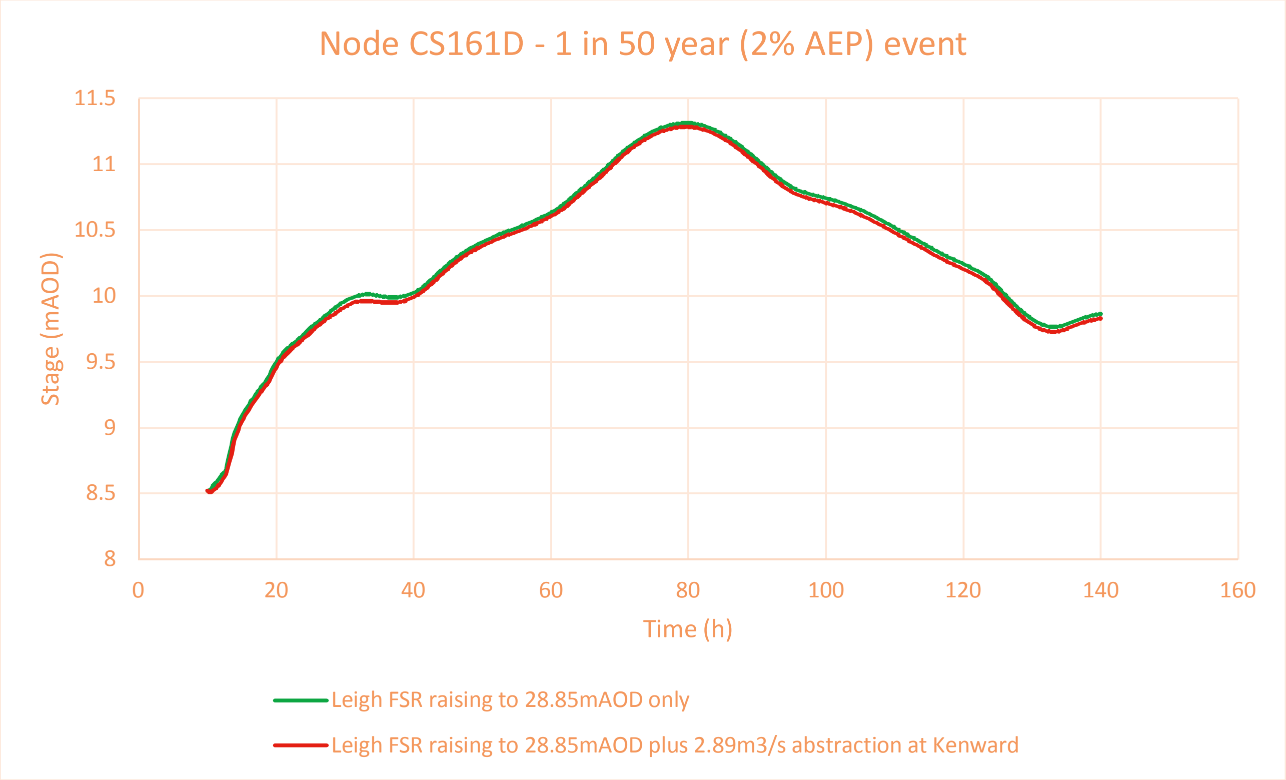

Figure 38a Modelled water levels at model node CS161D at the downstream confluence of Hampstead Lock Cut and the River Medway for a 2% (1 in 50 year) AEP event as modelled for East Peckham, with and without the maximum Southern Water abstraction at Kenward.

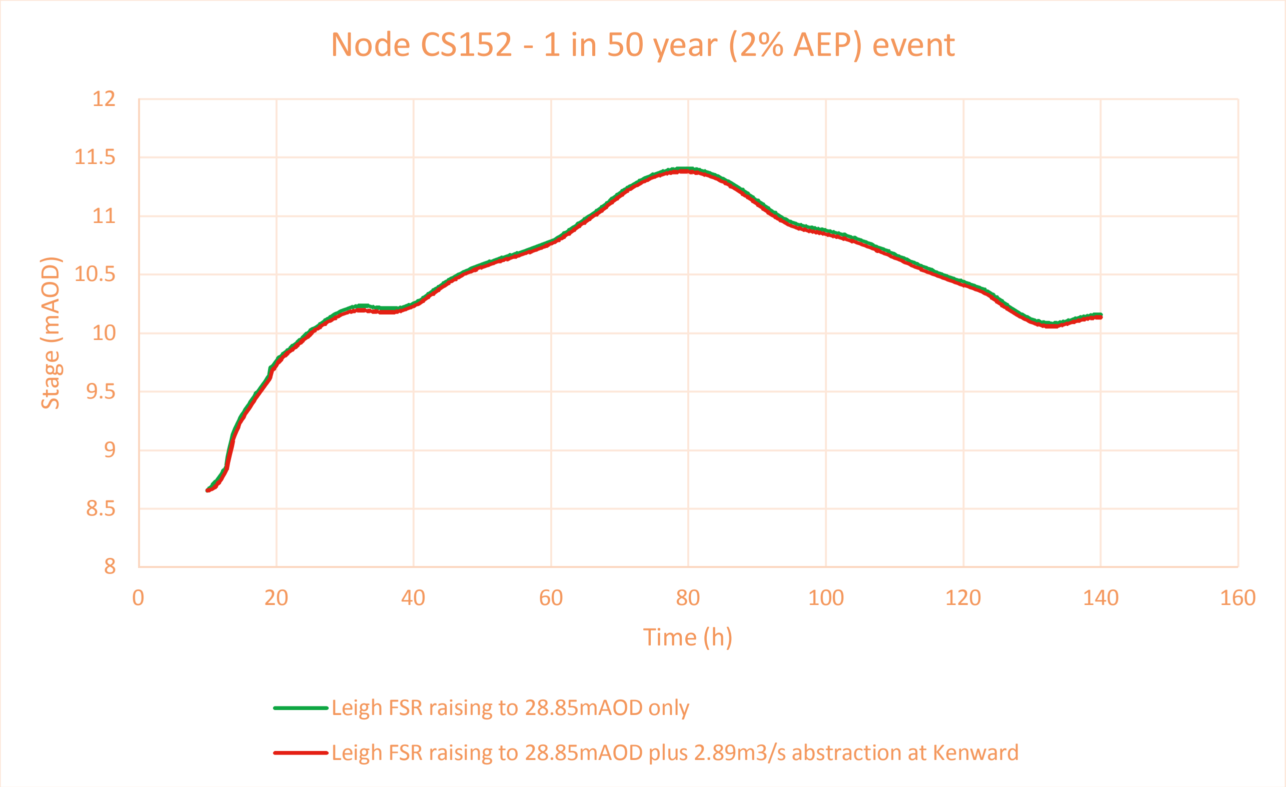

Figure 38b Modelled water levels at model node CS152 downstream of Twyford Bridge adjacent to The Lees for a 2% (1 in 50 year) AEP event as modelled for East Peckham, with and without the maximum Southern Water abstraction at Kenward.

2.6.6 A Drainage Tunnel

One option proposed by the JPFG and other stakeholders in the past is a drainage tunnel, to take excess flows from the catchment and direct them out to sea. Whilst this could theoretically work the size of the tunnel would need to be immense. In **Figure 39** both flow and stage are shown on the same hydrograph at node CS161D, just downstream of Hampstead Marina, at the upper end of the narrow constriction that forms the Medway Gorge. Note flow is shown on the left-hand axis and stage (water level) on the right-hand one. We also show the ground level of 9.2mAOD which is the point at which water passes out of bank at Hampstead. By showing these on the same graph we can see the flow at which water level exceeds top of bank, which at this location is 78.4m^3/s. The peak flow for a 2% (1 in 50 year) AEP flood event as modelled for East Peckham is 166.5m^3/s. Therefore any tunnel would need to be capable of taking 88.1m^3/s of flow to provide adequate protection for a 2% (1 in 50 year) flood event. A larger flood event would require an even larger tunnel.

A simple online calculation, not taking account of pipe roughness slowing the flow, indicates that, for a reasonable water velocity of 2m/s, a tunnel would need to be 7.5m in diameter to enable 88m^3/s to pass. For comparison, the tunnels being bored to serve the Crossrail trains under London are 6.1m diameter. The tunnel would need to be a minimum of 9.6km in length as it would need to start close to Hampstead and then outfall in the vicinity of Aylesford. We acknowledge that such a tunnel would cost very much more than any authority is likely to be able to justify and so we have not modelled this option.

