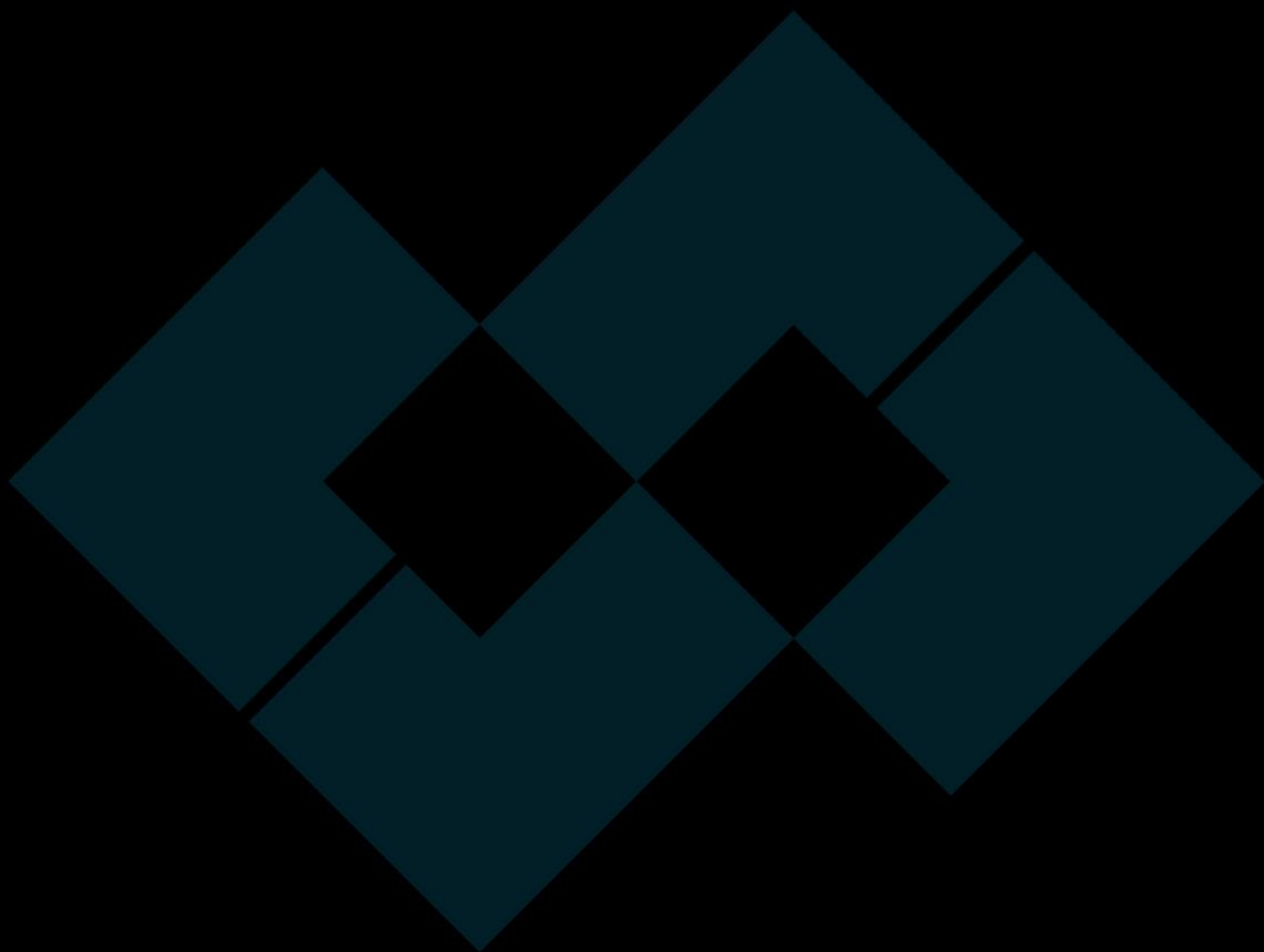




Appendix J4 – Hydrodynamic Modelling Report



Hydrodynamic Modelling Report
Langstone - 2022

Version 1.0

February 2022

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Document Information

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Department	Coastal Partners
Authors	Alex Hillawi

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EXECUTIVE SUMMARY

Low lying topography around Langstone village in Hampshire results in an increased risk of tidal flooding, leading to the proposal and initiation of a Flood and Coastal Erosion Risk Management (FCERM) scheme. The western edge of Langstone is bounded by a small stream known as the Langbrook which exhibits flashy flow regimes throughout the winter months. This has raised concerns that tidal flooding could be exacerbated, potentially risking the proposed defences being overtopped at lower return periods than previously considered. Hydrodynamic modelling using MIKE21 FM has been undertaken to investigate this risk. Results show that increases in flood levels were restricted to the early and late stages of the tidal curve, after which changes become negligible and do not affect the standard of protection of the scheme.

1. Background

1.1 Introduction

Langstone is a small coastal village located on the mainland immediately north of Hayling Island (see Figure 1). The frontage is popular with locals and tourists due to its unique setting and its important cultural heritage. Much of the topography of the village is low lying and subject to inundation at high spring tides, posing an increased risk to homes and critical infrastructure. This risk has led to the proposal and initiation of an FCERM scheme which aims to increase the standard of protection from tidal flooding at the site. The western edge of Langstone is fringed by a small stream known as the Langbrook which exhibits flashy flow regimes throughout the winter months. Considering a scenario that should a significant tidal event coincide with a high stream discharge, water levels along defences at the western side of the village might be significantly increased, potentially resulting in the proposed defences being overtopped at lower return periods than previously considered or outflanked from behind. To investigate the potential scenario further and associated impacts of this risk, Coastal Partners have undertaken hydrodynamic modelling using MIKE21 FM. This document summarises the approach, methods and results of this work.



Figure 1: Location of the Langbrook Stream

1.2 Aims and Objectives

1.2.1 Aim

To investigate the effects of increased fluvial discharge from the Langbrook stream on elevated tidal levels along the western edge of the Langstone FCERM scheme.

1.2.2 Objectives

- To compare the effect of high stream discharge on still water levels against a baseline condition;
- To understand topographic relief at the study site, its effect on flow paths and their resultant impact on water levels;
- To assess any differences exerted by the position and elevation of proposed defences.

1.3 Hydrodynamic Setting

1.3.1 Tidal

A typical spring tidal range within Langstone Harbour is approximately 4m. One characteristic within the tidal curve which should be taken into consideration as part of this study is a 'Double High water' by which the tidal peak is then immediately followed by a second (slightly reduced) peak. This effect is particularly evident on spring tides manifesting as a pause or period of reduced ebb speed immediately after the astronomical highwater. The whole event

lasts for around 3 hours before the full ebb flow begins. The tidal prism within Langstone Harbour is distinctly asymmetric, with ebb currents being of shorter duration than the flood. The nearest tide gauges at the site are located within Portsmouth and Chichester harbours. Tidal levels for both these locations respectively are shown below in *Table 1* (Admiralty Tide Tables, 2017):

Table 1: Tide levels at Portsmouth and Chichester Harbours

	Portsmouth		Chichester	
	mCD	mOD	mCD	mOD
HAT	5.1	2.37	5.3	2.56
MHWS	4.7	1.97	4.9	2.16
MHW	4.25	1.52	4.45	1.71
MHWN	3.8	1.07	4	1.26
MWL	2.9	0.17	2.9	0.16
MLWN	1.9	-0.38	1.9	-0.84
MLW	1.35	-1.38	1.4	-1.34
MLWS	0.8	-1.93	0.9	-1.84
LAT	0.1	-2.36	0.2	-2.54

1.3.2 Fluvial

The Langbrook Stream is a small watercourse which runs along the western side of Langstone, before discharging into the Harbour. It is fed by a confluence of two source inputs. Its main perennial baseflow is supplied by the Homewell spring located approximately 1.2 kilometers north, northwest from the study site (Figure 2). The Spring exhibits a stable discharge with its subsequent stream channel only marginally augmented by surface water input from its small catchment. There is no gauge data available for this source.



Figure 2: Homewell Spring

The Lavant is an ephemeral stream (known as a Winterbourne). Whilst fairly dormant throughout the summer months it experiences significant flows during the winter. Due to an upper catchment underlain mainly by clay and a heavily urbanised lower catchment it exhibits a flashy hydrograph, liable to sudden and rapid increases in flows. It is therefore deemed that extreme events in the lower tidal section of the Langbrook are driven by input from this stream rather than the more stable Homewell spring. The only record of discharge available for the Lavant is from a gauging station located in Havant town Centre which recorded peak discharges of 1.924 m/s on the 11/12/2000. This station was however decommissioned in 2003. Since this, it is known that a significant proportion of flow (of up to 3 cubic metres per second) has been diverted into the neighbouring Hermitage and Brockhampton catchments (Cole et al 2009).



Figure 3: Havant levels gauge (Site of decommissioned flow gauge)

Approximately 1 km downstream these two streams converge to form a single channel known as the Langbrook. This single channel is intermittently broken north of Mill Lane where the channel has been diverted into two branches to form an artificial island in-between. A weir is located on each of these stream channels (constructed as part of a water mill complex which was historically located there) which forms the general tidal limit for the lower section of the Langbrook. Both these channels converge once again immediately to the south of Mill Lane (see Figure 4) where a third channel enters the stream. This however is a small drainage ditch and deemed to have little effect on discharges into the tidal section of the channel. From here the stream runs approximately 2.6 kilometers south, southeastward before discharging into Langstone Harbour.

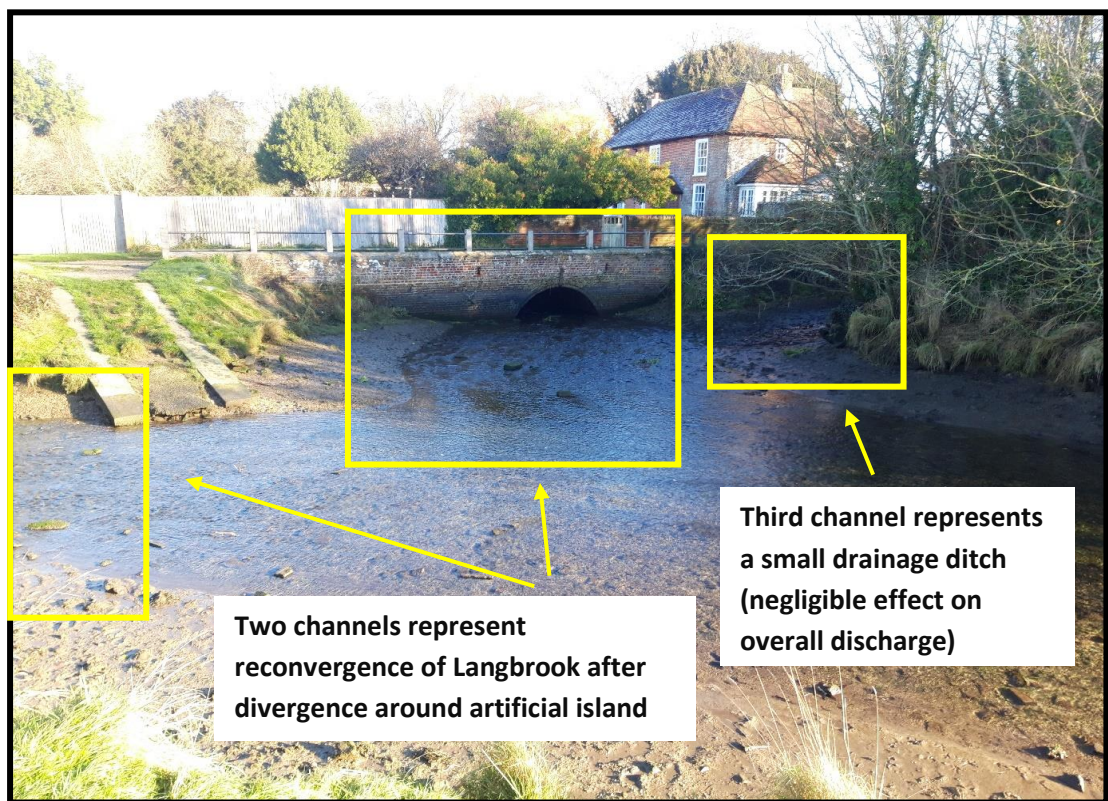


Figure 4: Channel convergence downstream of Mill Lane

2. Model Configuration

Modelling was undertaken using MIKE 21 Flow model FM. This was developed by the Danish Hydraulic Institute (DHI) to be used specifically for the simulation of two-dimensional processes within coastal and oceanographic environments. The software uses a flexible mesh composed of an unstructured grid of quadrilateral and triangular elements and simulates hydrodynamic processes by solving the Saint-Venant equations, continuity equation and equations of motion.

The main inputs required by this software to facilitate simulation of a coastal system are listed as follows:

- Suitable coastline data to encompass the required study site domain (including any proposed defence locations);
- Bathymetric and topographic data to reflect relief throughout the domain area;
- Input boundary condition data;
- Simulation period with relevant time interval.

The inputs used in the model to satisfy the above requirements are discussed below;

2.1 Domain

The northern boundary of the model domain was selected to encompass ground higher than 3.5m AOD. This was to ensure that shoreward terrain elevations exceed the defence threshold of the scheme and allow inclusion of both the known tidal limit of the Langbrook and the tie in of the proposed defence line. As explained in Section 1.3.2, the Langbrook river channel splits around the tidal limit reconverging just downstream of Mill Lane. To allow for this convergence of flows to occur, the fluvial boundary was set slightly downstream of this. The seaward extent of the mesh included a large section of the intertidal area. This was to allow a more natural simulation of tidal influx which initially excludes the influence of the shoreline (a diagram of domain extent is visible in Figure 9a and 9b, Section 2.6).