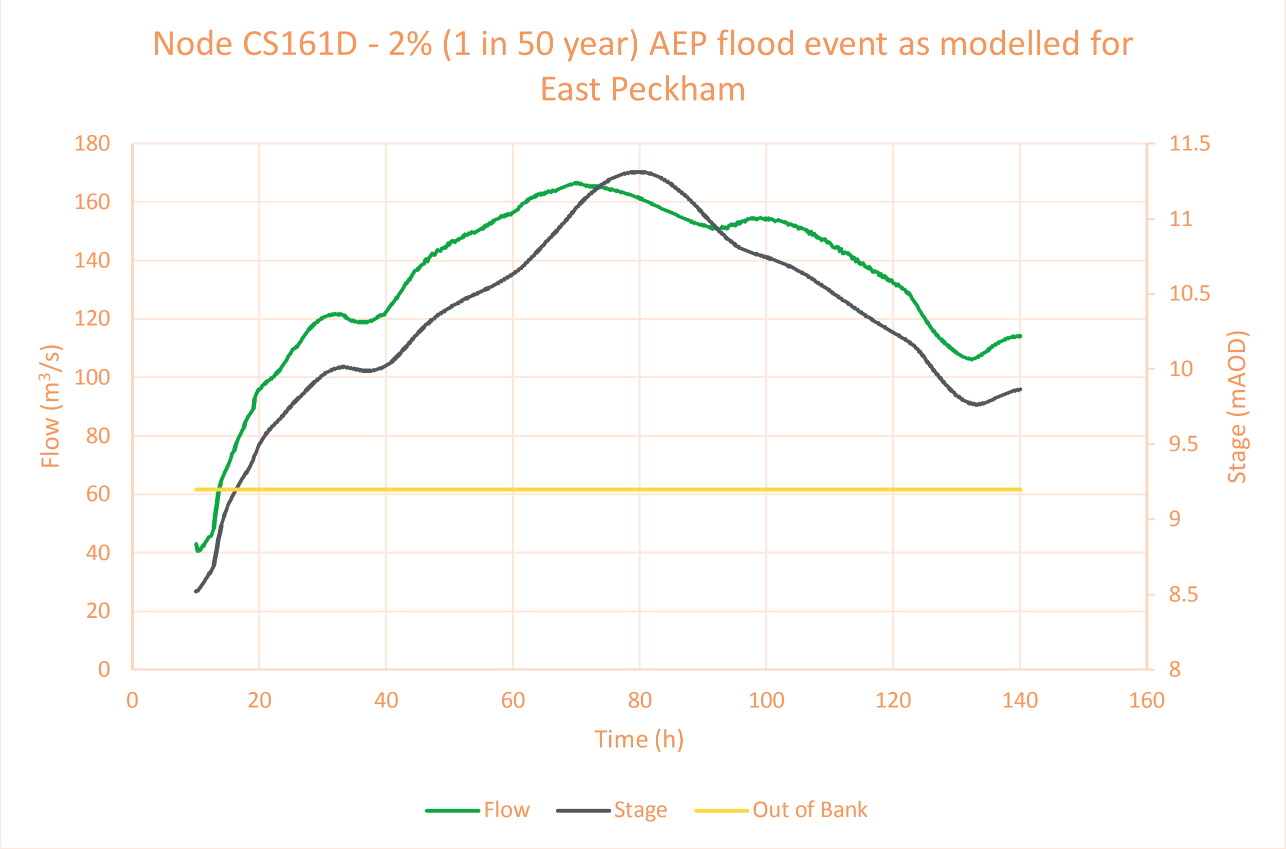

Figure 39 Modelled flow and water levels at model node CS161D at the downstream confluence of Hampstead Lock Cut and the River Medway for a 2% (1 in 50 year) AEP event as modelled for East Peckham, with out-of-bank flood level.

3 Economic Analysis

Only the option identified in section 2.5.3 above is being taken forward for economic appraisal. This is due to the insufficient protection offered by any of the other options assessed in this study.

3.1 Costing

Costing of walls, embankments, steel sheet piling, culverts, outfall structures and flood gates has been assessed using the Environment Agency's Unit Cost Database, which is available online and is assembled from prices of delivered flood alleviation projects across the country. These prices are indicated in **Tables 6** to **10** below. For PLP measures the Environment Agency have recommended using a general £7,500 per property estimate, with the proviso that individual properties may require significantly more or less than this depending on the property type, expected depth of flooding and existing threshold. This is higher than the nationally accepted average value of £5,000 per property but is the value the EA are considering in connection with their proposed scheme in the Weald Basin so is used to make a fair comparison.

Note there has been no estimate made for land purchase or compensation costs.

For each of the following tables, prices have been inflated using the Consumer Price Index downloaded from https://www.ons.gov.uk/economy/inflationandpriceindices/timeseries/d7g7/mm23. This gives a cumulative inflation of 32.8% for the period 2006-2016, 22.5% for the period 2008-2016 and 17.7% for the period 2010-2016.

In **Table 11** we allocate the costs derived from **Tables 6** to **10** to the components of the proposed scheme listed in **Table 4** in Section 2.5.3.

Table 6 Environment Agency Unit Cost Database mean unit costs for embankments (Table 1.4 from http://evidence. environment-agency.gov.uk/FCERM/Libraries/FCERM_Project_Documents/SC080039_ cost_fluvial_defences.sflb.ashx) (2010 prices)

Volume band	Mean cost per m^3 fill volume (£)	Mean cost per m length (£)	Number of projects	Mean cost per m^3 fill volume (£) (inflated to 2016 prices)
<500 m3	188	£3,384	9	221
500–5,000 m3	94	£1,692	28	111
5,000–15,000 m3	64	£1,152	11	75
>15,000 m3	33	£594	18	39*

* We have used the highest volume band for all sections as collectively they exceed 15,000 m^3 of fill

Table 7 Environment Agency Unit Cost Database wall raising and wall construction mean costs per m length (Table 1.1 from http://evidence. environment-agency.gov.uk/FCERM/Libraries/FCERM_Project_Documents /SC080039_cost_fluvial_defences.sflb.ashx) (2010 prices)

Height band	Wall raising (£/m)	All wall types (£/m)	All wall types (£/m) inflated to 2016 prices
<1.2m	1,029	1,419	1,670
1.2–2.1m	2,177	2,905	3,419
2.1–5.3m	–	3,577	4,210
>5.3m	–	11,168	13,145
All heights	1,526	2,984	3,512

Table 8 Environment Agency Unit Cost Database mean unit costs for sheet piling (Table 1.7 from http:// evidence. environment-agency.gov.uk/FCERM/Libraries/FCERM_Project_Documents/SC080039_cost_ fluvial_defences.sflb.ashx) (2010 prices)

Reach type	Average (£/m^2)	Average (£/m length)	Number of projects	Average (£/m^2) inflated to 2016 prices
Urban reach <100 m	1,287	9,148	8	1,515
Urban reach >100 m	484	2,476	19	570
Rural reach	212	1,843	29	250

Table 9 Environment Agency Unit Cost Database mean unit costs for a one-way valve outfall (Table 1.8 from http://evidence.environment-agency.gov.uk/FCERM/Libraries/FCERM_Project_Documents/SC080039_cost_ control_assets.sflb.ashx).

Outfall size	Cost (2006 base data)	Cost (inflated to 2016 prices)
Small (1,000 mm diameter)	£59,000	£78,352
Medium (2,000 mm diameter)	£80,000	£106,240
Large (2 x 1,500 mm diameter)	£108,000	£143,424

Table 10 Environment Agency Unit Cost Database mean unit costs for selected flood gates (adapted from Table 1.5 from http://evidence.environment-agency.gov.uk/FCERM/Libraries/FCERM_Project_Documents/SC080039_cost_control_assets.sflb.ashx)

Dimension	Automatic / manual	Capital Cost (2008 prices)	Capital Cost (inflated to 2016 prices)
8m x 1m	Not specified	£21,000	£25,725
12m x 1m	Not specified	£50,000	£61,250
5m x 0.6m	Manual	£5,500	£6,738
5m x 0.6m	Automatic	£17,000	£20,825
3m x 1.25m	Not specified	£24,000	£29,400
7m x 2.1m	Not specified	£71,000	£86,975
12m x 2.5m	Not specified	£169,000	£207,025

Table 11 Approximate costs of constructing the refined alignment defence (see Table 4 for section descriptions)

Section	Wall / Embankment / Other	Cost basis	Cost (£) (2016 prices)
1a	330m of 0.5m high embankment with 4m deep clay core	Clay core 1m wide x 4.5m deep, 0.75m2 of embankment fill per 1m of embankment – 5.25m2 of material per 1m embankment in total	67,568
1b	200m of 2.8m high wall		842,000
1b	200m of 4m deep sheet piling foundation for the wall	800m^2 of sheet piling, rural setting	200,000
1c	385m of 2.8m high embankment with 4m deep clay core	Clay core 1m wide x 6.8m deep, 23.5m^2 of embankment fill per 1m of embankment – 30.3m^2 of material per 1m of embankment in total	454,955
1c	Outfall structure with one-way valve at The Lees	Assume 'large' size	143,424
1c	Sealable flood gate across Lees Road	7m width gate (or stop boards with polythene membrane) with docking pillars on both sides of the road (base on 7m x 2.1m gate price, although this gate will be only 1.5m high)	86,975
1d	80m of steel sheet piling wall, 10m deep, crest 3.8m above river bank	800m^2 of sheet piling, rural setting	200,000
2a	310m of sheet piled wall, 10m deep, 3.8m high	3100m^2 of sheet piling, rural setting	775,000

Section	Wall / Embankment / Other	Cost basis	Cost (£) (2016 prices)
2b	50m of 0.8m high embankment with 4m deep clay core	Clay core 1m wide x 4.8m deep, 1.92m^2 of embankment fill per 1m of embankment – 6.72m^2 of material per 1m embankment in total	13,104
3a	65m of steel sheet piling wall, 10m deep, crest 4.7m above river bank	650m^2 of sheet piling, urban setting	370,500
3a	Cladding on exposed section of wall	65m x 2 sides x 1.5m. Assume price for 2 x 1.5m walls	444,470
3b	470m of 3.1m high embankment with 4m deep clay core	Clay core 1m wide x 7.1m deep, 28.9m^2 of embankment fill per 1m of embankment – 36.0m^2 of material per 1m of embankment in total	659,880
4a	320m of 1.2m high embankment with 4m deep clay core	Clay core 1m wide x 1.2m deep, 4.32m^2 of embankment fill per 1m of embankment – 9.52m^2 of material per 1m of embankment in total	118,810
4b	1020m of 1.0m high embankment with 4m deep clay core	Clay core 1m wide x 5m deep, 3m^2 of embankment fill per 1m of embankment – 8m^2 of material per 1m embankment in total	318,240
5a	450m of 1.0m high embankment with 4m deep clay core	Clay core 1m wide x 5m deep, 3m^2 of embankment fill per 1m of embankment – 8m^2 of material per 1m embankment in total	140,400
5a	Outfall structure with one-way valve on UMIDB drain	Assume 'large' size	143,424
5b	175m of 1.75m high embankment with 4m deep clay core	Clay core 1m wide x 5.75m deep, 9.2m^2 of embankment fill per 1m of embankment – 14.95m^2 of material per 1m of embankment in total	102,034
5c	195m of 1.6m high embankment with 4m deep clay core	Clay core 1m wide x 5.6m deep, 7.7m^2 of embankment fill per 1m of embankment – 13.3m^2 of material per 1m of embankment in total	101,147
5d	65m of 0.5m high embankment with 4m deep clay core	Clay core 1m wide x 4.5m deep, 0.75m^2 of embankment fill per 1m of embankment – 5.25m^2 of material per 1m embankment in total	13,309
5e	360m of 1.5m high embankment with 4m deep clay core	Clay core 1m wide x 5.5m deep, 6.8m^2 of embankment fill per 1m of embankment – 12.3m^2 of material per 1m of embankment in total	172,692
5f	990m of 1.0m high embankment with 4m deep clay core	Clay core 1m wide x 5m deep, 3m^2 of embankment fill per 1m of embankment – 8m^2 of material per 1m embankment in total	308,880
5g	40m of 1.25m high embankment with 4m deep clay core	Clay core 1m wide x 5.25m deep, 4.7m^2 of embankment fill per 1m of embankment – 9.95m^2 of material per 1m of embankment in total	15,522
5h	715m of 1.0m high embankment with 4m deep clay core	Clay core 1m wide x 5m deep, 3m^2 of embankment fill per 1m of embankment – 8m^2 of material per 1m embankment in total	223,080