2.2 Proposed Defence Line

Current proposed defences for the Langstone FCERM scheme, comprise both a primary and secondary defence line. The primary defence ties in to existing high ground along Mill Lane at an elevation of 3.5m AOD (shown by the blue line in Figure 5). This increases to 3.6m AOD in a southward direction for the majority of the embankment (between chainages 10A – 190A). It then meets an existing sea wall which runs east to west along the southern shoreline of the site at an elevation of around 3.8m AOD. The secondary defence runs along the eastern section of the study site (shown by the red line in Figure 5) and maintains an elevation of 3.6m AOD, tying in to ground level at 3.5m AOD near Mill Lane, where it is significantly set back from the frontage.

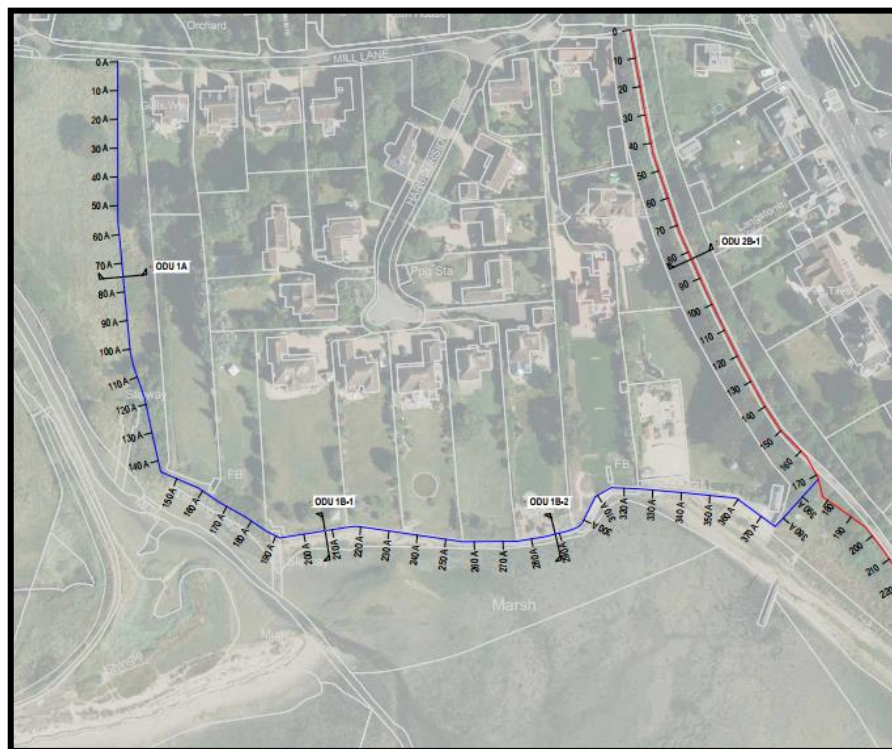


Figure 5: Proposed defence lines

2.3 Topographic / Bathymetric Data

The most recent available LIDAR Data (2020) which sufficiently covered the study area was acquired from the national LIDAR programme, accessed at <https://data.gov.uk/.../national-lidar-programme>. This was downloaded as a sequence of processed Digital Terrain Models (DTM) which were then sampled down into XYZ data using ARCGIS and interpolated into the model.

2.4 Boundary Conditions

2.4.1 Tidal

The nearest high resolution real-time record of tidal elevations to the site which could be used to input tidal elevation heights at the model boundary were available from the Chimet station located approximately one mile out to sea from the entrance of Chichester Harbour at West Pole Beacon, (50° 45'. 45N, 00° 56'. 59W). Data for two spring diurnal tidal cycles were extracted from station records with the second tide artificially increased to produce two separate datasets. One where the tide peak at 3.5m and one which peaks at 3.6m AOD. The resultant timeseries of tidal levels used to simulate tidal boundary conditions are shown below in Figures 6 and 7.

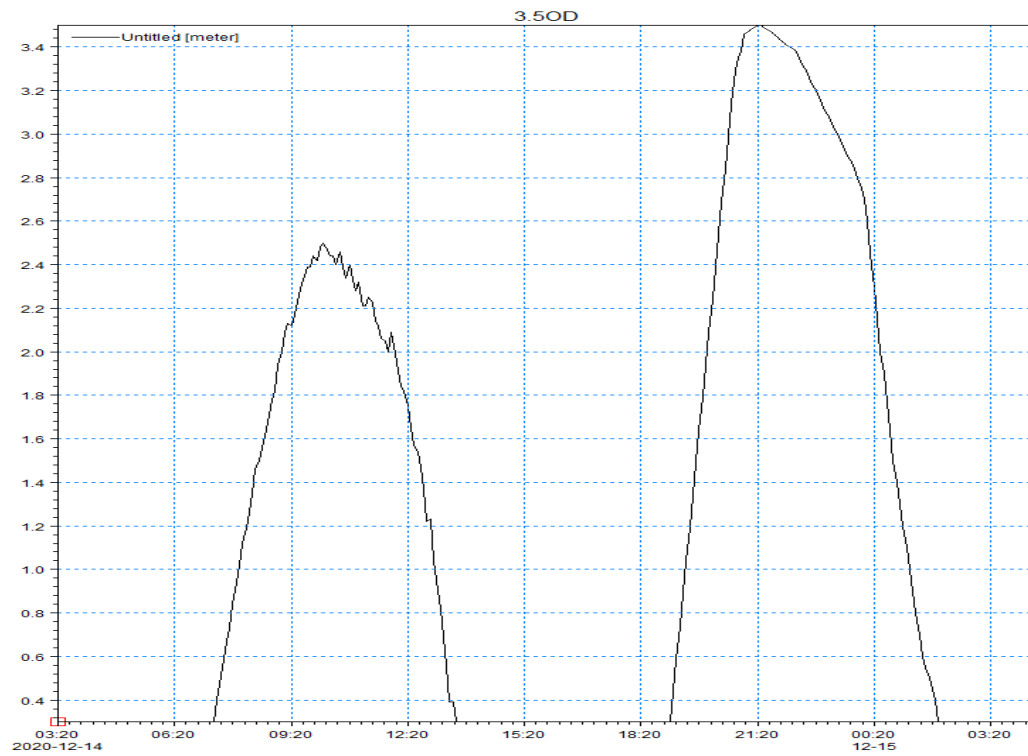


Figure 6: Tidal boundary condition timeseries (3.5 m AOD)

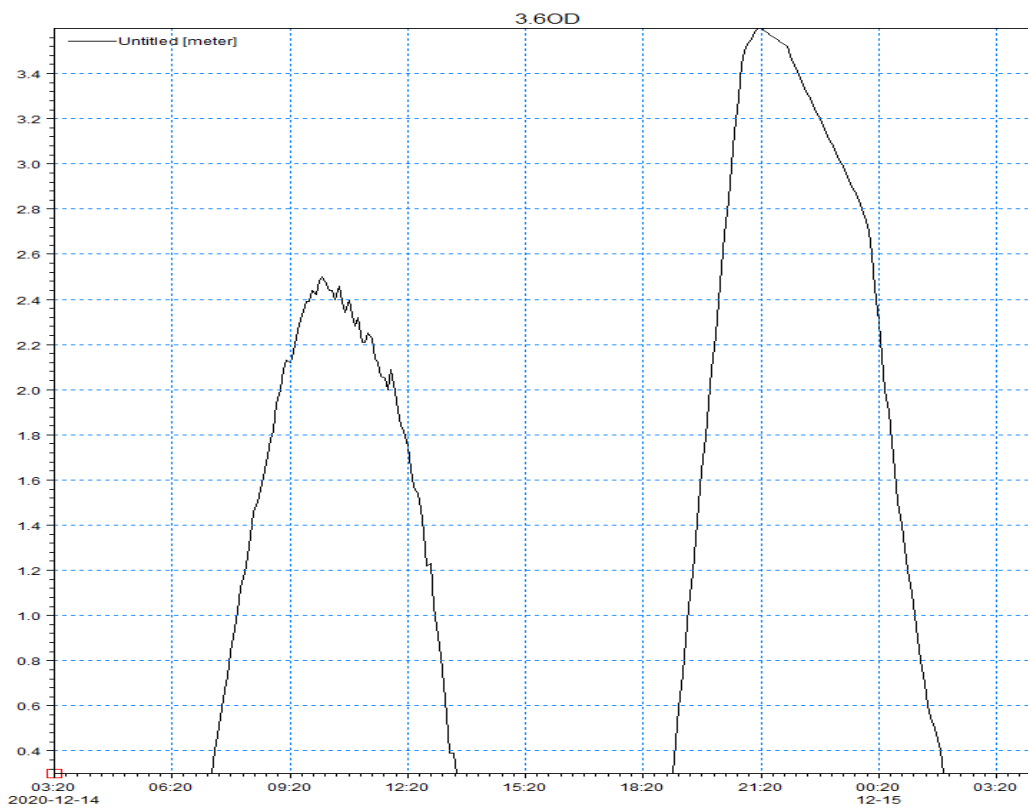


Figure 7: Tidal boundary condition timeseries (3.6 m AOD)

2.4.2 Fluvial

An archive of recorded discharges covering dates between 02/06/1981 and 31/03/2003 was taken from the now defunct Lavant flow gauge, previously located in Havant town centre. However, as stream discharges vary depending on catchment size and hydraulic radius, peak discharge recorded at this gauge (located at an upstream location from the study site) could not be considered a direct reflection of discharges downstream at the Langbrook where the hydraulic radius and effective catchment is larger. To ensure discharges at the study site were not underrepresented by the model, gauge records were modified to include 8.5 m³/s peak. This value reflects a 1 in 100-year event at the neighboring Chichester Lavant (Cole et al, 2009) which is a larger stream which shares similar hydrogeological characteristics to the Havant Lavant. A chart showing a timeseries of tidal levels used to simulate the tidal boundary condition is shown below in Figure 8).

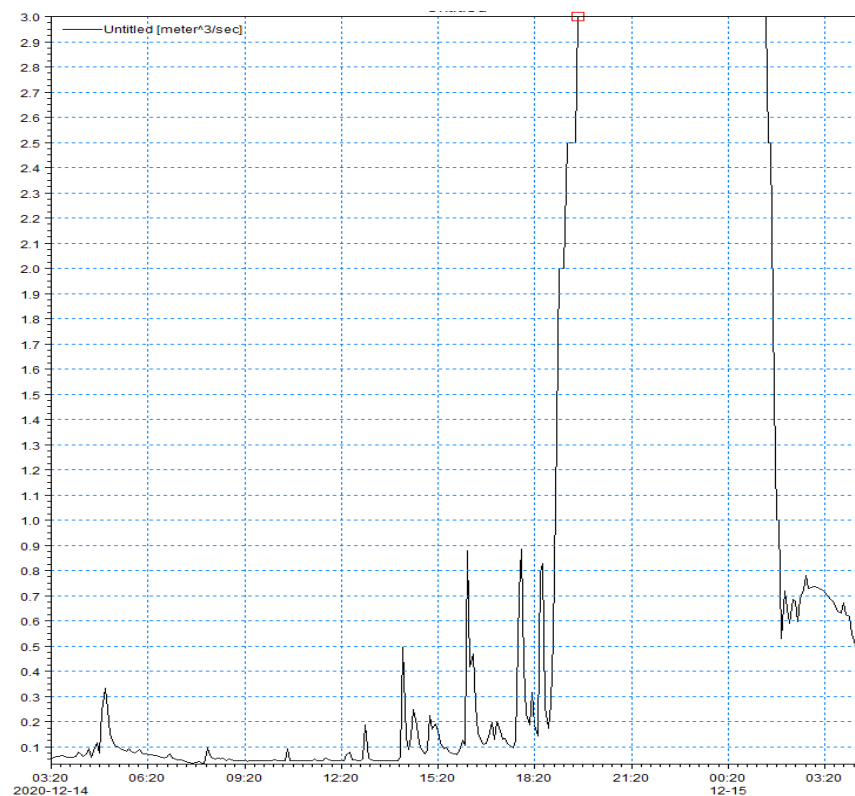


Figure 8: Fluvial Boundary condition timeseries

2.5 Simulation Period

Chimet (website) records tidal elevation data in 5-minute intervals. This yielded the highest timestep resolution of which could be used by the model. The model was run for two tidal cycles. This amounted to 302 timesteps in total. The first tidal cycle was simulated to allow a run up time by which all wetted areas of bathymetry could be filled up, allowing the system to behave more naturally, whilst all analysed results were taken from the second tidal cycle. Tidal levels for the second tidal cycle peak at timestep 217.

2.6 Mesh Generation

A flexible triangular mesh was constructed using MIKE 21 mesh generator. To ensure the river channel area could be sufficiently resolved, element size was reduced in this location to allow approximately ten cells to lie across the channel width. With the exception of narrow banks which fringe the stream channel, wider relief in the area exhibits relatively gentle gradients. As significant topographic change in these areas occurs over large areas, a larger resolution was sufficient to achieve suitable resolution. A diagram of the mesh used can be seen below in Figure 9a whilst a 3D render reflecting its subsequent resolve of underlying Topography / Bathymetry is displayed in Figure 9b.