Section	Wall / Embankment / Other	Cost basis	Cost (£) (2016 prices)
5i	145m of 1.5m high embankment with 4m deep clay core	Clay core 1m wide x 5.5m deep, 6.8m^2 of embankment fill per 1m of embankment – 12.3m^2 of material per 1m of embankment in total	69,557
5j	275m of 2.0m high embankment with 4m deep clay core	Clay core 1m wide x 6m deep, 12m^2 of embankment fill per 1m of embankment – 18m^2 of material per 1m of embankment in total	193,050
5k	220m of 2.4m high embankment with 4m deep clay core	Clay core 1m wide x 6.4m deep, 17.3m^2 of embankment fill per 1m of embankment – 23.7m^2 of material per 1m of embankment in total	203,346
5l	35m of 1.0m high embankment with 4m deep clay core	Clay core 1m wide x 5m deep, 3m^2 of embankment fill per 1m of embankment – 8m^2 of material per 1m embankment in total	10,920
5l	300mm diameter culvert	Treat as a ‘small’ outfall	78,352
6	385m of 1.3m high embankment with 4m deep clay core	Clay core 1m wide x 5.3m deep, 5.1m^2 of embankment fill per 1m of embankment – 10.4m^2 of material per 1m embankment in total	156,156
7	80m of 1.2m high embankment with 4m deep clay core	Clay core 1m wide x 5.2m deep, 4.32m^2 of embankment fill per 1m of embankment – 9.52m^2 of material per 1m of embankment in total	29,703
8a	1150m of 1.5m high embankment with 4m deep clay core	Clay core 1m wide x 5.5m deep, 6.8m^2 of embankment fill per 1m of embankment – 12.3m^2 of material per 1m of embankment in total	551,655
8b	300m of 0.6m high embankment with 4m deep clay core	Clay core 1m wide x 4.6m deep, 1.1m2 of embankment fill per 1m of embankment – 5.7m2 of material per 1m embankment in total	66,690
8b	150mm diameter culvert with flap valve	Treat as a ‘small’ outfall	78,352
9	730m of 1.8m high embankment with 4m deep clay core	Clay core 1m wide x 5.8m deep, 9.8m^2 of embankment fill per 1m of embankment – 15.6m^2 of material per 1m of embankment in total	444,132
	Additional Property Level Protection for 110 properties at residual or increased risk	Assume £7,500 per property (guidance advised by Environment Agency)	825,000
		Optimism Bias on capital works (60%)	5,173,396
	NPV cost of maintenance, inspection and repair (100 year period)		87,856
		TOTAL COST (*not including property purchase and compensation for properties adversely affected*)	**13,795,723**

Although the model was run with all the sections of embankment in **Table 4**, there are some properties in Marden and Hunton not showing detriment in a 1.33% (1 in 75 year) AEP flood event, so it could be possible to remove those sections of embankment from the scheme. However, the 2% (1 in 50 year) AEP baseline runs of the model did show some detriment in these areas. This could be due to anomalies within the CS hydrology and the fact that a 2% AEP storm at Smarden could be a much larger event at Hunton if the storm is focussed on the lower part of the Beult valley. Therefore we would recommend that these sections of embankments continue to be included in the scheme.

3.2 Benefits

In order to determine the benefits we need to establish the existing Standard of Protection, and the frequencies at which properties are flooding. To do this exactly we would need to run multiple additional model runs to obtain the numbers of flooded properties at 4% (1 in 25 year) AEP and 2% (1 in 50 year) AEP flood events. This would take greater time than is available to the project team, and so we have opted for a simplified approach. This however involves taking the 1.33% (1 in 75 year) AEP baseline flood depth at properties affected, and estimating a flood frequency based on the depth of flooding at the property. A property flooding to greater than 1.0m depth at a 1.33% AEP event is assumed to flood at a 4% AEP event, and a property flooding to greater than 0.5m depth is assumed to flood at a 2% AEP event. Using this analogy we estimate that 46 properties currently have less than a 4% AEP Standard of Protection and 169 properties currently have less than a 2% AEP Standard of Protection.

In addition to these residential properties the following non-residential properties are affected:

Table 12 List of non-residential properties benefitting from the proposed revised alignments scheme

Type of property	Floor Area (m^2)	Depth of flooding in a 1.33% AEP event	Implied Standard of Protection (Raised Leigh FSR crest level only)	Standard of Protection (revised barrier alignments option)
Retail shop	120	>1.0m	<4% AEP	1.33% AEP
Retail shop	319	>0.5m	<2% AEP	1.33% AEP
Retail shop	541	<0.5m	<1.33% AEP	1.33%AEP
Public house	206	>1.0m	<4% AEP	1.33% AEP
Public house	350	<0.5m	<1.33% AEP	1.33%AEP
Motor garage	51	>1.0m	<4% AEP	1.33% AEP
Motor garage	283	<0.5m	<1.33% AEP	1.33%AEP
Garden Centre	284	<0.5m	<1.33% AEP	1.33%AEP
Post office	10	>1.0m	<4% AEP	1.33% AEP
Office	412	<0.5m	<1.33% AEP	1.33%AEP
Warehouse	161	>0.5m	<2% AEP	1.33% AEP
Warehouse	232	<0.5m	<1.33% AEP	1.33%AEP
School	606	<0.5m	<1.33% AEP	1.33%AEP
Health Centre	450	>0.5m	<2% AEP	1.33% AEP

Community Centre	436	<0.5m	<1.33% AEP	1.33%AEP
Factory	354	<0.5m	<1.33% AEP	1.33%AEP
Electricity substation	220	>1.0m	<4% AEP	1.33% AEP
Electricity substation	440	>0.5m	<2% AEP	1.33% AEP
Pumping station	120	>1.0m	<4% AEP	1.33% AEP

The proposed scheme would provide a 1.33% (1 in 75 year) AEP Standard of Protection for 101 (155) detached, 76 (133) semi-detached, 60 (80) terraced houses and 26 (34) flats, together with the non-residential properties listed in Table 12. The figures in brackets include properties protected by the scheme together with additional PLP. In addition, East Farleigh sub-station benefits marginally but would require further local measures to achieve a 1.33% AEP Standard of Protection). Of those, we estimate 9 (9) detached, 2 (2) semi-detached, 13 (13) terraced and 6 (6) flats to be currently at greater than 4% AEP risk, and 23 (28) detached, 20 (26) semi-detached, 30 (30) terraced and 15 (16) flats to be currently at greater than 2% AEP risk.

We have applied a Net Present Value (NPV) calculator provided by the Environment Agency to the properties being protected, to ensure the damages valuation is on the same basis as the existing Medway IA. This calculator had pre-set values for damages at 4%, 2% and 1% AEP events but did not include for damages at 1.33% AEP events. We have therefore had to estimate a damages value for a 1.33% AEP event. This was calculated using a best-fit curve (**Figure 40**) and was found to be approximately equal to the relationship:

Damages (1.33% AEP) = Damages (1% AEP) + 0.25 (Damages (2% AEP) – Damages (1% AEP))

We have used the approved NPV discounting rate of 3.5% to year 30, 3.0% to year 75 and 2.5% thereafter, and this generates an NPV benefits value of **£5,608,781** (calculated by including the properties provided with additional PLP as well as the main works). This gives a scheme benefit/cost ratio of **0.40**. See **Appendix C**.

Using the DEFRA Partnership Funding Calculator for Flood and Coastal Erosion Risk Management Grant in Aid (version 8 January 2014) (**Appendix D**) the low benefit/cost ratio would demand a very large partnership funding contribution of **£12,778,962**.

There is potentially a case to be made for raising the benefits value, in the benefit/cost analysis, due to the relatively high value of many of the properties at risk but the methodology used in this study is in accordance with DEFRA economic appraisal guidelines. Consequently amending the benefits value would not affect the Partnership Funding Calculator. We have also not applied any financial benefit value to those properties which are subject to reduced peak water levels but which would still be at risk of flooding, or those which could be protected at up to a 2% (1 in 50 year) AEP standard but which would flood during a larger event (the latter would require additional model runs).

In addition to the low benefit/cost ratio the proposed scheme would also cause a worsening of flood risk at up to 89 properties, 54 of which are unlikely to be suitable for PLP due to type of construction or the modelled depth of water in a 1.33% AEP event.

Therefore this option, although more technically viable than the others considered here, is not economically viable.