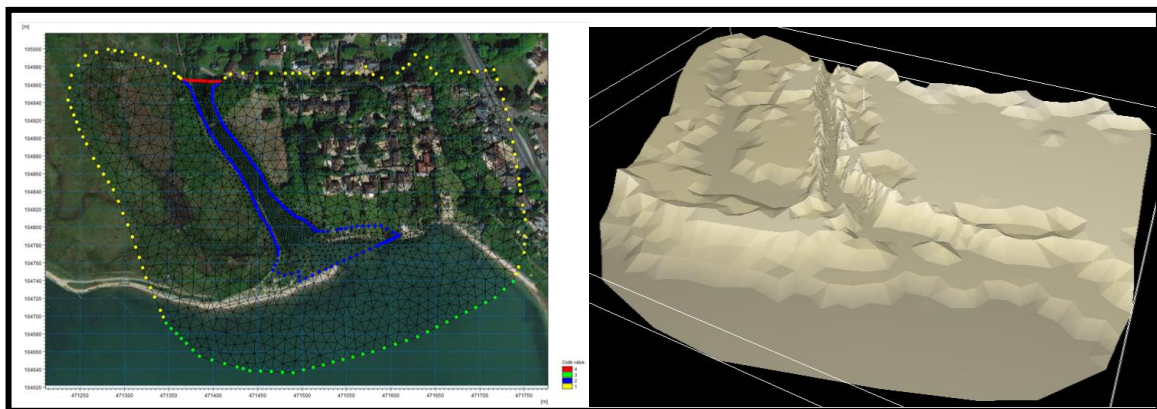


Figure 9a and 9b: Model mesh and 3d render

3. Modelling Approach (Scenarios)

In order to isolate the impact of river discharge on water levels, a baseline condition was required by which comparison could then be undertaken. The model was therefore first run with tidal effects only. The model was then run again with fluvial discharge included and resultant changes assessed. In order to ascertain any impacts which may occur due to the proposed defence line, both of the above scenarios were then run again with the defence line in place. These runs are listed as follows (NOTE each run was undertaken for both 3.5 and 3.6 m AOD tidal levels);

- No defences - tidal only
- No defences - tidal + fluvial
- Proposed defence line included - tidal only
- Proposed defence line included - tidal + fluvial

4. Results

4.1 Timeseries

Three points were selected within the river channel to produce separate timeseries of water surface elevations.

Results for both 3.5m AOD (Figure 10) and 3.6m AOD (Figure 11) tidal boundary conditions showed that the input of fluvial discharge produced significantly elevated levels within the channel at the early part of the tidal curve when compared with tidal levels alone. The magnitude of this effect reduced in a seaward direction and with time, disappeared at timestep 208 (This is concurrent to when bankfull levels within the channel are exceeded, as discussed below in Section 4.2).

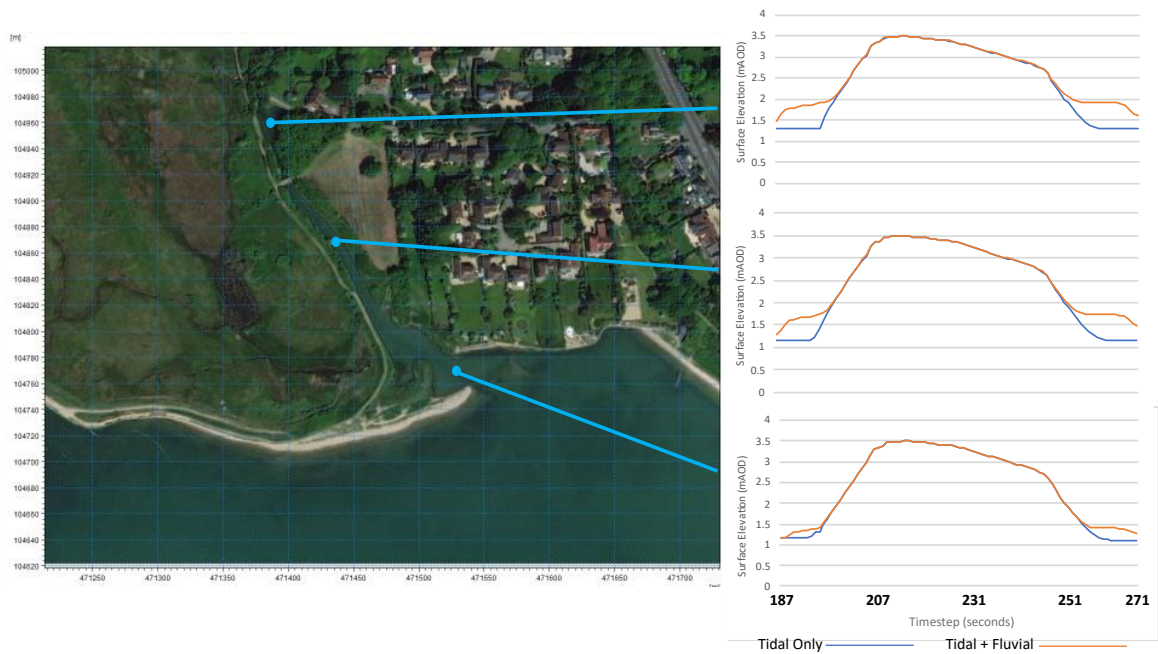


Figure 10: Tidal curve comparisons at upper, mid, and lower part of channel for a 3.5m AOD tidal peak

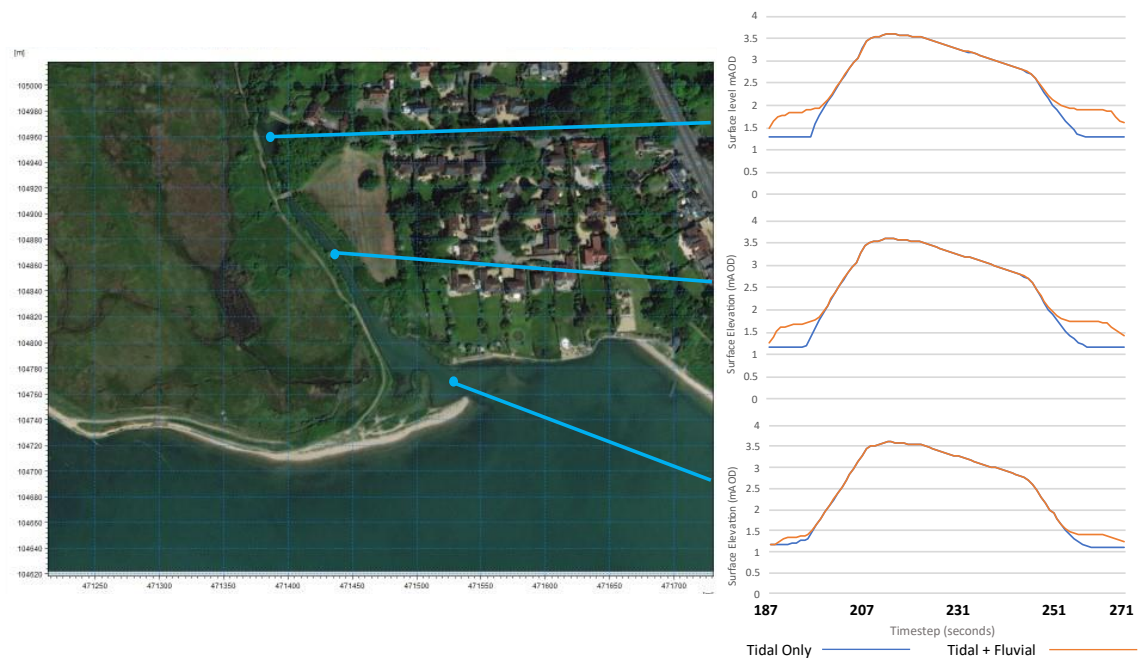


Figure 11: Tidal curve comparisons at upper, mid, and lower parts of the channel (3.6m AOD tidal peak)

4.2 Flood Area Extents

The following sequence of images show modelled surface elevations (m AOD) for selected timesteps which represent key stages throughout the flood phase of the tidal cycle. Enlarged versions of the below images can be viewed in appendix A.

Timestep 195

Tidal levels reach 1.19m AOD and the river channel becomes completely inundated by tidal inflow. When fluvial discharge is included, levels at the top of the river channel increase by up to 56cm with the anomaly reducing in a seaward direction. A minor change in flood extent can also be observed at the top of the channel where pooling evident on its eastern side is not evident under the baseline condition (Figure 12).

Baseline

Tidal + Fluvial

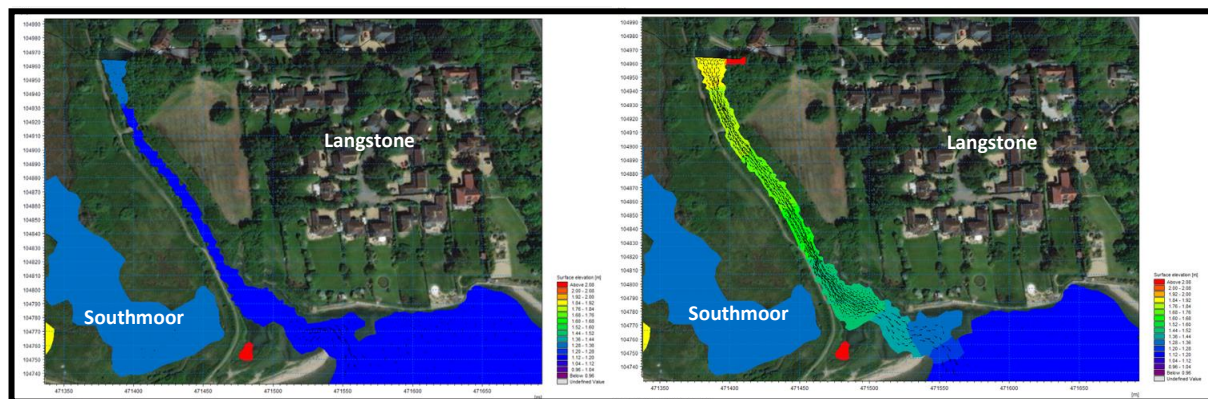


Figure 12: Timestep 195 flood extent

Timestep 204

The tidal boundary condition reaches 2.65m AOD. Inundation of Southmoor to the east side of the channel begins due to an existing breach in defences along the southern shoreline (see Figure 14). When fluvial discharge is introduced, elevated levels within the river channel observed at timestep 195 are no longer seen. Pooling previously identified at the top of the channel can be observed to have grown in size and a new pool has formed to the west of the channel. Flood extents and levels throughout the rest of the domain did not change (Figure 13).

Baseline

Tidal + Fluvial

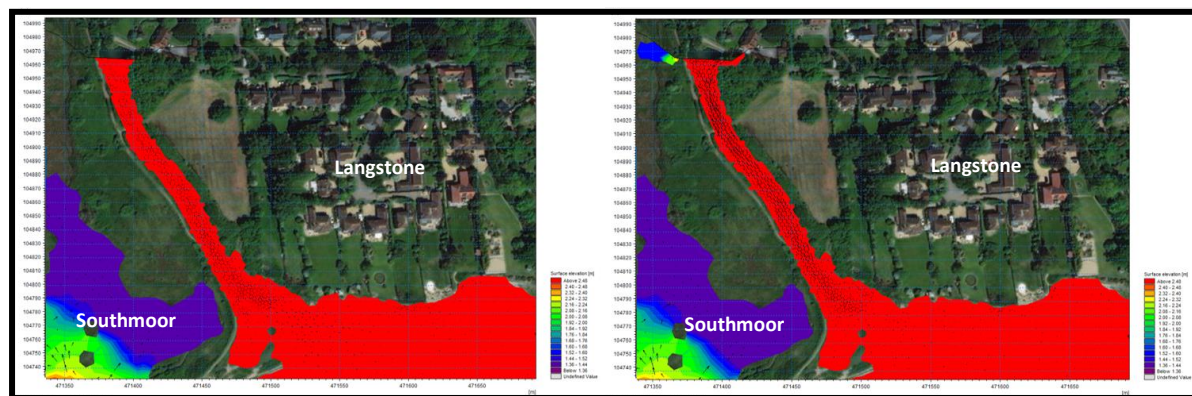


Figure 13: Timestep 204 flood extent



Figure 14: Southmoor breach

Timestep 206

The tidal boundary condition reaches 2.84m AOD. At this stage the bankfull level along the western side of the channel becomes exceeded in places. This results in breaches forming resulting in water flowing from the river channel into Southmoor to its west. When fluvial input is included, flood extent within Southmoor varies little from the baseline condition with the exception of the ponding at the north of the stream on the west side of the channel (Figure 15).

Baseline

Tidal + Fluvial

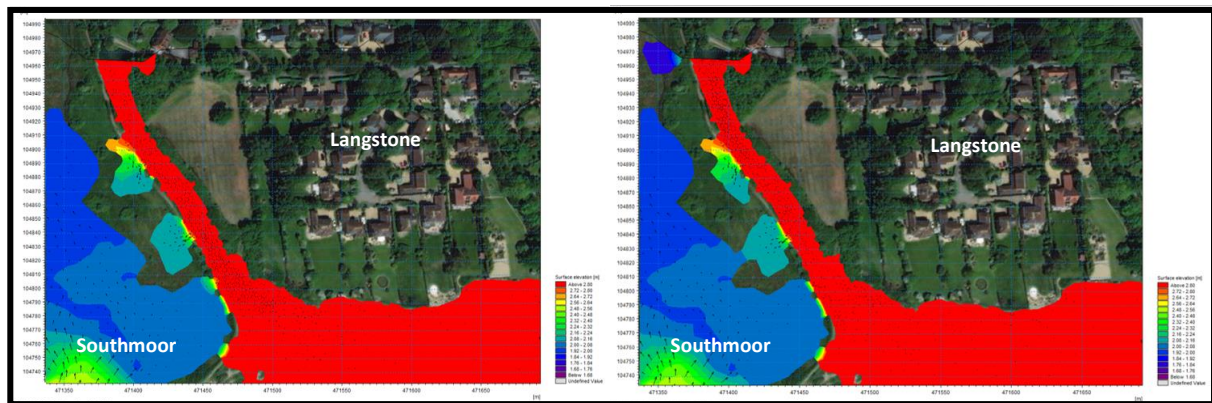


Figure 15: Timestep 206 flood extent

Timestep 208

The tidal boundary condition reaches 3.14 AOD. At this stage Southmoor becomes almost completely inundated and represents the first stage whereby a breach on the Langstone side of the channel can be seen. When fluvial input was introduced the extent of flooding surrounding this breach became slightly increased (Figure 16).

Baseline

Tidal + Fluvial

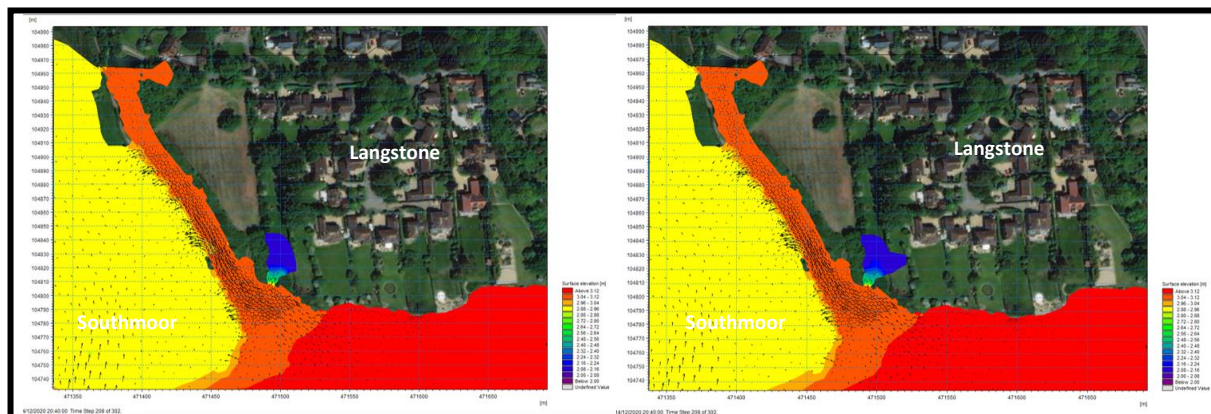


Figure 16: Timestep 208 flood extent

Timestep 210

The tidal boundary condition reaches 3.35m AOD. At this stage Langstone becomes significantly inundated under the existing scenario. Flood extents under both conditions approximate each other well. Any changes in levels observed are sub millimetre (Figure 17). With the proposed Langstone FCERM scheme defences incorporated, inundation is prevented. Flood extents matched each other with only sub-millimetre changes in levels observed (Figure 18).

Baseline

Tidal + Fluvial

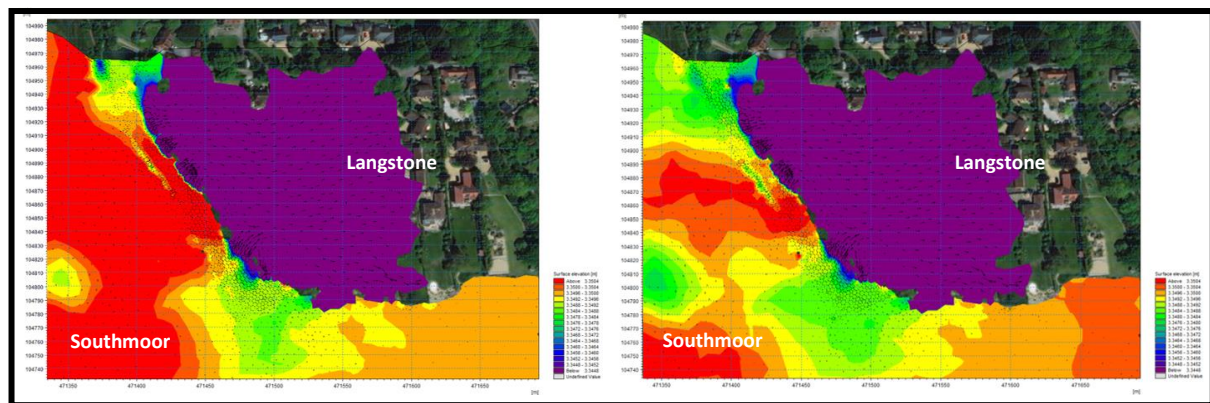


Figure 17: Timestep 210, flood extent

Proposed Defence Lines Included

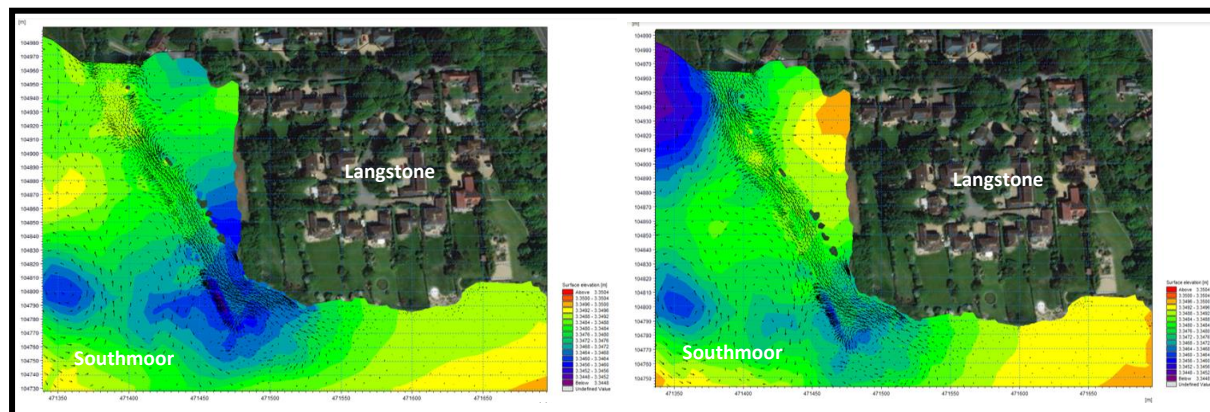


Figure 18: Timestep 210, flood extent (including proposed defence line)

Timestep 217 (3.5m AOD boundary condition)

The tidal boundary condition reaches 3.5m AOD. This represents the peak of the flood tide. Flood extents match very closely with any changes in levels remaining very minor (Figure 19). When the proposed Langstone FCERM scheme defence line is incorporated, inundation is prevented with surface elevations matching closely under both conditions. A sub millimetre dampening of levels can be observed when proposed defences are included (Figure 20).

Baseline

Tidal + Fluvial

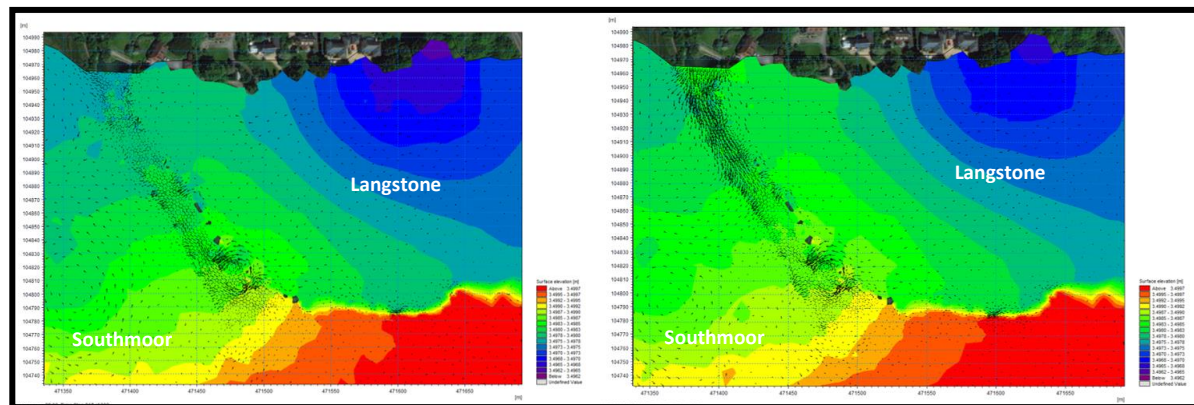


Figure 19: Timestep 217 flood extent

Proposed Defence Line Included

Baseline

Tidal + Fluvial

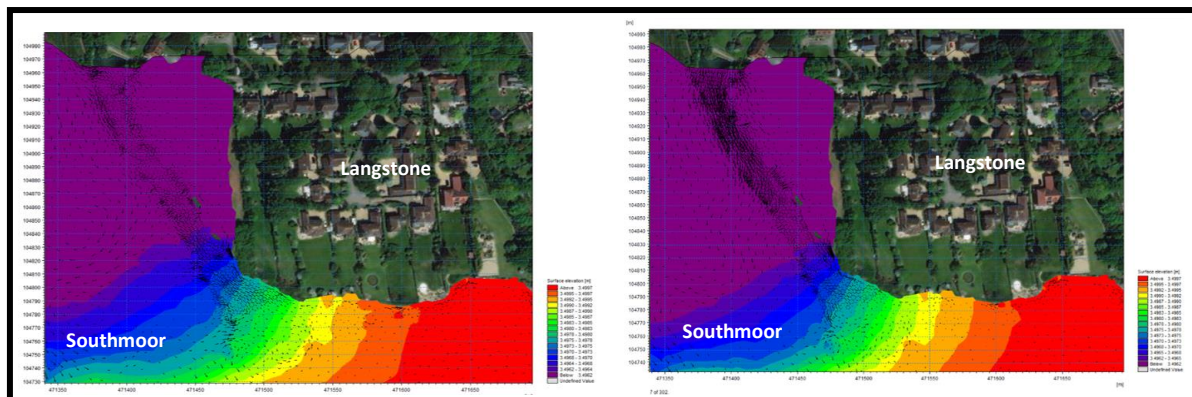


Figure 20: Timestep 217 flood extent (including proposed defence line)

Timestep 217 (3.6m AOD boundary condition)

When the model was run with a tidal peak at 3.6m AOD the tidal curve peaks at timestep 216, flood extents match exactly, with any changes in levels remaining very minor (Figure 21). When

the proposed Langstone FCERM scheme defence line is incorporated, inundation remains prevented and surface elevations match closely under both conditions (Figure 22).

Baseline

Tidal + Fluvial

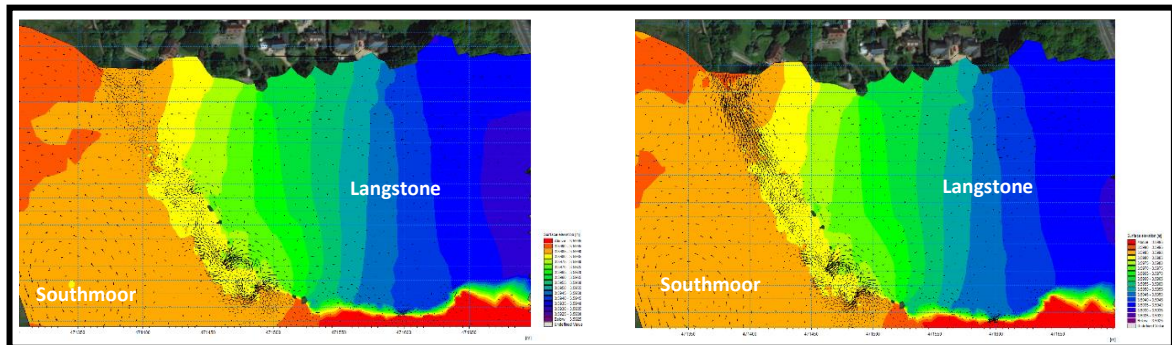


Figure 21: Timestep 217 flood extent

Proposed Defence Line Included

Baseline

Tidal + Fluvial

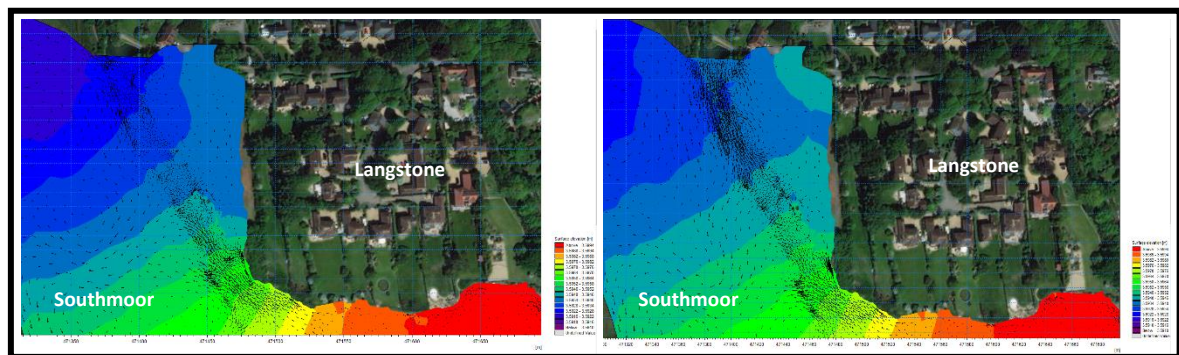


Figure 22: Timestep 217 flood extent (including proposed defence line)

4.3 Transects

Transects of surface water level elevations across the flooded area were extracted for the peak of the tidal curve both with and without fluvial discharge included. These are displayed below for both modelled 3.5 m and 3.6 m AOD tidal peaks. Fluvial input results in a slight (less than 0.2 of a millimetre) increase in levels, visible in particular when a 3.5 m AOD tidal peak is modelled (Figure 23). This effect is reduced when modelled with a 3.6m tidal peak (Figure 24).