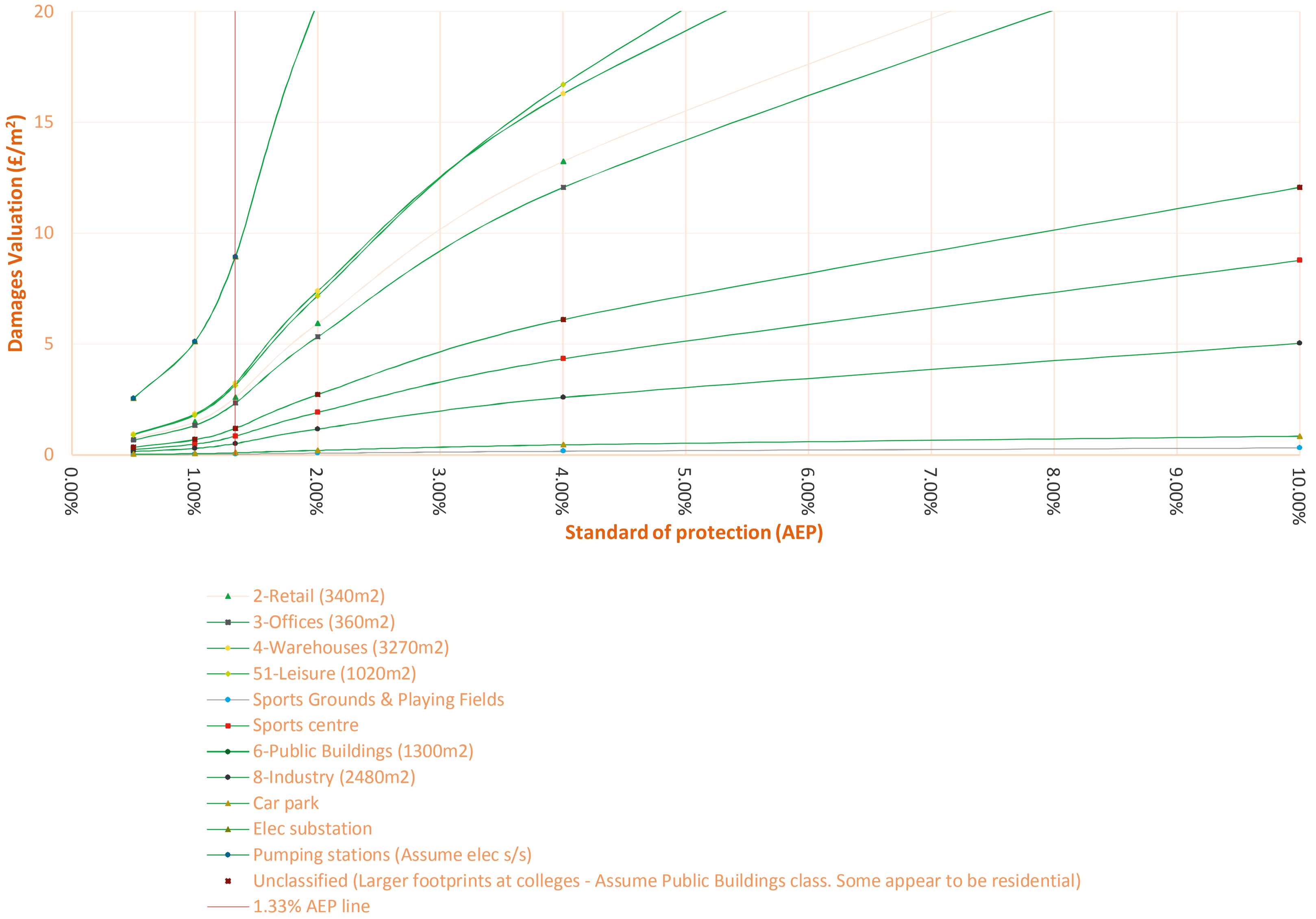

Figure 40 Graph of best-fit curves used to estimate the benefits / damages valuation for a 1.33% AEP event.

4 Conclusions

In any flood study the process of reaching a preferred solution is necessarily iterative. This study has taken as a starting point the list of options proposed by the JPFG and has assessed each option initially using LiDAR and engineering judgment, and then applied the Environment Agency's most recent hydraulic modelling and tested the options against the model. As detailed above, there are constraints as to how the model can be used, particularly as regards how the hydrology, the simulated flood inflows, is set up. However, the modelled hydrographs show similar characteristics to the observed flood events, including the effect of multiple peaks on each key tributary river.

The Weald Basin is a uniquely challenging flood environment, with high runoff rates due to clay-rich soils and surrounding hills; multiple sources of flooding; spread-out communities; a large expanse of virtually level floodplain and a narrow gorge forming its only downstream drainage channel. A large flood entering the basin is analogous to three large diameter hoses being directed into a bathtub with the plug out. The water will eventually drain away once the hoses are switched off, but due to the small diameter of the plughole water will partly fill the bathtub before then. Any scheme to protect one group of properties is likely to have a detrimental effect somewhere else as the water, constricted in its downstream flow, is forced to move laterally. Any effective solution would need to direct the water away from groups of properties and make best use of the floodplain without increasing risk at any other property. The option considered here for economic assessment has made the best use of the available floodplain yet still caused detriment to some other properties. There is only one large expanse of floodplain within the Weald Basin that does not have at least several properties located in it (the Lesser Teise valley east of Haviker Street). The most sparsely populated areas are around Tilden and along the line of the Collier Street Brook, but in both of these areas there are some properties which are potentially subject to increased flood risk if the land in that vicinity is utilised to provide flood storage.

None of the options tested in this study has produced a technically viable solution to reduce flood risk, and the economic assessment on one of the more realistic (but still imperfect) optionsdemonstrates that option is not economically viable. Many options provide little or no change in flood risk, and those that have provided improvement in some locations have also exacerbated flooding elsewhere. However, with each model output we have generated, we have looked for ways to improve on what was tested to see if further refinement might produce a viable solution. Although we have aimed to address all remaining unmodelled options, in order to provide a timely response we have had to leave some potential variations of the options out, for example experimenting with different outfall apertures at the proposed Chainhurst FSR embankment. Given the relatively low economic benefits value generated for the refined embankments and walls option and the very much more costly and environmentally damaging embankments needed for the Chainhurst FSR we feel justified that this option would not have been technically and economically acceptable to pursue further.

It would be possible to refine the embankments and walls option further to see what flood protection could be provided more cost effectively, and to try further to eliminate the risk of detriment to other properties. However, given the very low benefit/cost ratio identified it is considered not economically justifiable to do so. There could be a case for considering a partial scheme to protect some areas only. However, the area at greatest risk of flooding is Yalding left bank, and any scheme here would require construction of a wall joining onto the historic Town Bridge on the downstream left bank, which is one of the most costly elements of the scheme as well as being potentially unacceptable on aesthetic and heritage grounds.

A shallow embankment around the east of Haviker Street and south of Collier Street could provide a good standard of protection to properties in Collier Street, and reduce the flood risk to Yalding from the south, although the existing Standard of Protection here is relatively high and so the benefits value would be comparatively low. Note that unless the scheme element to restrict backflow on the IDB drain between Den Cottages and the Lesser Teise / Beult confluence is enacted, no measures at Collier Street would aid protection at Yalding as this is an evident flow route for water from the Beult and Lesser Teise to affect the south end of Yalding around Benover Road.

There are some very minor improvements in flood risk identified for some of the options tested. However, these are so small that even if taken together they would still not produce a significant reduction in the number of properties being affected by flooding.

We do recommend that any low-cost environmentally-friendly flood alleviation measures, such as improving land management practices and creating upstream ‘leaky dams’ to slow the flow of smaller flood events, and also riparian cleaning out of drainage channels be considered where possible. However, it should be recognised that such measures, while helpful for small floods, would have negligible effect for larger flood events such as those we are considering in this report.

Appendix A List of Options Proposed by JPFG

The following table details the full list of suggestions for option appraisal provided from the Joint Parishes Flood Group, together with an indication of where this has been addressed either in this report or the Medway IA, or why it has not been considered within either report.

Option Number	Option as described by JPFG	How and where this is considered
1	Independent survey of the Medway from Yalding to Rochester to include consideration of removal of silt shoals and other pinch points, clearing the arches of all bridges.	The Medway IA considered major dredging and bridge replacement on the Medway downstream of Yalding. This demonstrated that even major capital works would have limited success and be extremely expensive. Figure 13 in this report shows the floodplain pinch point at Wateringbury which is the most significant constriction to downstream flow. Given that major works and the replacement of all historic bridges to allow through flow still only provides marginal increase in flood risk small works such as desilting and opening the northern arch at Teston Bridge would have negligible effect in a major flood.
2	Build a relief channel through the Syngenta site using pipes with or without pumps to bypass Yalding to merge downstream.	Addressed in section 2.4.1 of this report.
3	Hold back more water through natural flood storage measures. Investigate options on the Teise between Horsmonden and Collier Street.	The Medway IA considered large flood storage areas at Stonebridge and Cottage Wood and demonstrated that these provided relatively limited flood protection. We have reviewed this in section 2.2.2 of this report. Given that large schemes provide inadequate protection the application of small-scale schemes would have negligible effect in a major flood. Also in section 1.3 of this report demonstrates that for many relatively large and rare floods on the Teise, the Beult and Medway would still provide the dominant flood mechanism so any measures on the Teise would have relatively little effect for properties at risk from all the rivers.
4	Build a bund on Mill Lane to prevent flooding onto Benover Road.	This is considered within section 2.5.2 of this report and refined within section 2.5.3 of this report.
5	Compulsory purchase of the fish farm at Style Bridge for use as an FSA as per original proposals, which currently displaces >1 million m3	The Medway IA considered the Chainhurst FSA, which would include any flood storage within a Stilebridge FSA. That report demonstrated that even with the larger Chainhurst FSA it would not be possible to store enough of the flow to provide adequate protection for downstream at risk properties. Section 2.2.1 of this report considers an even larger FSA on the Beult, by using the Chainhurst alignment but raising the crest level higher. Even this would not provide adequate storage to attenuate a major flood.
6	Increase the bund size at Brook Farm to prevent water going down Green Lane, Collier Street.	This is considered within section 2.5.1 of this report and refined within section 2.5.3 of this report.
7	Nettlestead - Allington channel/bore (12 miles, bore to Bewl 14 miles, £14m)	This is considered within section 2.6.6 of this report. The JPFG cost estimate is probably significantly underpriced. The undertaking would require a tunnel similar in dimensions and length to Crossrail, which is currently priced at £14bn not £14m.

8	Syngenta relief channel - the geometry of the Medway as it skirts Yalding lends itself to some by-pass potential.)	Addressed within section 2.4.1 of this report.
9	Afforestation to slow the flow of rainwater into rivers by increasing interception. A relatively low cost option that enhances the environmental quality of the drainage basin. Slow the flow [NFF Apr16]	Addressed within sections 2.6.1 and 2.6.3 of this report.
10	Build small-scale FSAs - dams along the course of a river to control the amount of discharge. Water is held in a reservoir behind the dam and released in a controlled way to control flooding. e.g. Teise (see file Teise FSA 21Oct16)	Please see answer to point 3 – the effect of small-scale FSAs would be the same as for any small-scale storage option.
11	Embankments (or artificial levees) are raised banks along the river and they effectively make the river deeper so it can hold more water. They're expensive and they don't look natural but they do protect the land around them.	Addressed within sections 2.5.1 and 2.5.2 of this report. The main problem with levees is they cut off use of the floodplain, hence the refinement assessed in section 2.5.3 of this report, where the embankments are set back to retain as much floodplain connectivity as possible.
12	Flood walls are more solid versions of embankments that are built around housing and factories. Unsightly but effective. Often lined with stone or concrete.	The 'Yalding Walls' option considered with the Medway IA and in earlier studies has been refined within section 2.5.3 of this report. There are some points where spill from the river into the communities is through relatively narrow corridors where there is insufficient room for an embankment. In these locations only walls would be necessary. We would only expect to use walls in the vicinity of Town Bridge where properties are close to the riverbank.
13	Beult / Medway junction deflector wall.	In a major flood the location of the Beult/Medway confluence and its surrounding floodplain would be completely submerged and any structure between the rivers would make flooding worse as it would form an obstruction. Water gathers in this area as the downstream outflow route is highly constricted at Wateringbury (see Figure 13 of this report)
14	Beult - Allington submerged pipeline along the river bed using existing Kenward pumping station.	In section 2.6.5 of this report we consider use of the Southern Water pumping station and demonstrate that, in a major flood, maximum pump capacity is negligible compared to the flow in the rivers. If a new pipeline was laid in the riverbed downstream of Yalding this would contribute to the constriction at Wateringbury. Also in section 2.6.6 of this report we demonstrate the size of pipe / tunnel needed to pass the flow downstream and it would not be possible to bury a 7.5m diameter pipe in the riverbed.
15	Gravel pits. Put a pump on the gravel pits at East Peckham. Drain them down when a big flow is forecast and fill them back up	In a flood event any gravel pits in the floodplain would fill up naturally and quickly. Gravels form the base of many river valleys and allow groundwater connectivity between the river and any excavations within the gravels. Therefore the gravel pits would not function effectively as storage areas. The largest mobile pumps