3.5m AOD

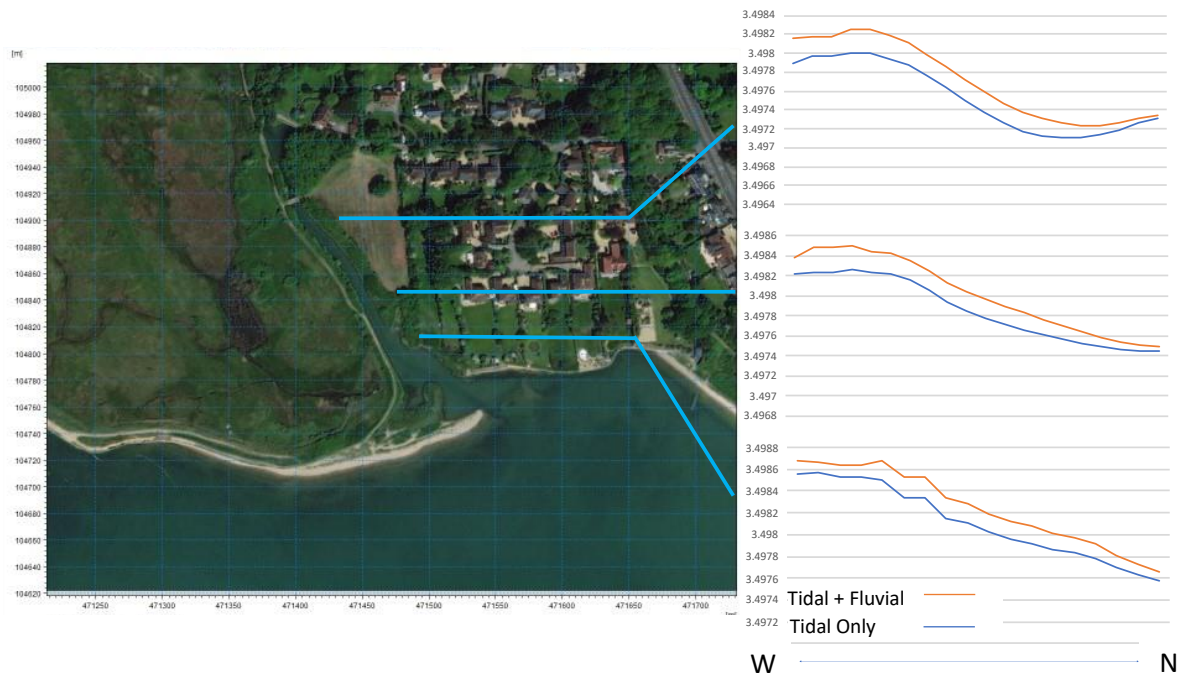


Figure 23: Transects showing water surface elevations for a 3.5 m AOD flood (proposed defences not included **3.6m AOD**)

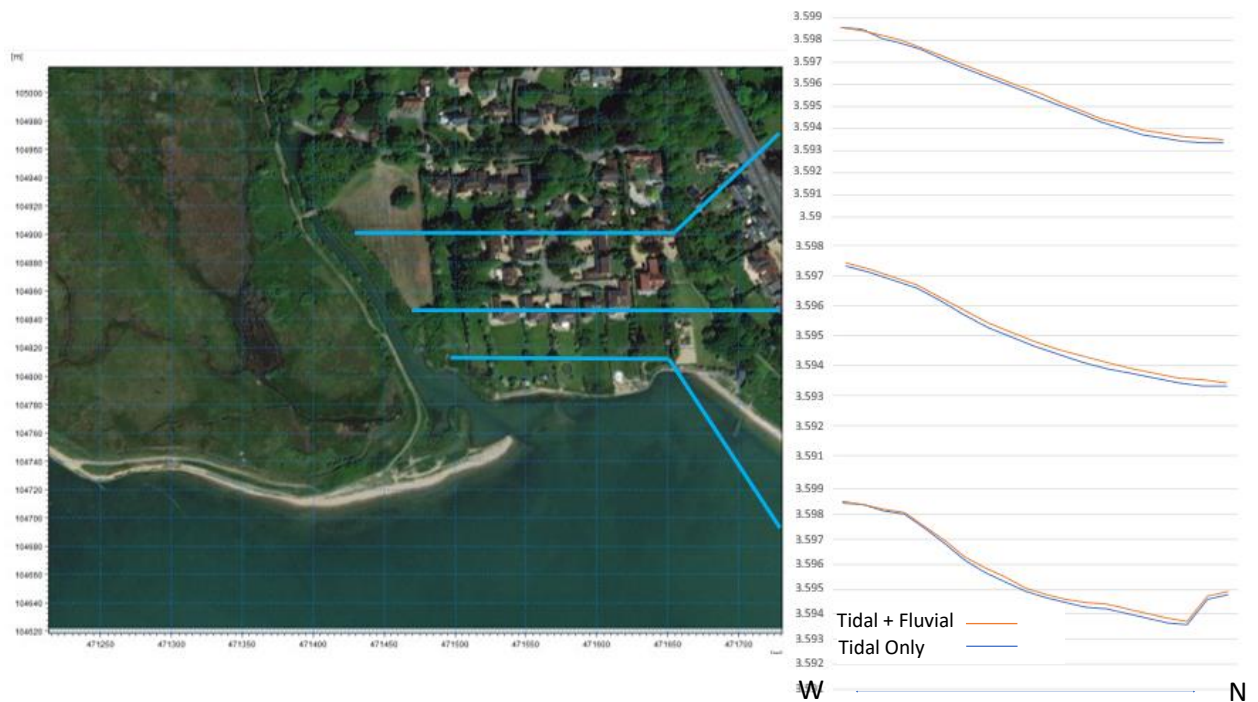


Figure 24: Transect showing water surface elevations for a 3.6 m AOD flood (proposed defences not included)

5. Summary and Conclusion

Whilst initially the addition of an 8.5 m/s fluvial discharge into the domain area had notable effect on water level within the stream channel and extent at the top of the stream around Mill Lane, this effect was restricted to the early and late stages of the tidal curve with any significant changes to water level or extent becoming negligible when bankfull elevations were exceeded. This occurred around 2.14m AOD, well below the standard of protection offered by the Langstone FCERM scheme. Under the existing scenario, once bankfull levels were exceeded, increased fluvial input had little effect on flood extent with any level variations remaining minor (sub-millimetre). When proposed defences were included, they were successful in preventing inundation under all boundary conditions with no evidence of an increased risk of overtopping or bypassing when fluvial discharge was introduced.

6. References

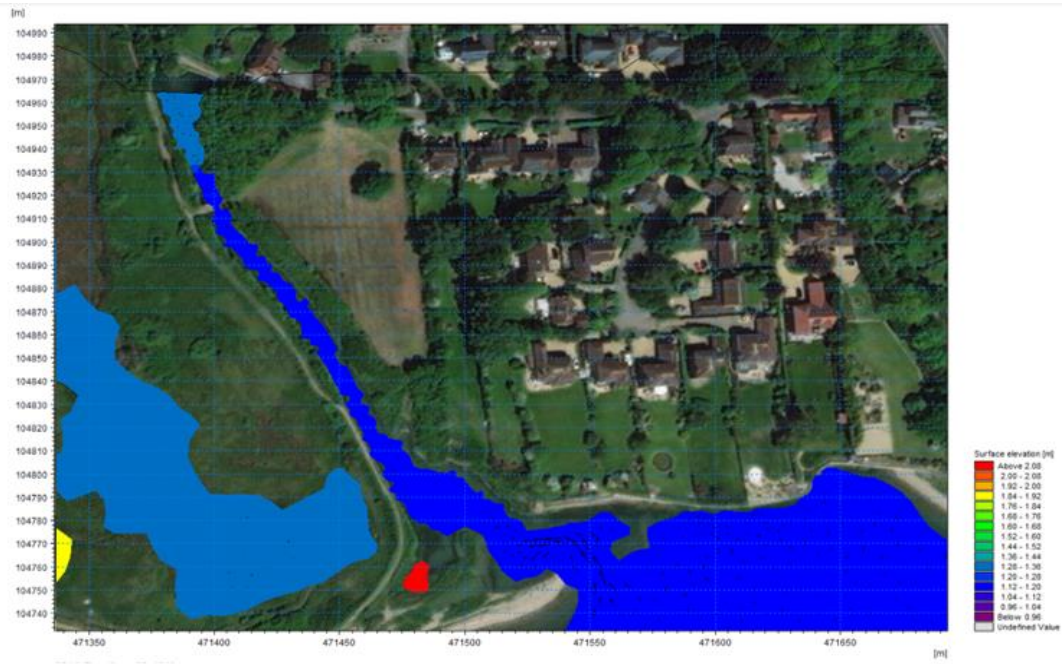
Cole, S. J., Howard, P. J., & Moore, R. J. (2009). Hydrological modelling for the Rivers Lavant and Ems. Commissioned report to the Environment Agency.

7. Appendix

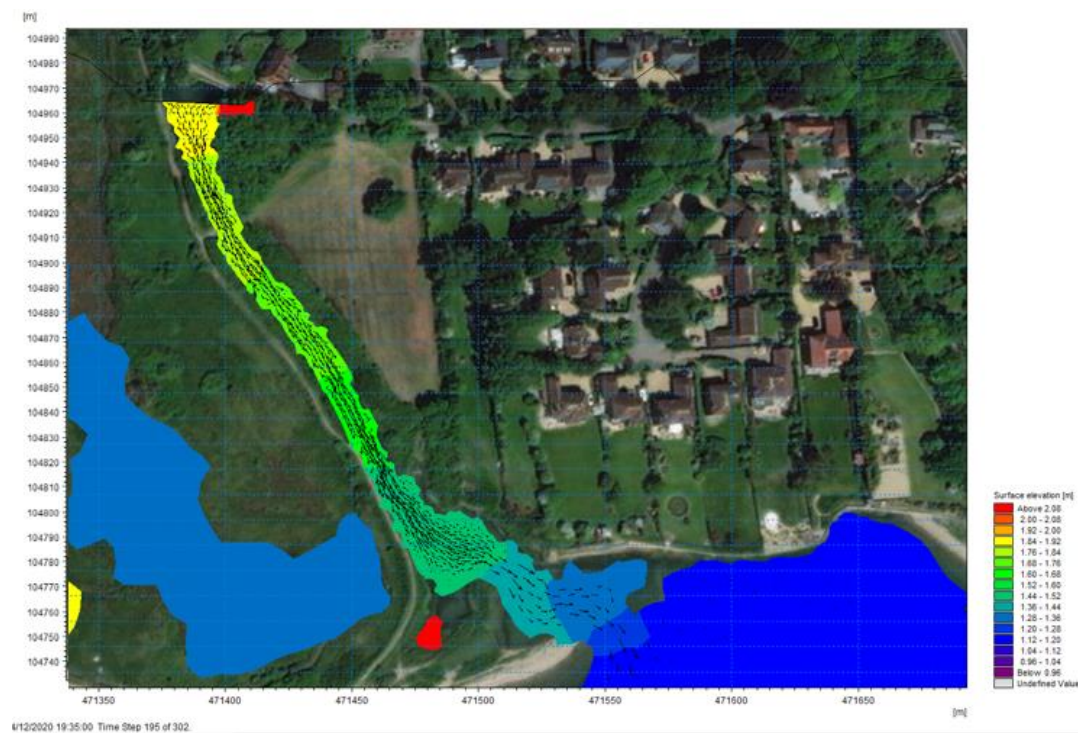
Enlarged flood images

Timestep 195 (1.19m AOD)

Baseline

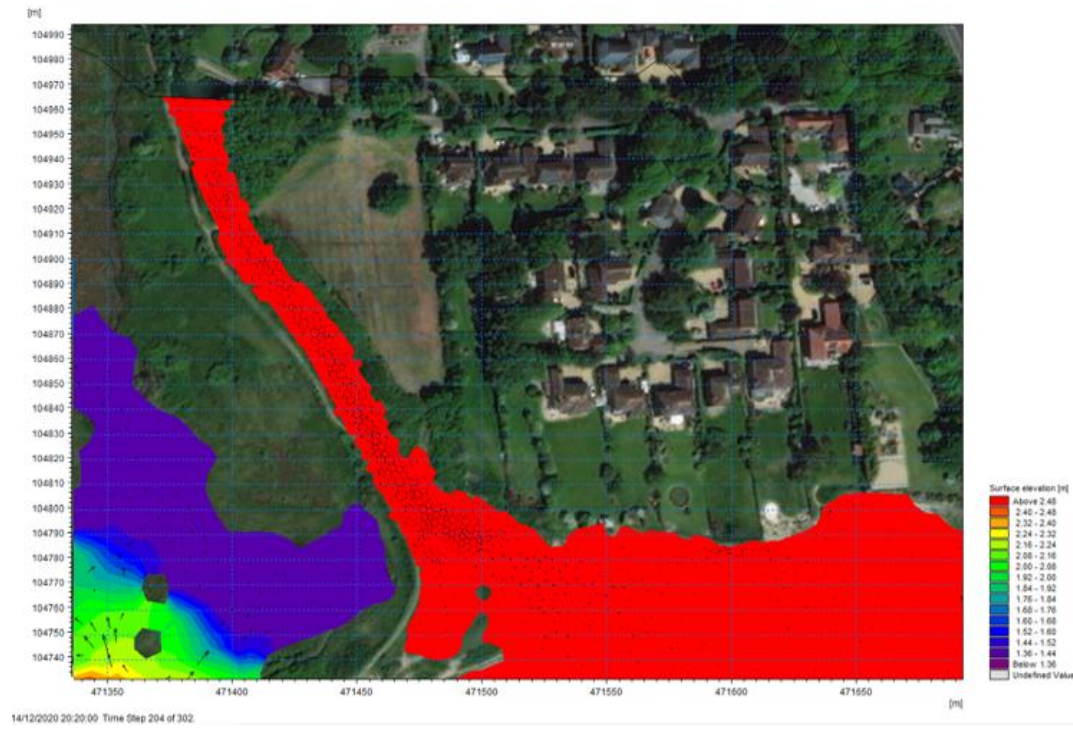


Tidal + Fluvial

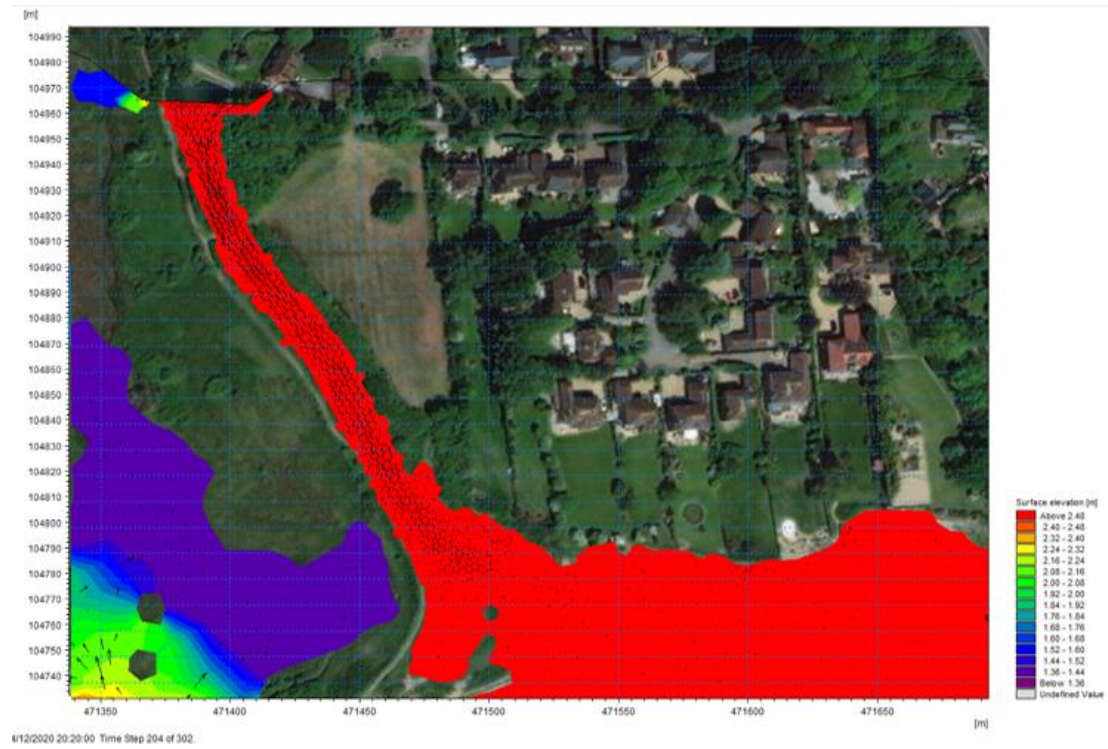


Timestep 204 (2.65m AOD)

Baseline

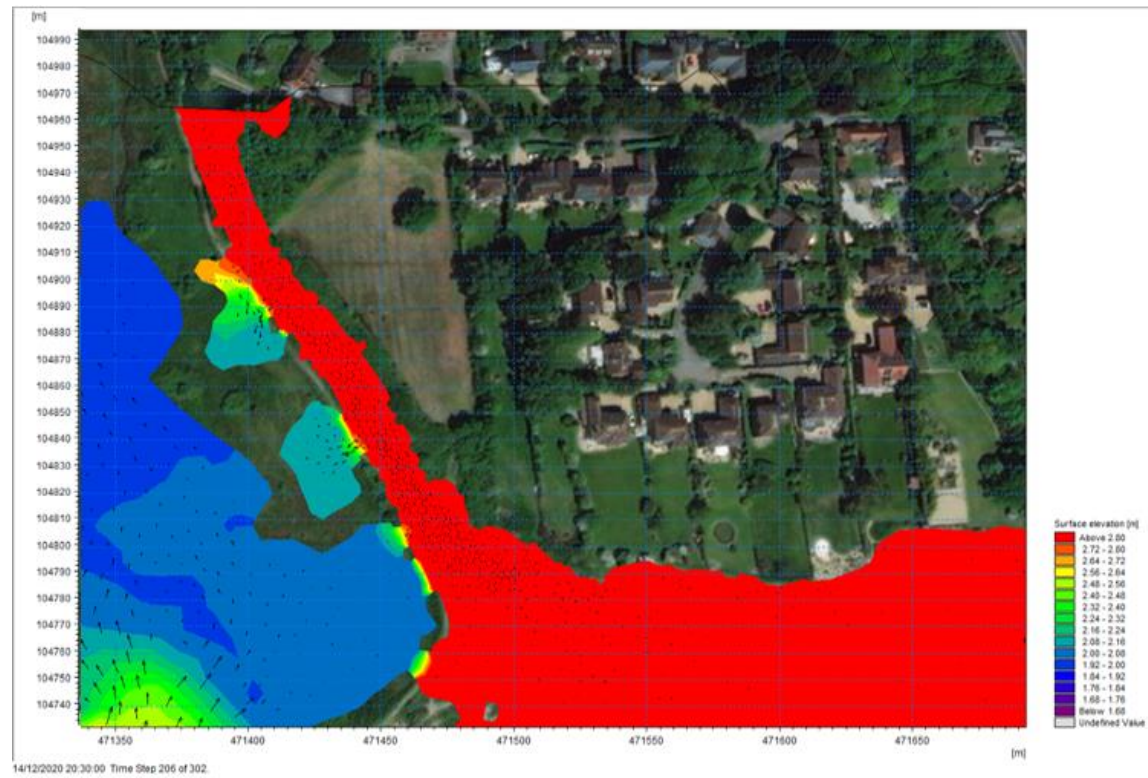


Tidal + Fluvial

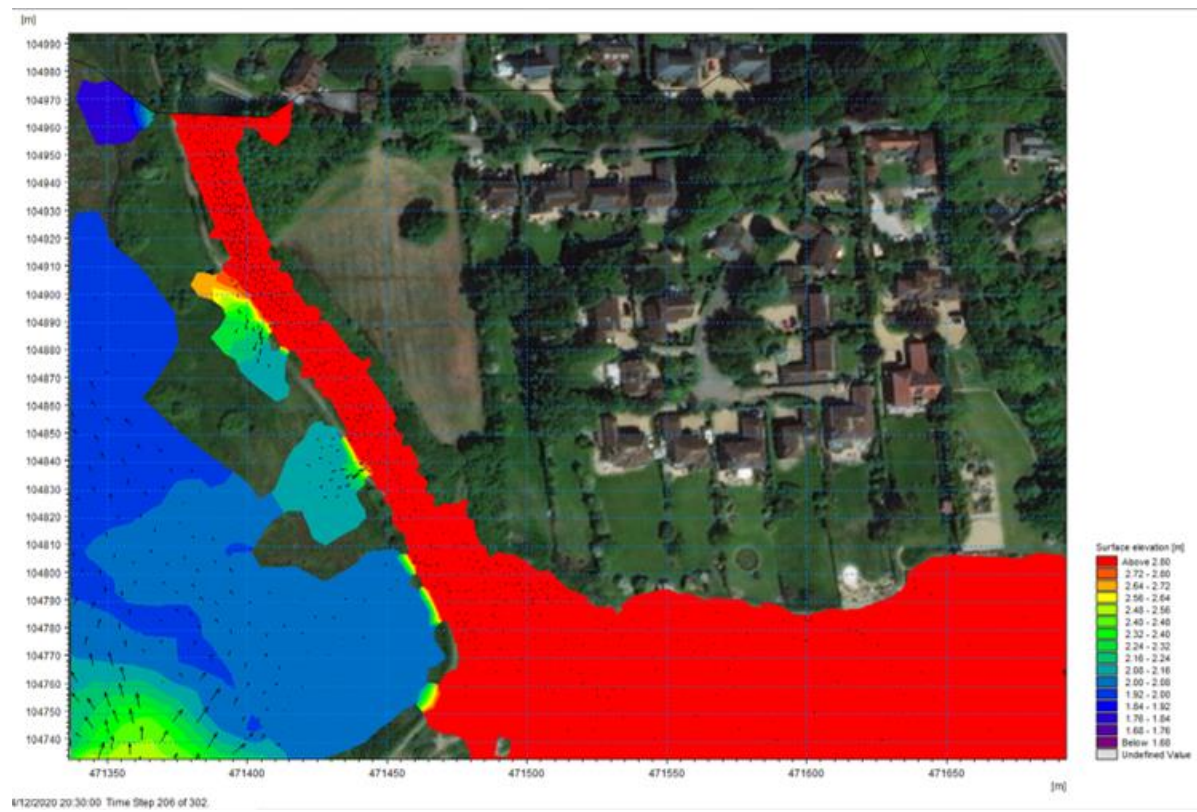


Timestep 206 (2.84M AOD)

Baseline

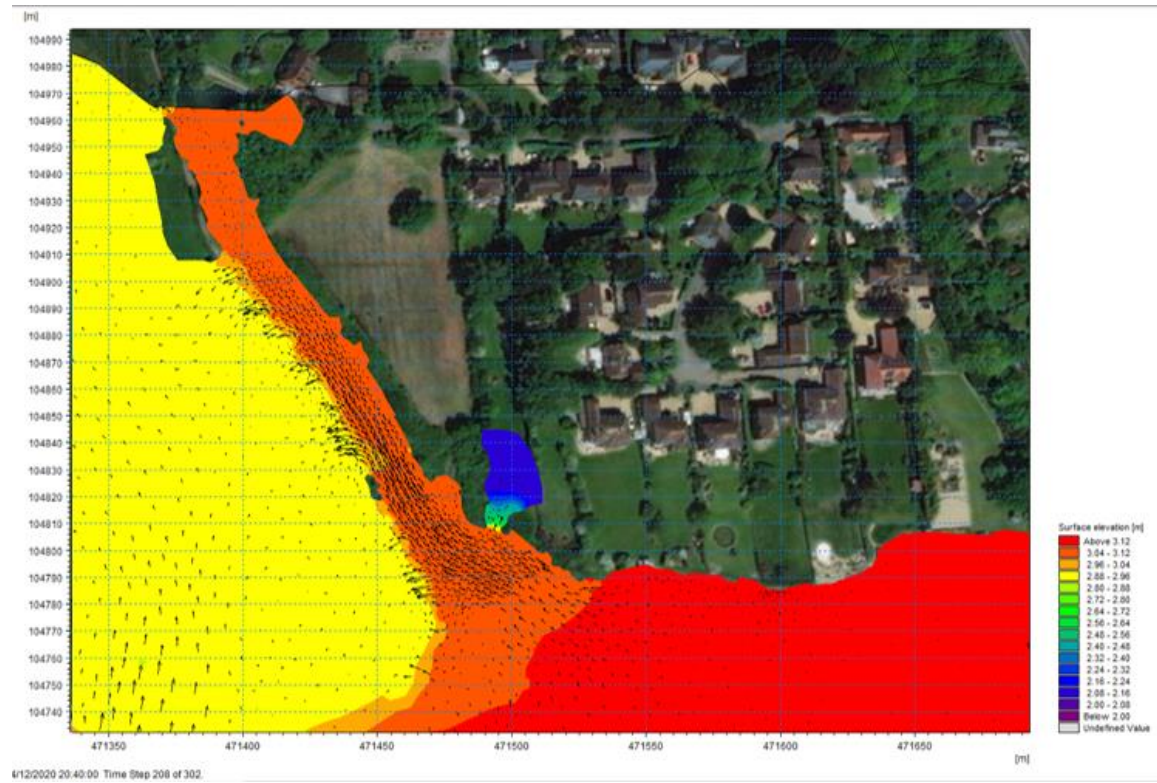


Tidal + Fluvial

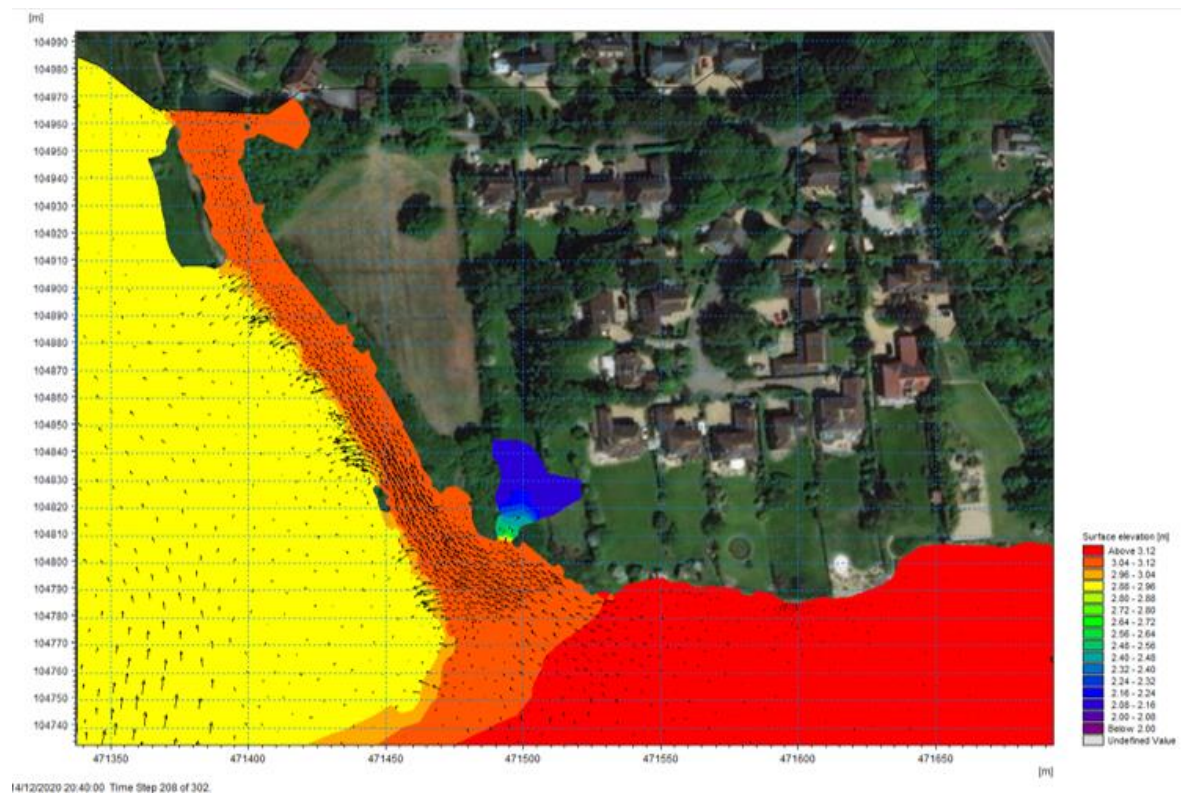


Timestep 208 (3.14m AOD)