	during the flood. Maybe 1-2m cubic meters to be had here?	currently available within the UK can pump approximately 1.8m^3/s, and it would require 56 of these, plus further relaying units, all pumping together for greater than 130 hours to drain the peak excess flow for even a 2% (1 in 50 year) AEP event (see **Figure 39**)
16	Yalding Tatt wall (pump for downhill underground flow).	This is considered within section 2.5.3 of this report
17	Yalding library temporary barrier.	A small raised embankment upstream of Town Bridge on the (northern) right bank is considered within section 2.5.3 of this report. It might be possible to use 1m high temporary barriers to fill small gaps in or augment a permanent embankment for larger floods, but these would require active deployment by the Environment Agency, KCC, MBC, contractors, emergency services or the community. These could only be used in areas where the flooding is shallower than 0.8m.
18	Great Cheveney, volume 2.1 Mm^3 Potential for reduced flood damage downstream in Collier Street – option retained.	Any upstream storage on the River Teise would have a similar effect to the modelled FSRs addressed in the Medway IA and revisited in section 2.2.2 of this report. The optimum FSR arrangement was explored in the Medway IA, with the Stonebridge and Cottage Wood embankments.
19	Reprofiling on the Medway between Laddingford and Allington. Possibility of reduced flood damage in Maidstone – recommended for further study	This was considered in the Medway IA, section 4.3, and in Appendix D, section 4 of that report. The option considered a 5m channel widening and conveyance improvements at bridges. Findings indicated that for a 2% (1in 50 year) AEP event peak water level in Yalding could be reduced by no more than 0.24m. It is therefore to be expected that any smaller-scale works would have less effect on reducing flood levels. Section 2.3.1 of this report considers a small-scale option for improving downstream conveyance, and demonstrates that improvement in flood risk can occur at early stages of a major flood, but with no significant change in flood depths at the flood peak.
20	If they did a 'Peter Hall' on the big field between you and me (owned by the Yalding gardens?) that must be 60 hectares or 450,000 m using a pro rata figure based on Peter's project. That would probably do it for us. 20 houses for £100k (again at a pro rata figure) and a pretty big dent on the volume of water in the Yalding basin too. And you'd still get change from the spend per house in T&MBC's patch.	We understand this refers to the creation of small-scale wetlands to function as flood storage areas on farmland upstream from the communities at risk. While this could help improve flood risk for small-scale floods such storage would be insufficient to provide protection for the size of floods that would attract FDGiA funding.
21	The flow below Allington Lock is tidal, so half the time flood water is battling against the tide. On the River Somme in France they have installed a barrage with a high tide pumping system which aids flow and in effect creates low tide 24 hours a day.	It is possible to use tidal barrages to keep upstream levels low, as indeed the Environment Agency actively do with the Thames Barrier when upstream flood flows are predicted. However, this would only address flooding between East Farleigh and Allington. In section 2.3.1 of this report we considered how early drawdown at Teston could work and what its limitations were. This would provide some additional downstream storage which could reduce flood risk in Maidstone. However, this would not affect the serious constriction at Wateringbury which is the main cause of backing-up of high flows affecting Yalding.

22	Twyford Bridge has a brick topping. Please could the topping of the bridge be evaluated as to whether it impedes the flow of flood water through the river. If its purpose is as a balustrade and is a modern addition it could possibly be replaced with a structure that is more flow friendly than a solid wall.	The brick parapet of Twyford Bridge is elevated above the ground level of The Lees. Water flooding out of bank from the River Medway will spread across The Lees floodplain long before it reaches the level of the Twyford Bridge parapet and any impeding effect of the parapet will only commence once the flood level has already inundated the west end of Yalding village.
23	Clear the arches in the historic bridges downstream of Tonbridge.	The Medway IA, section 4.3, identified that a much larger downstream conveyance improvement would have relatively little effect in reducing flood levels in Yalding. Therefore simply opening up existing arches (such as the footpath arch at Teston) would have a very small, possibly negligible effect in a major flood. Also opening up any arches between Tonbridge and Yalding would have the marginal effect of speeding up arrival of flood water in Yalding.
24	Use flood meadows for a new channel in the area upstream of the gap through the Greensand ridge at Nettlestead.	Addressed within section 2.4.1 of this report.
25	Change the Leigh FSA operating procedures to better serve downstream communities in terms of release protocols and to ensure that peaks of the Medway do not coincide with the Beult and Teise, as per recommendations of independent reviews.	This was addressed in ‘Leigh Flood Storage Area Review: Independent audit of operation in the December 2013 flood’ (HR Wallingford 2015). This is outside the scope of this report and our understanding of the hydraulic model is that it is not capable of being sufficiently fine-tuned to assess such changes in procedures.
26	Improve flows through Yalding at Town Bridge and the Tatt.	Flooding in Yalding is predominantly from out-of-bank flow on the left bank upstream, at Mill Lane and, in extreme events, behind The George, from backflow up the UMIDB drainage ditch past Den Farm or from downstream flows backing up from the Medway and crossing The Lees. Town Bridge is a constriction to flows from the Beult. Improving flow through Town Bridge is likely to increase downstream water levels and increase flood risk at The Tatt.
27	Increase the current storage at the Leigh Barrier by utilising the freeboard of the existing embankment crest level.	This is outside the scope of this report, but the freeboard is designed as a safety feature in line with guidance under the Reservoirs Act 2010. The only way to safely increase storage capacity will be to raise the crest level, as per the option considered in the Medway IA and assumed for all the options assessed in this report. The Medway IA indicates the relative effect in Yalding of increasing the Leigh FSR embankment crest level, and demonstrates that any changes to the Leigh FSR will have a relatively minor effect at Yalding due to the large amount of unattenuated inflow downstream of Leigh added to the inflow from the Beult and the Teise.
28	Beult to Bewl. Use the Kenward-Bewl pumping station to remove pre-peak flood water from the Yalding basin to Bewl Water for later release.	Addressed within section 2.6.5 of this report.

29	Establish wetland areas for flood storage on redundant or underused farmland. Also washlands - parts of the floodplain that are allowed to flood.	The floodplain in the Weald Basin is completely inundated during a major flood event, as would be expected. Creating wetlands, ponds and other depressions in the ground level across the floodplain may increase flood storage capacity for very small floods, but once the floodplain is flooded such excavations can provide no additional storage. Therefore this would only work for reducing the risk from very small floods which are unlikely to cause property flooding.
30	Consider paying compensation to farmers to allow fields to flood in flood years. Some bunds should be considered to help with this work.	All farm fields that are within floodplain are likely to flood in a major event. If fields don't flood they are likely to be on higher ground. Once the floodplain is inundated it is not possible to store further water on it unless a flood storage reservoir is constructed. Those options were addressed in the Medway IA and revisited in sections 2.2.1 and 2.2.2 of this report.
31	Train all Leigh FSA operators on a realistic computerised real time simulator every year. Manage the Leigh freeboard better.	This is beyond the scope of this report. It is our understanding that all Leigh FSR operators undergo rigorous training and refresher courses on a regular basis and this was supported by the findings in 'Leigh Flood Storage Area Review: Independent audit of operation in the December 2013 flood' (HR Wallingford 2015).
32	Real time (say every 15 mins) publication of raw and processed rain gauge figures giving reliable representation of the whole catchment.	Raw 15 minute interval rain gauge data is available. Processing of data cannot be done in real time. The current monitoring regime is beyond the scope of this report as it is not anything that can be modelled. However, the catchments feeding into Weald Basin are reasonably well monitored and most floods can be predicted at least a day in advance. Historically a key issue has been follow-on storms, where additional heavy rainfall falls on a catchment already saturated from previous flooding. The 2000 and 2013 events both show this characteristic.
33	Give farmers an incentive to increase the organic content of their fields do help with water retention.	This would have a similar but lesser effect to afforestation as a natural means of water retention using biomass. Sections 2.6.1 and 2.6.3 of this report address the afforestation options.
34	Introduce meanders into the upper reaches of the rivers to slow the passage of water downstream.	Addressed within sections 2.6.2 and 2.6.4 of this report.
35	Revisit the proposal to increase the size of the ditch from Green Lane to the Beult and the proposal to create a new ditch around Den Farm.	The ditches between Haviker Street and the Lesser Teise were recently inspected by an Arcadis representative and there is evidence of much clearance in some sections, believed to have been undertaken by riparian owners. In a major flood event this area is completely inundated as floodplain but in section 2.5.3 of this report we consider making better use of this area by raising a shallow embankment to protect adjacent properties but maximise shallow floodplain storage.
36	Reinstate the ditches alongside Green Lane.	This could help in a relatively small flood but for major floods the whole area would be inundated anyway and hence there would be overland flow.
37	Look at incentives for land owners to clean out and maintain ditches to allow more storage during heavy rains.	As with point 36, this would help for small flood events which probably do not affect properties but the effect would be negligible in major floods