Baseline

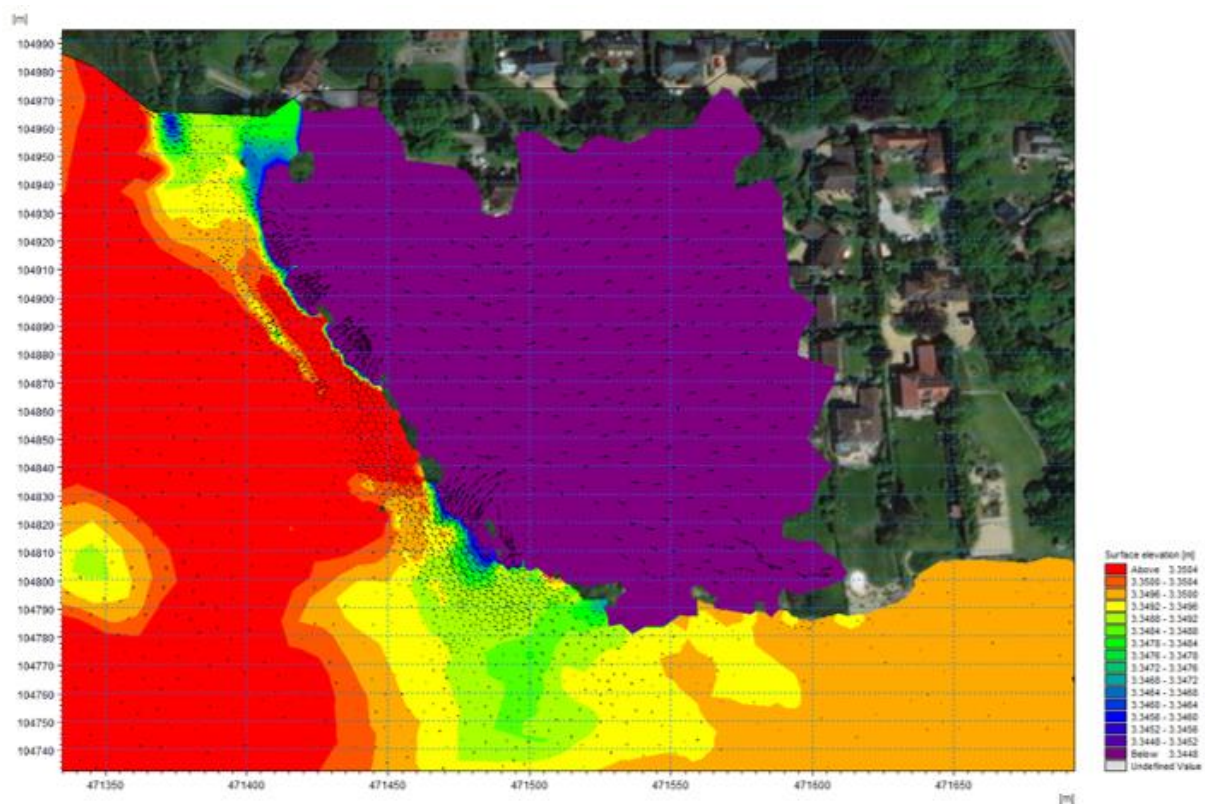


Tidal + Fluvial

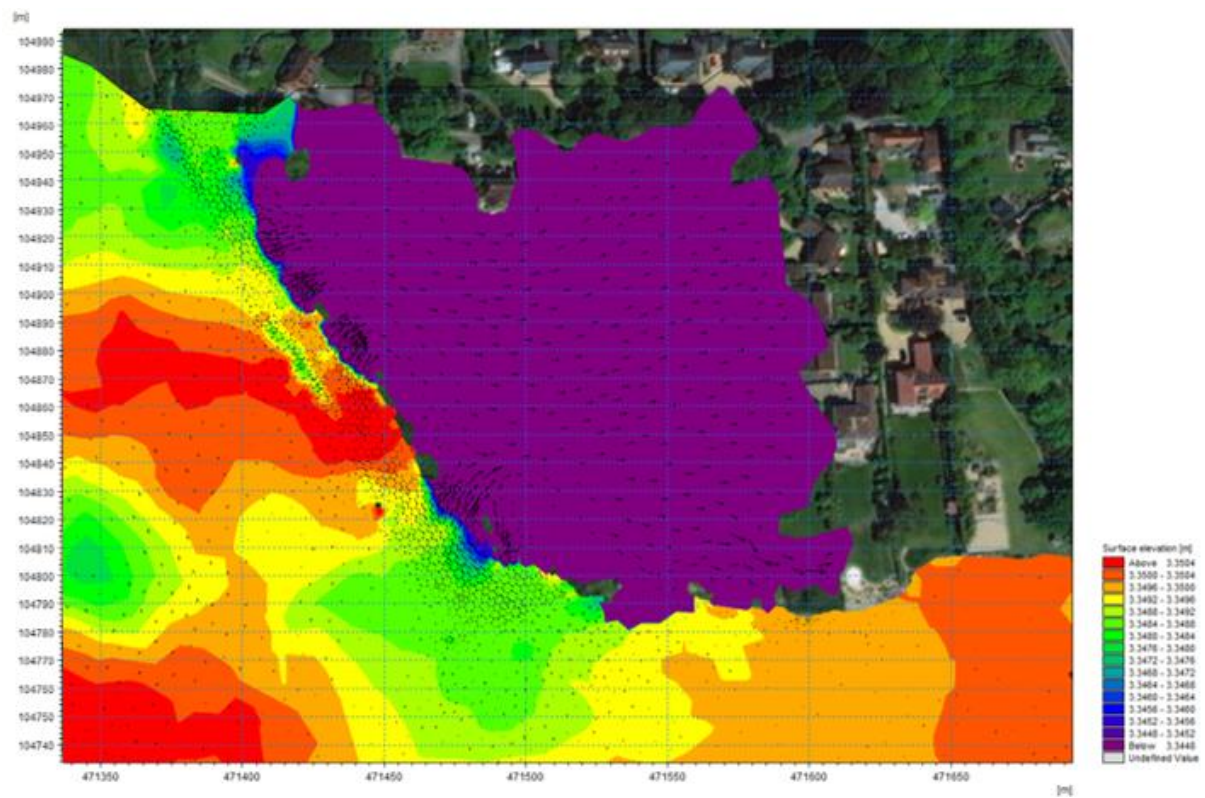


Timestep 210 (3.35m AOD)