38	Reintroduce land drainage grants to encourage landowners to improve the field drainage. Changes in agricultural practice have led to more field run off into ditches that are not maintained.	As with the above 3 points, this would have a beneficial effect for small scale floods but the effect would be negligible for major floods where the floodplain is completely inundated.
39	Produce a map showing all the areas of concern and the potential solutions.	**Figure 9** in this report shows the various options in context.
40	Joined-up catchment management. Integrated flood management.	As with several above options, catchment management could help alleviate small-scale flooding, but would be unable to address issues with the very large multiple-peak events that have historically caused flooding in the past. The main issue with large events is the constriction at Wateringbury that causes backing-up into Yalding, and no amount of management can address the Wateringbury issue.
41	Planning (land use zoning); soakaways, SUDS (sustainable urban drainage).	It should be a matter of course that any new development in the Medway, Beult or Teise valleys is designed to standards that attenuate offsite surface flows to greenfield rates, i.e. a new development does not increase downstream flood risk. SuDS comprises a number of elements, but the best known (use of soakaways) is unfortunately not practicable in the Weald Basin due to the underlying clay, which will prevent infiltration.
42	Downstream conveyancing; clearing waterways (2nd after FSAs in DEFRA's list of flood protection measures)	This has been considered both in the Medway IA section 4.3 and in section 2.3 of this report.
43	(Judiciously) clear ditches.	This is effectively the same option as point 37 above.
44	Targeted de-silting.	This is effectively the same option as point 37 above, and would have the same effect.
45	The Pickering model (we are hoping to get an academic opinion on this for MBT)	There is widespread misunderstanding of the contribution to flood storage of the upstream catchment at Pickering. Firstly, the catchment upstream of Pickering involves a large expanse of high, relatively empty peat moorland with plenty of storage potential (unlike the Beult, with a very shallow lowland clay catchment with many spaced-out properties across it and the tightly constrained Teise with narrow upland valleys). Secondly, there is a conventional flood storage reservoir (FSR) upstream of Pickering, which worked well when tested. 'Natural' storage methods helped to augment the attenuation provided by the FSR, but did not prevent flooding in Pickering on their own.
46	LFSA procedures (the EA's remit, but they have shared their procedures with us, and undertaken to review the flow rate at which impounding starts)	This is outside of the scope of this report. Refer to 'Leigh Flood Storage Area Review: Independent audit of operation in the December 2013 flood' (HR Wallingford 2015) for recommendations.
47	Ensure that telemetry from all areas (especially on Beult and Teise) is available in good working order at all times. (Control centre	It is our understanding that recording gauges are maintained robustly. In our experience there are occasions when gauges fail, and these could be due to a range of possible malfunctions including circuit and equipment attrition, damage due to weather

	should notice if a sensor is not responding)	conditions (e.g. large debris impacting the sensor or the solar panel) and also some sensors being unable to read very high flows and so they give a false plateau in the data. If a failure occurs shortly before the onset of a flood the operations team members who would otherwise be assigned to repair it will probably be at work deploying flood protection assets or clearing debris from trash screens elsewhere. We recommend this is discussed with the Environment Agency to establish their repair and maintenance protocol, which we would expect would demonstrate a commitment to maintaining all equipment in good condition as far as reasonable.
48	Beavers.	This would be considered under ‘natural flood storage measures’ and the effect would be the same as for option (3) above. Sections 2.2.1 and 2.2.2 of this report assess large-scale flood storage options, and indicate that these would be relatively ineffective at providing adequate flood attenuation in the Weald Basin. Smaller-scale ‘natural’ schemes would have even less effect in a major flood.
49	Woodland creation, installation of woody debris dams, re-meandering, reconnecting waterways to their floodplains, and using bunds and offline storage in liaison with the Woodland Trust who are currently working with many flood areas to alleviate flooding by trees and woods.	Addressed within sections 2.6.1 and 2.6.3 of this report.
50	Use Allington sluices as flood control structure.	Any operation of the sluices to manage the levels in the Medway to accommodate flood flows would have to be exercised at Teston and East Farleigh as well as Allington. We have considered how early drawdown at Teston could affect levels in section 2.3.1 of this report.
51	Community to introduce a system of river monitoring wardens who can check the levels of rivers and report back to the EA.	A local monitoring regime will assist in the provision of general catchment data and flag up areas where clearance might be needed. However, all the major rivers flowing into Weald Basin, and rain gauges in the vicinity, are monitored by telemetry upstream of the communities at risk, which provides the best available warning of storms which could cause flooding.
52	Community to (judiciously) clear ditches.	This would have the same effect as point 37 above.

Appendix B Weighted Annual Average Damages Benefits Calculator

The following tables include all properties potentially protected by the proposed refined alignment for embankments and walls option. Where a property may be subject to reduced flood levels but not complete protection at a 1.33% AEP event the property is excluded. The tables include all non-residential properties listed in **Table 12**.

This is an Environment Agency form provided by the EA's Kent & South London Area team and is used for comparison with the options assessed in the EA's Medway IA study.

We have assumed a 20% 'very affluent' / 80% 'mid-range – closer to very affluent' split for residential property values, given the high number of properties set back from roadways in their own grounds, and high general property values in the locality.

The first table indicates damages under the baseline (current) scenario, the second table indicates damages following implementation of the revised embankment alignments scheme, and gives a difference value which is the benefits of the scheme. This is calculated on the basis of a 1.33% AEP Standard of Protection and a 1 in 75 year whole life benefits period.

Please note there is no valuation for the properties potentially detrimented by the scheme.

MEDWAY, BEULT AND TEISE ADDITIONAL FLOOD ALLEVIATION OPTIONS

FCRM: Asset Investment Planning - SOUTHERN

Flood Damages Calculator - KSL FCRM East Kent PSO updated July 2016

Scheme Name: Medway Beult and Teise Additional Flood Alleviation Options (damages before scheme)

Instructions to complete the Calculator

1/ Enter the number of properties at risk under each level of risk category where known. Where these are not known, use NaFRA risk grid layer and assign properties at risk in (VH to 1 in 25), (H to 1 in 75), (M to 1 in 100) and (L to 1 in 200).

2/ Under a SoP, where property fields have been filled out, complete the % of property field for "Weighting Factors by Social Class". Guidelines for these are at the bottom of the sheet although most are anticipated to fall within C1 and C2. The % should be based upon best engineering and spatial judgements if there are differences in Social class within that risk boundary.

3/ Enter the number of buinesses/Offices/Services within the risk categories under the orange section. Assumptions have been made for the average size of these units based on a national average.

4/ The calculator will add up the average annual damages based on the results inputted. The correct factor needs to be applied to the AAD to calculate the PV damages for the required benefits period e.g 29.7 for 100 year period.

N.B. This spreadsheet has been dervied using the MCM-Online values.
Flood damages for infrastructure, agriculture & vehicles can be added belowbusiness damages using the guidance on MCM-Online. The correct factor should be applied for the benefits period e.g. AAD x 29.7 for 100 year benefits period.

Benefits Period		Project Reference No:	
Properties		Team Cost Code:	

Residential Property Damages

SoP	**Cost PA (£)**	**No. of Properties**					
1 in 2	4737	0	Weighting Factors by Social Class			Weighted Class total for 1 in 2	
			Class	Weighting	Property %		
			AB	0.74	0	0	
			C1	1.12	0	0	
			C2	1.22	0	0	
			DE	1.64	0	0	-
SoP	**Cost PA (£)**	**No. of Properties**					
1 in 5	2878	0	Weighting Factors by Social Class			Weighted Class total for 1 in 5	
			Class	Weighting	Property %		
			AB	0.74	0	0	
			C1	1.12	0	0	
			C2	1.22	0	0	
			DE	1.64	0	0	-
SoP	**Cost PA (£)**	**No. of Properties**					
1 in 10	1481	30	Weighting Factors by Social Class			Weighted Class total for 1 in 10	
			Class	Weighting	Property %		
			AB	0.74	20	6575.64	
			C1	1.12	80	39809.28	
			C2	1.22	0	0	
			DE	1.64	0	0	46,385
SoP	**Cost PA (£)**	**No. of Properties**					
1 in 25	709	70	Weighting Factors by Social Class			Weighted Class total for 1 in 25	
			Class	Weighting	Property %		
			AB	0.74	20	7345.24	
			C1	1.12	80	44468.48	
			C2	1.22		-	
			DE	1.64		0	51,814
SoP	**Cost PA (£)**	**No. of Properties**					
1 in 50	302	302	Weighting Factors by Social Class			Weighted Class total for 1 in 50	
			Class	Weighting	Property %		
			AB	0.74	20	13498.192	
			C1	1.12	80	81718.784	
			C2	1.22		-	
			DE	1.64		0	95,217
SoP	**Cost PA (£)**	**No. of Properties**					
1 in 75	189		Weighting Factors by Social Class			Weighted Class total for 1 in 75	
			Class	Weighting	Property %		
			AB	0.74	20	0	
			C1	1.12	80	0	
			C2	1.22		0	
			DE	1.64		0	-
SoP	**Cost PA (£)**	**No. of Properties**					
1 in 100	75	0	Weighting Factors by Social Class			Weighted Class total for 1 in 100	
			Class	Weighting	Property %		
			AB	0.74	0	0	
			C1	1.12	0	0	
			C2	1.22	0	0	
			DE	1.64	0	0	-
SoP	**Cost PA (£)**	**No. of Properties**					
1 in 200	38	0	Weighting Factors by Social Class			Weighted Class total for 1 in 200	
			Class	Weighting	Property %		
			AB	0.74	0	0	
			C1	1.12	0	0	
			C2	1.22	0	0	
			DE	1.64	0	0	-
Total Residential Property Damages (AAD)							193,416
Total Residential Property Damages (PV over benefits period)							**5,434,979**

Assumptions
75 year benefits period - use PV multiplier of 28.1

Businesses / Offices / Services Damages

Bulk Class (indicative floor area)	**Description**	**Actual / assumed floor area (m²)**	No. of businesses in flood plain								Weighted annual damages by standard of protection (£/m²)								Costed No. of businesses in the flood plain pa								Business damages for each class (AAD)
			1 in 2	1 in 5	1 in 10	1 in 25	1 in 50	1 in 75	1 in 100	1 in 200	1 in 2	1 in 5	1 in 10	1 in 25	1 in 50	1 in 75	1 in 100	1 in 200	1 in 2	1 in 5	1 in 10	1 in 25	1 in 50	1 in 75	1 in 100	1 in 200	
2-Retail (340m2)	Shop / Store	120			1						56.00	35.33	25.73	13.24	5.92	2.59	1.48	0.74	-	-	3,088	-	-	-	-	-	22,812
	Shop / Store	319				1													-	-	-	4,224	-	-	-	-	
	Shop / Store	541					1												-	-	-	-	3,203	-	-	-	
	Public House	206			1														-	-	5,300	-	-	-	-	-	
	Public House	350					1												-	-	-	-	2,072	-	-	-	
	Vehicle Services	51			1														-	-	1,312	-	-	-	-	-	
	Vehicle Services	283					1												-	-	-	-	1,675	-	-	-	
	Garden Centre	284					1												-	-	-	-	1,681	-	-	-	
	Post Office	10			1														-	-	257	-	-	-	-	-	
																			-	-	-	-	-	-	-	-	
																			-	-	-	-	-	-	-	-	
3-Offices (360m2)	Offices	412					1				51.00	31.88	23.89	12.06	5.32	2.33	1.33	0.66	-	-	-	-	2,192	-	-	-	2,192
	Telephone exchange - assume computer centre																		-	-	-	-	-	-	-	-	
																			-	-	-	-	-	-	-	-	
4-Warehouses (3270m2)	Warehouse	161				1					69.00	44.40	32.10	16.28	7.38	3.23	1.84	0.92	-	-	-	2,621	-	-	-	-	4,333
	Warehouse	232					1												-	-	-	-	1,712	-	-	-	
	Land used for storage																		-	-	-	-	-	-	-	-	
51-Leisure (1020m2)	Hotel										74.00	45.93	36.38	16.70	7.17	3.14	1.79	0.90	-	-	-	-	-	-	-	-	-
	Caravans																		-	-	-	-	-	-	-	-	
	Recreation / Social club																		-	-	-	-	-	-	-	-	
	Holiday let																		-	-	-	-	-	-	-	-	
52-Sport	Sports Grounds & Playing Fields										0.70	0.41	0.31	0.16	0.07	0.03	0.02	0.01	-	-	-	-	-	-	-	-	-
	Sports centre										19.00	11.68	8.77	4.33	1.91	0.84	0.48	0.24	-	-	-	-	-	-	-	-	
6-Public Buildings (1300m2)	School	606					1				26.00	16.24	12.07	6.10	2.71	1.19	0.68	0.34	-	-	-	-	1,642	-	-	-	5,569
	Health centre	450				1													-	-	-	2,745	-	-	-	-	
	Residential Home																		-	-	-	-	-	-	-	-	
	Community Centre	436					1												-	-	-	-	1,182	-	-	-	
	Fire/Ambulance station																		-	-	-	-	-	-	-	-	
	Church																		-	-	-	-	-	-	-	-	
8-Industry (2480m2)	Workshop										11.00	6.92	5.03	2.59	1.16	0.51	0.29	0.14	-	-	-	-	-	-	-	-	411
	Factory	354					1												-	-	-	-	411	-	-	-	
	Sewage TW																		-	-	-	-	-	-	-	-	
9-Miscellaneous	Car park										1.90	1.19	0.84	0.45	0.20	0.09	0.05	0.03	-	-	-	-	-	-	-	-	47,652
	Elec substation	220			1	2					180.00	114.83	81.93	44.99	20.39	8.93	5.10	2.55	-	-	18,025	19,796	-	-	-	-	
	Pumping stations (As	120			1						180.00	114.83	81.93	44.99	20.39	8.93	5.10	2.55	-	-	9,832	-	-	-	-	-	
																			-	-	-	-	-	-	-	-	
																			-	-	-	-	-	-	-	-	
	Unclassified (Larger footprints at colleges - Assume Public Buildings class. Some appear to be resider										26.00	16.24	12.07	6.10	2.71	1.19	0.68	0.34	-	-	-	-	-	-	-	-	
Total Business Damages (AAD)																											82,969
Total Business Damages (PV over benefits period)																											**2,331,422**

Infrastructure Damages - Roads, Rail & Utilities	
Agriculture Damages	
	-
Vehicle Damages	
	-
Evacuation Costs	
	-
Intangible effects of flooding	
	-

Total Damages (£ PV over benefits period)	
Residental Property	5,434,979
Business	2,331,422
Infrastructure	-
Agriculture	-
Vehicle	-
Sub total	**7,766,401**
Saltwater flooding factor	1.000
Emergency Costs Factor	1.107
Evacuation Costs	-
Intangible effects	-
Total Damages	**8,597,405**

Social Class Weighting

AB	Very affluent area (Generally private roads/estates)
C1	Mid ranged property (closer to AB)
C2	Mid ranged property (closer to DE)
DE	Deprived communities (use deprived communities layer on G drive)

MEDWAY, BEULT AND TEISE ADDITIONAL FLOOD ALLEVIATION OPTIONS

FCRM: Asset Investment Planning - SOUTHERN

Flood Damages Calculator - KSL FCRM East Kent PSO updated July 2016

Scheme Name: Medway Beult and Teise Additional Flood Alleviation Options (damages after scheme)

Instructions to complete the Calculator

1/ Enter the number of properties at risk under each level of risk category where known. Where these are not known, use NaFRA risk grid layer and assign properties at risk in (VH to 1 in 25), (H to 1 in 75), (M to 1 in 100) and (L to 1 in 200).

2/ Under a SoP, where property fields have been filled out, complete the % of property field for "Weighting Factors by Social Class". Guidelines for these are at the bottom of the sheet although most are anticipated to fall within C1 and C2. The % should be based upon best engineering and spatial judgements if there are differences in Social class within that risk boundary.

3/ Enter the number of buinesses/Offices/Services within the risk categories under the orange section. Assumptions have been made for the average size of these units based on a national average.

4/ The calculator will add up the average annual damages based on the results inputted. The correct factor needs to be applied to the AAD to calculate the PV damages for the required benefits period e.g 29.7 for 100 year period.

N.B. This spreadsheet has been dervied using the MCM-Online values.

Flood damages for infrastructure, agriculture & vehicles can be added belowbusiness damages using the guidance on MCM-Online. The correct factor should be applied for the benefits period e.g. AAD x 29.7 for 100 year benefits period.

Benefits Period		Project Reference No:	
Properties		Team Cost Code:	

Residential Property Damages

SoP	Cost PA (£)	No. of Properties	Weighting Factors by Social Class			Weighted Class total for 1 in 2	
			Class	Weighting	Property %		
1 in 2	4737		AB	0.74	0	0	
			C1	1.12	0	0	
			C2	1.22	0	0	
			DE	1.64	0	0	-

SoP	Cost PA (£)	No. of Properties	Weighting Factors by Social Class			Weighted Class total for 1 in 5	
			Class	Weighting	Property %		
1 in 5	2878		AB	0.74	0	0	
			C1	1.12	0	0	
			C2	1.22	0	0	
			DE	1.64	0	0	-

SoP	Cost PA (£)	No. of Properties	Weighting Factors by Social Class			Weighted Class total for 1 in 10	
			Class	Weighting	Property %		
1 in 10	1481		AB	0.74	0	0	
			C1	1.12	0	0	
			C2	1.22	0	0	
			DE	1.64	0	0	-

SoP	Cost PA (£)	No. of Properties	Weighting Factors by Social Class			Weighted Class total for 1 in 25	
			Class	Weighting	Property %		
1 in 25	709		AB	0.74	0	0	
			C1	1.12	0	0	
			C2	1.22	0	-	
			DE	1.64	0	0	-

SoP	Cost PA (£)	No. of Properties	Weighting Factors by Social Class			Weighted Class total for 1 in 50	
			Class	Weighting	Property %		
1 in 50	302		AB	0.74	0	0	
			C1	1.12	0	0	
			C2	1.22	0	-	
			DE	1.64	0	0	-

SoP	Cost PA (£)	No. of Properties	Weighting Factors by Social Class			Weighted Class total for 1 in 100	
			Class	Weighting	Property %		
1 in 75	189	402	AB	0.74	20	11244.744	
			C1	1.12	80	68076.288	
			C2	1.22	0	0	
			DE	1.64	0	0	79,321

SoP	Cost PA (£)	No. of Properties	Weighting Factors by Social Class			Weighted Class total for 1 in 100	
			Class	Weighting	Property %		
1 in 100	75		AB	0.74	0	0	
			C1	1.12	0	0	
			C2	1.22	0	0	
			DE	1.64	0	0	-

SoP	Cost PA (£)	No. of Properties	Weighting Factors by Social Class			Weighted Class total for 1 in 200	
			Class	Weighting	Property %		
1 in 200	38		AB	0.74	0	0	
			C1	1.12	0	0	
			C2	1.22	0	0	
			DE	1.64	0	0	-

Total Residential Property Damages (AAD)	79,321
Total Residential Property Damages (PV over benefits period)	**2,228,921**

Assumptions

75 year benefits period - use PV multiplier of 28.1

Businesses / Offices / Services Damages

Bulk Class (indicative floor area)	Description	Actual / assumed floor area (m²)	No. of businesses in flood plain								Weighted annual damages by standard of protection (£/m²)								Costed No. of businesses in the flood plain pa								Business damages for each class (AAD)
			1 in 2	1 in 5	1 in 10	1 in 25	1 in 50	1 in 75	1 in 100	1 in 200	1 in 2	1 in 5	1 in 10	1 in 25	1 in 50	1 in 75	1 in 100	1 in 200	1 in 2	1 in 5	1 in 10	1 in 25	1 in 50	1 in 75	1 in 100	1 in 200	
2-Retail (340m2)	Shop / Store	120						1			56.00	35.33	25.73	13.24	5.92	2.59	1.48	0.74	-	-	-	-	-	311	-	-	5,605
	Shop / Store	319						1											-	-	-	-	-	826	-	-	
	Shop / Store	541						1											-	-	-	-	-	1,401	-	-	
	Public House	206						1											-	-	-	-	-	534	-	-	
	Public House	350						1											-	-	-	-	-	907	-	-	
	Vehicle Services	51						1											-	-	-	-	-	132	-	-	
	Vehicle Services	283						1											-	-	-	-	-	733	-	-	
	Garden Centre	284						1											-	-	-	-	-	736	-	-	
	Post Office	10						1											-	-	-	-	-	26	-	-	
								1											-	-	-	-	-	-	-	-	
								1											-	-	-	-	-	-	-	-	
3-Offices (360m2)	Offices	412						1			51.00	31.88	23.89	12.06	5.32	2.33	1.33	0.66	-	-	-	-	-	960	-	-	960
	Telephone exchange - assume computer centre																		-	-	-	-	-	-	-	-	
																			-	-	-	-	-	-	-	-	
4-Warehouses (3270m2)	Warehouse	161						1			69.00	44.40	32.10	16.28	7.38	3.23	1.84	0.92	-	-	-	-	-	520	-	-	1,269
	Warehouse	232						1											-	-	-	-	-	749	-	-	
	Land used for storage							1											-	-	-	-	-	-	-	-	
51-Leisure (1020m2)	Hotel										74.00	45.93	36.38	16.70	7.17	3.14	1.79	0.90	-	-	-	-	-	-	-	-	-
	Caravans																		-	-	-	-	-	-	-	-	
	Recreation / Social club																		-	-	-	-	-	-	-	-	
	Holiday let																		-	-	-	-	-	-	-	-	
52-Sport	Sports Grounds & Playing Fields										0.70	0.41	0.31	0.16	0.07	0.03	0.02	0.01	-	-	-	-	-	-	-	-	-
	Sports centre										19.00	11.68	8.77	4.33	1.91	0.84	0.48	0.24	-	-	-	-	-	-	-	-	
6-Public Buildings (1300m2)	School	606						1			26.00	16.24	12.07	6.10	2.71	1.19	0.68	0.34	-	-	-	-	-	721	-	-	1,775
	Health centre	450						1											-	-	-	-	-	536	-	-	
	Residential Home																		-	-	-	-	-	-	-	-	
	Community Centre	436						1											-	-	-	-	-	519	-	-	
	Fire/Ambulance station																		-	-	-	-	-	-	-	-	
	Church																		-	-	-	-	-	-	-	-	
8-Industry (2480m2)	Workshop										11.00	6.92	5.03	2.59	1.16	0.51	0.29	0.14	-	-	-	-	-	-	-	-	181
	Factory	354						1											-	-	-	-	-	181	-	-	
	Sewage TW																		-	-	-	-	-	-	-	-	
9-Miscellaneous	Car park										1.90	1.19	0.84	0.45	0.20	0.09	0.05	0.03	-	-	-	-	-	-	-	-	6,965
	Elec substation	220						3			180.00	114.83	81.93	44.99	20.39	8.93	5.10	2.55	-	-	-	-	-	5,894	-	-	
	Pumping stations (As	120						1			180.00	114.83	81.93	44.99	20.39	8.93	5.10	2.55	-	-	-	-	-	1,072	-	-	
																			-	-	-	-	-	-	-	-	
																			-	-	-	-	-	-	-	-	
	Unclassified (Larger footprints at colleges - Assume Public Buildings class. Some appear to be resider										26.00	16.24	12.07	6.10	2.71	1.19	0.68	0.34	-	-	-	-	-	-	-	-	
Total Business Damages (AAD)																											16,756
Total Business Damages (PV over benefits period)																											**470,830**

Infrastructure Damages - Roads, Rail & Utilities	
Agriculture Damages	
	-
Vehicle Damages	
	-
Evacuation Costs	
	-
Intangible effects of flooding	
	-

Total Damages (£ PV over benefits period)	
Residental Property	2,228,921
Business	470,830
Infrastructure	-
Agriculture	-
Vehicle	-
Sub total	**2,699,751**
Saltwater flooding factor	1.100
Emergency Costs Factor	1.107
Evacuation Costs	-
Intangible effects	-
Total Damages - After	**2,988,625**
Total Damages - Before	**8,597,405**
Total Benefits	**5,608,781**

Social Class Weighting

AB	Very affluent area (Generally private roads/estates)
C1	Mid ranged property (closer to AB)
C2	Mid ranged property (closer to DE)
DE	Deprived communities (use deprived communities layer on G drive)

Appendix C DEFRA FCRM Partnership Funding Calculator

This table calculates the partnership funding requirement from the costs and benefits determined above. While DEFRA guidance allows for the inclusion of non-residential property in assessing the benefit / cost ratio, partnership funding is determined on residential properties protected only.

FCRM Partnership Funding Calculator for Flood and Coastal Erosion Risk Management Grant in Aid (FCRM GiA)

Version 8 January 2014

Project Name	Maidstone Consultancy Advice - Medway, Beult and Teise Addiitonal Flood Alleviation Options Initial Assessment
Unique Project Number	UA008306

Key Input cells / Calculated cells

All figures are in £'s

Figures in Blue to be entered onto Medium Term Plan

SUMMARY: prospect of FCRM GiA funding

Scheme Benefit to Cost Ratio:	0.40	to 1
Effective return to taxpayer:	**0.40**	to 1
Effective return on contributions:	**n/a**	to 1

Raw Partnership Funding Score	8%	(1)
External Contribution or saving required to achieve an Adjusted Score of 100%	**12,778,962**	(2)
Adjusted Partnership Funding Score (PF)	8%	(3)
PV FCERM GiA towards the up-front costs of this scheme (PV Cost for Approval)	-	(4)

Cell (2) shows the minimum amount of contributions and/or reductions in scheme cost that are required to raise the Adjusted PF Score to at least 100%. Further increases on this will improve this scheme's chances of an FCRM GiA allocation in the desired year. Planned savings and contributions should be entered into cells(9,10,12) and cells(14-17). See NOTE below.

1. Scheme details

Risk Management Authority type of asset maintainer	LA	(5)
Duration of Benefits (years)	75	(7)
PV Whole-Life Benefits:	5,608,781	(8)
PV Costs		
PV Appraisal Costs		(9)
PV design & Construction Costs	13,916,000	(10)
Sub Total - PV Cost for Approval (appraisal,design,construction)	**13,916,000**	(11)
PV Post-Construction Costs	88,000	(12)
PV Whole-Life Costs:	14,004,000	(13)
PV Contributions secured to date		
PV Local Levy secured to date		(14)
PV Public Contributions secured to date		(15)
PV Private Contributions secured to date		(16)
PV Funding form other Environment Agency functions/sources secured to date		(17)
PV Total Contributions secured to date	0	(18)

WARNING: Contributions less than minimum required in cell (2)

Yes (6)
Is evidence available that a Strategic Approach has been taken, and that double counting of benefits has been avoided ?

All costs and benefits must be on a Present Value (PV) Whole-Life basis over the Duration of Benefits period. Where Contributions are identified these should also be on a Present Value basis.

The total value of any necessary contributions will depend on whether maintenance (ongoing costs) is funded through revenue FCRM GiA, or by other means.

NOTE: This scheme is to be maintained by an RMA other than the EA (ref cell 5). Capital FCRM GiA will fund the appropriate share of the up-front costs (cell 11) with any shortfall needing to be paid for via contributions identified in cells(14-17). Future ongoing costs (cell 12) and any contriubutions towards them are a matter for local agreement by the RMA and should NOT be included in cells(14-17). It is recommended that the RMA takes the opportunities created during scheme development to separately secure contributions towards future ongoing costs (cell12).

2. Qualifying benefits under Outcome Measure 2: households better protected against flood risk

Number of households in:	Before			After			Change due to scheme		
At:	Moderate risk	Significant risk	Very significant risk	Moderate risk	Significant risk	Very significant risk	Moderate risk	Significant risk	Very significant risk
20% most deprived areas							0	0	0
21-40% most deprived areas							0	0	0
60% least deprived areas		372	30	402			402	-372	-30
Annual damages avoided (£), compared with a household at low risk							150	600	1,350

Change in household damages, in:	Per year	Over lifetime of scheme		**Qual. benefits (discounted)**
20% most deprived areas	£ -	£ -	**OM2 (20%)**	£ -
21-40% most deprived areas	£ -	£ -	**OM2 (21-40%)**	£ -
60% least deprived areas	-£ 203,400	-£ 15,255,000	**OM2 (60%)**	£ 5,721,140

3. Qualifying benefits under Outcome Measure 3: households better protected against coastal erosion

Number of households in:	Before	
	Long-term loss	Medium-term loss
20% most deprived areas		
21-40% most deprived areas		
60% least deprived areas		

Damages per household avoided:	Long-term loss	Medium-term loss	
Annual damages avoided	£ 6,000	£ 6,000	
Loss expected in	50	20	years
Present value of Year 1 loss (i.e. first year damages, discounted based on when loss is expected)	£ 1,184	£ 3,015	

Change in household damages, in:	Year 1 loss avoided:	Over lifetime of scheme:		**Qual. benefits (discounted):**
20% most deprived areas	£ -	£ -	**OM3 (20%)**	**£ -**
21-40% most deprived areas	£ -	£ -	**OM3 (21-40%)**	**£ -**
60% least deprived areas	£ -	£ -	**OM3 (60%)**	**£ -**

4. Qualifying benefits under Outcome Measure 4: statutory environmental obligations met

Payments under:			Assumed benefits per unit:		**Qual. benefits (discounted):**
OM4a		Hectares of net water-dependent habitat created	£ 15,000	OM4a	£ -
OM4b		Hectares of net intertidal habitat created	£ 50,000	OM4b	£ -
OM4c		Kilometres of protected river improved	£ 80,000	OM4c	£ -
				OM4	**£ -**

5. Qualifying benefits arising from the overall scheme, for entry into the Medium-Term Plan

OM, deprivation:		Qual. benefits:	Payment rate:		FCRM GiA contribution:
OM1		Ltd by high OM2,3,4 values	5.56	p in the £1	£ -
OM2	20% most	£ -	45.0		£ -
	21-40%	£ -	30.0		£ -
	Least 60%	£ 5,721,140	20.0		£ 1,144,228
OM3	20% most	£ -	45.0		£ -
	21-40%	£ -	30.0		£ -
	Least 60%	£ -	20.0		£ -
OM4		£ -	100.0		£ -
Total		£ 5,721,140			**£ 1,144,228**

Maximum for Outcomes delivered. The actual value any scheme is elligible for may be less.

Sensitivity Testing. *It is important that users of this calculator appreciate the implications on funding from changes to input data which may become necessary as the project develops and better information is available. Five typical tests are provided below. Users should consider how appropriate these are to their project, what other tests may be appropriate and how best to use the information with all those that may be involved in the project.*

	Raw Score	Contribution for 100% Score (£k)
As scenario above	8%	12,778,962
Sensitivity 1 - Change in PV Whole Life Cost (25% increase)	3%	16,883,333
Sensitivity 2 - Change in OM2 - 50% of households in Very Significant (Before) risk may already be in Significant Risk band	8%	12,830,585
Sensitivity 3 - Change in OM3 - 50% of households in Medium Term loss (Before) may already be in Long Term loss	8%	12,778,962
Sensitivity 4 - Increase Duration of Benefits by 25%	9%	12,724,297
Sensitivity 5 - Reduce Duration of Benefits by 25%	8%	12,854,252

END OF WORKSHEET

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