Baseline

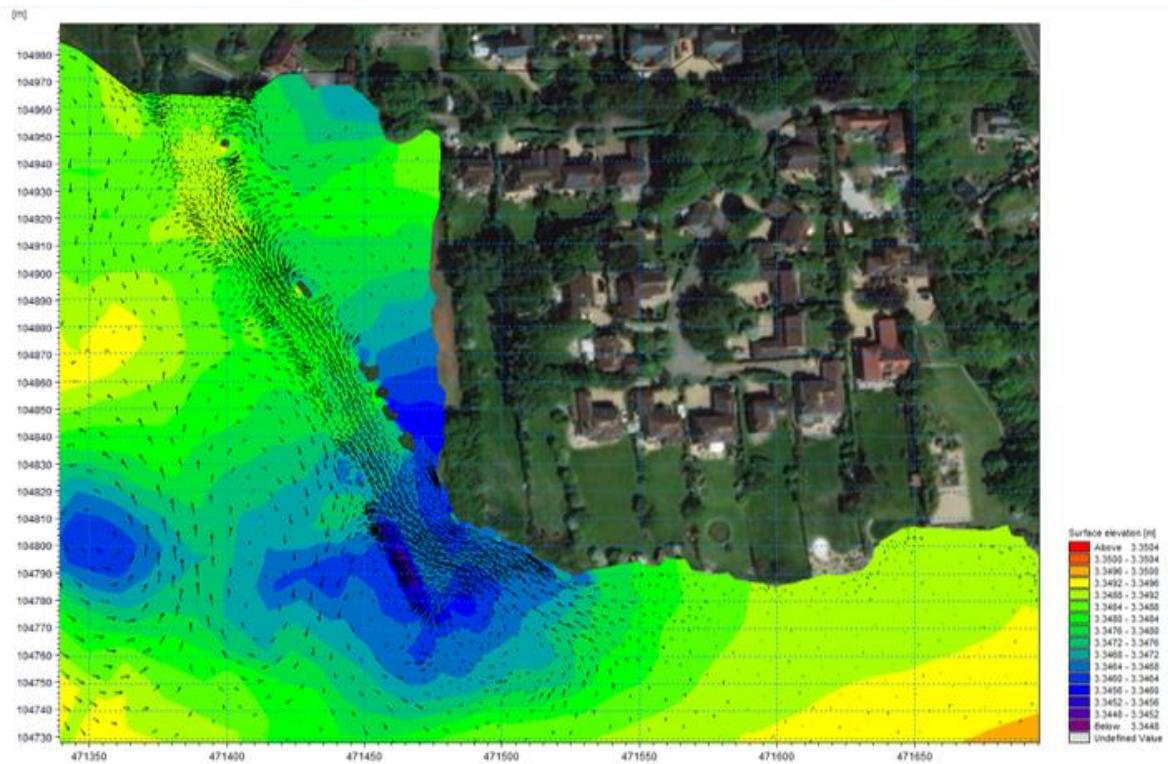


Tidal + Fluvial

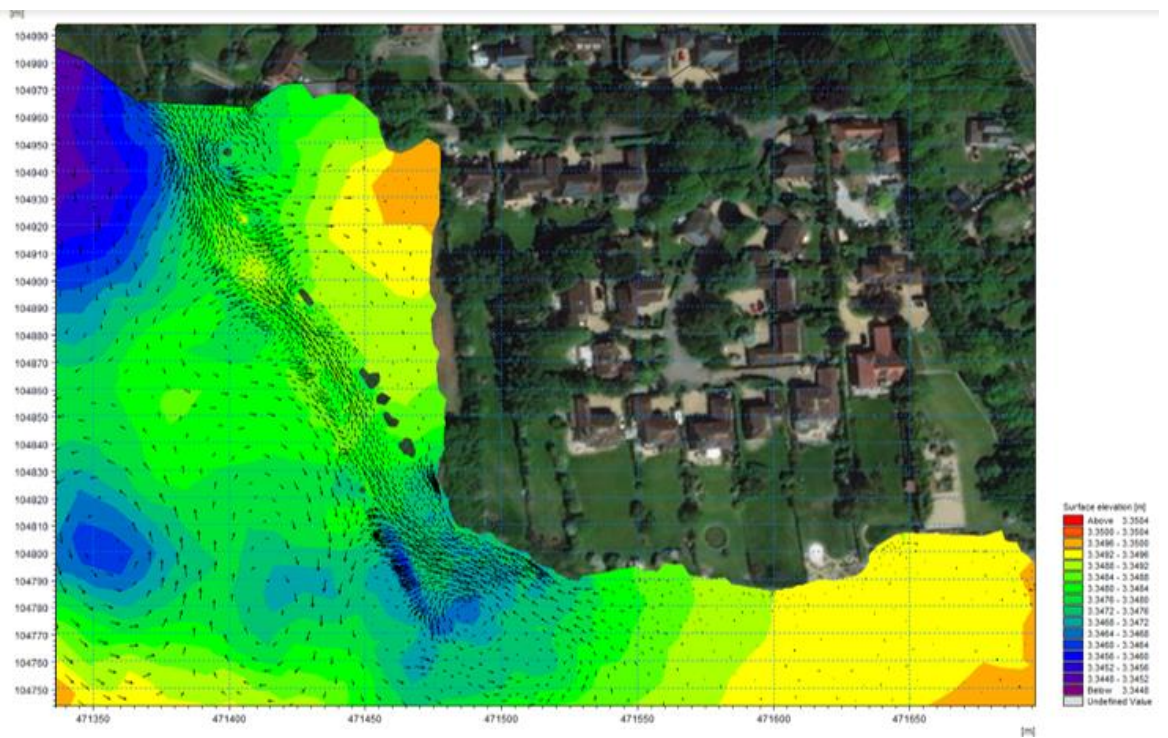


Defences Included

Baseline

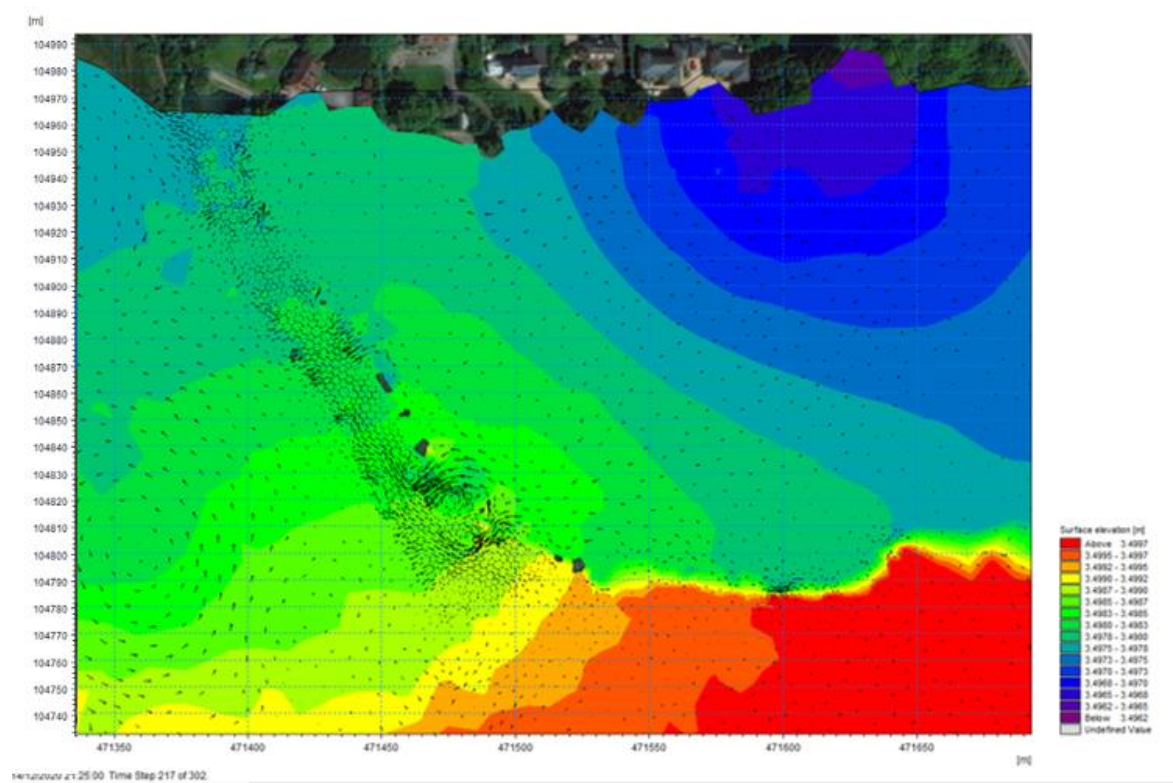


Tidal+Fluvial

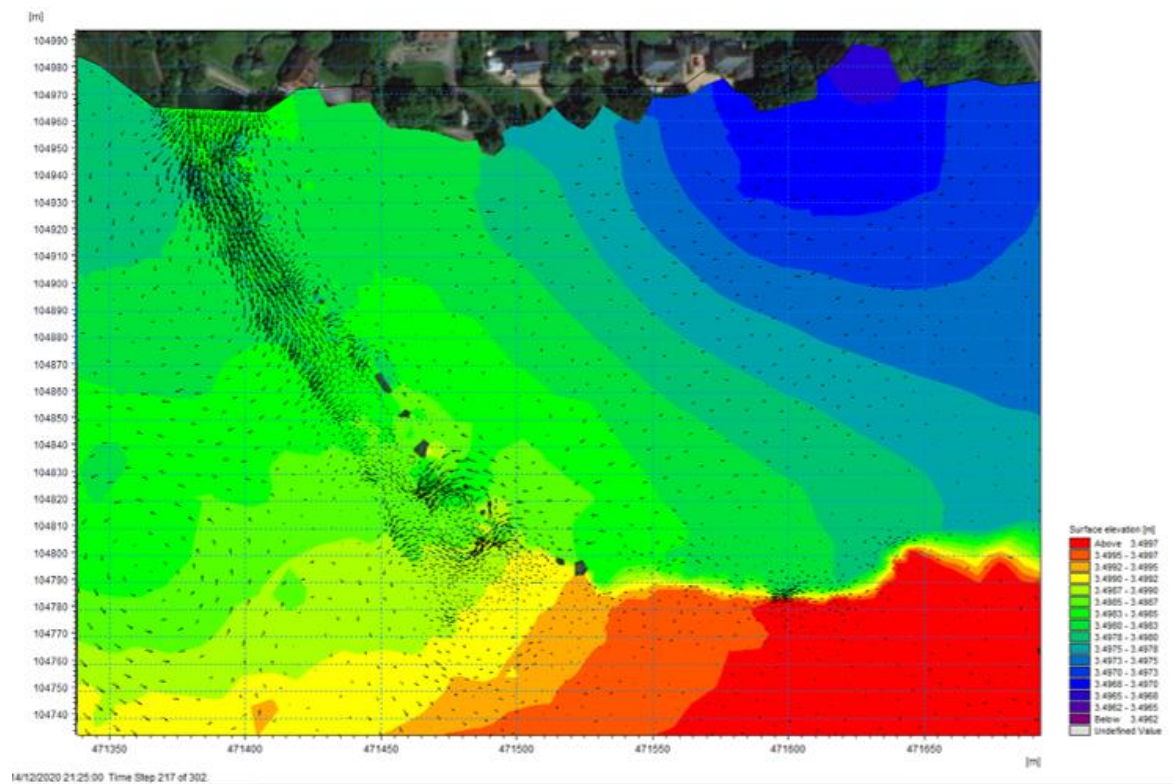


Timestep 217 (3.5m AOD Peak)

Baseline

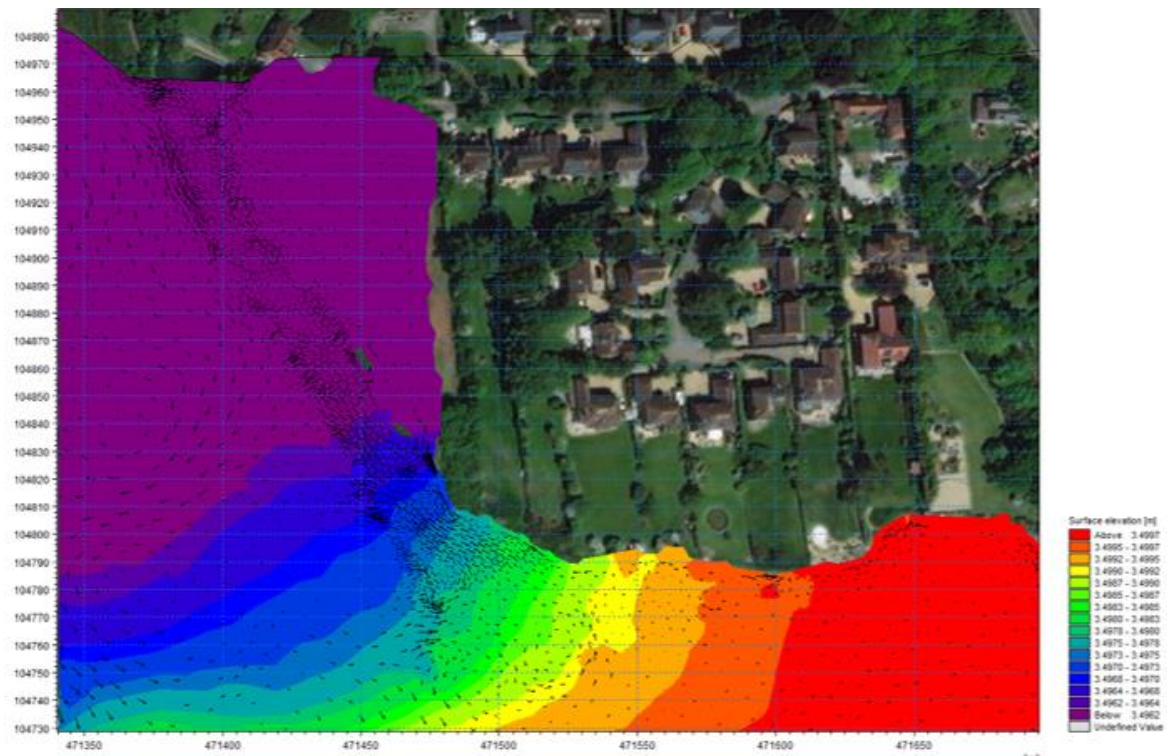


Tidal + Fluvial

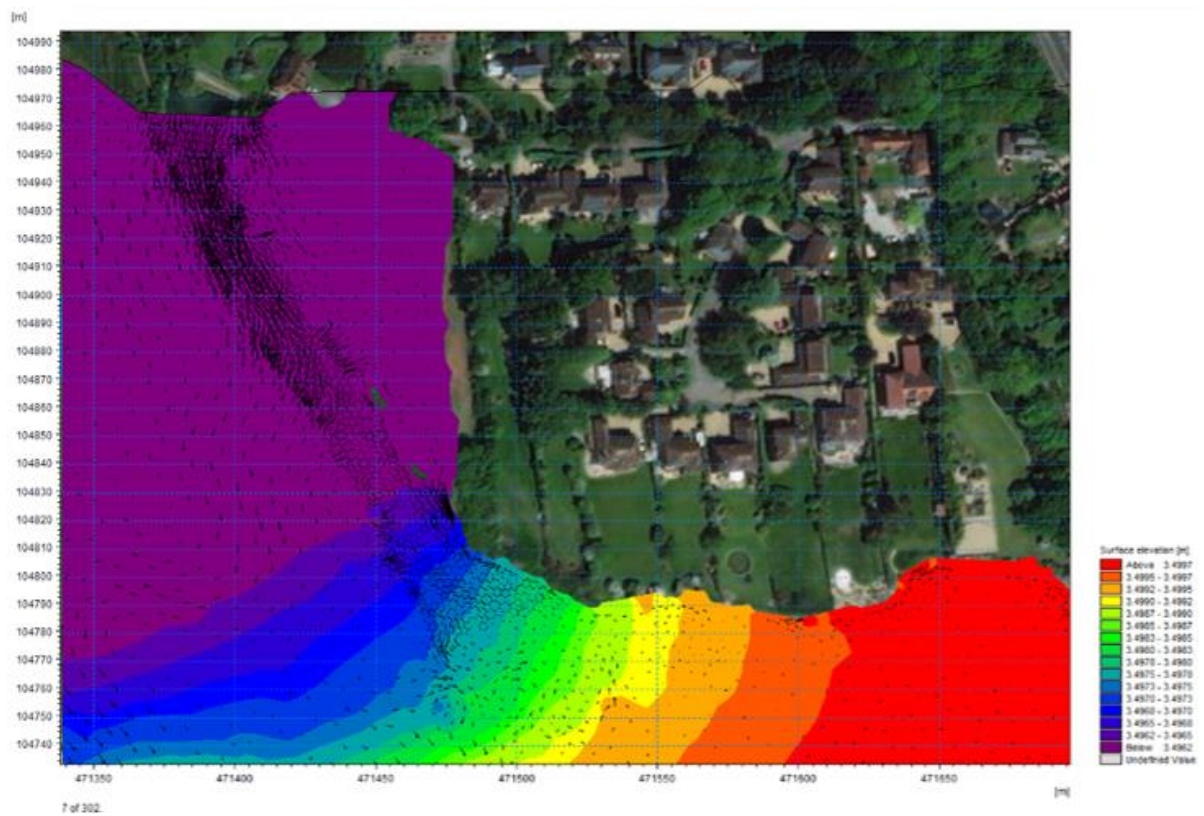


Defences Included

Baseline

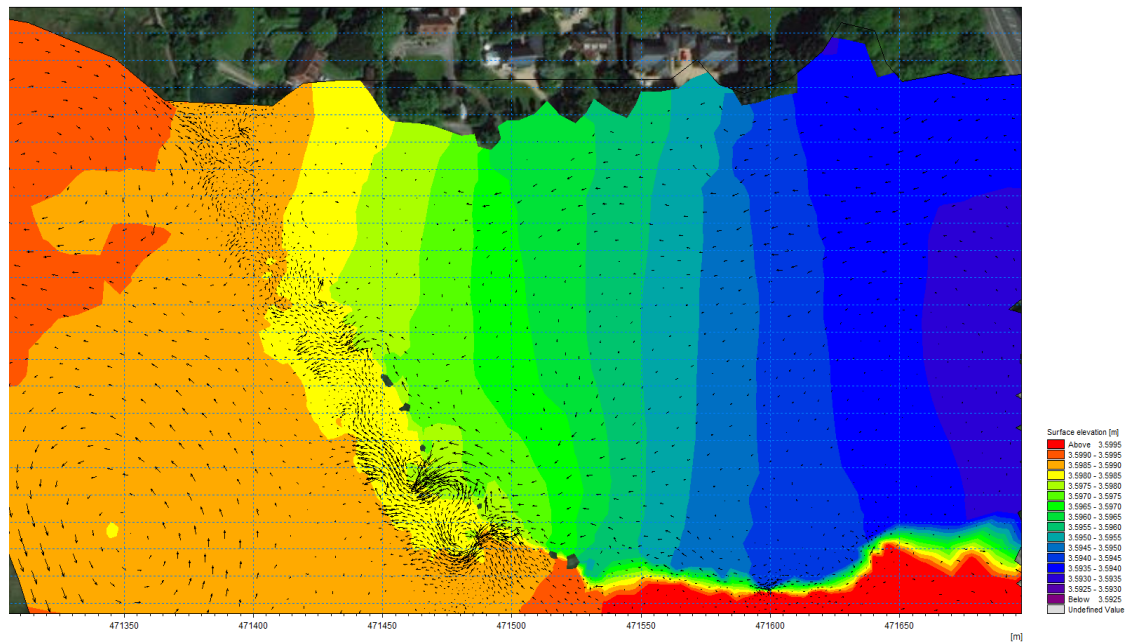


Tidal + Fluvial

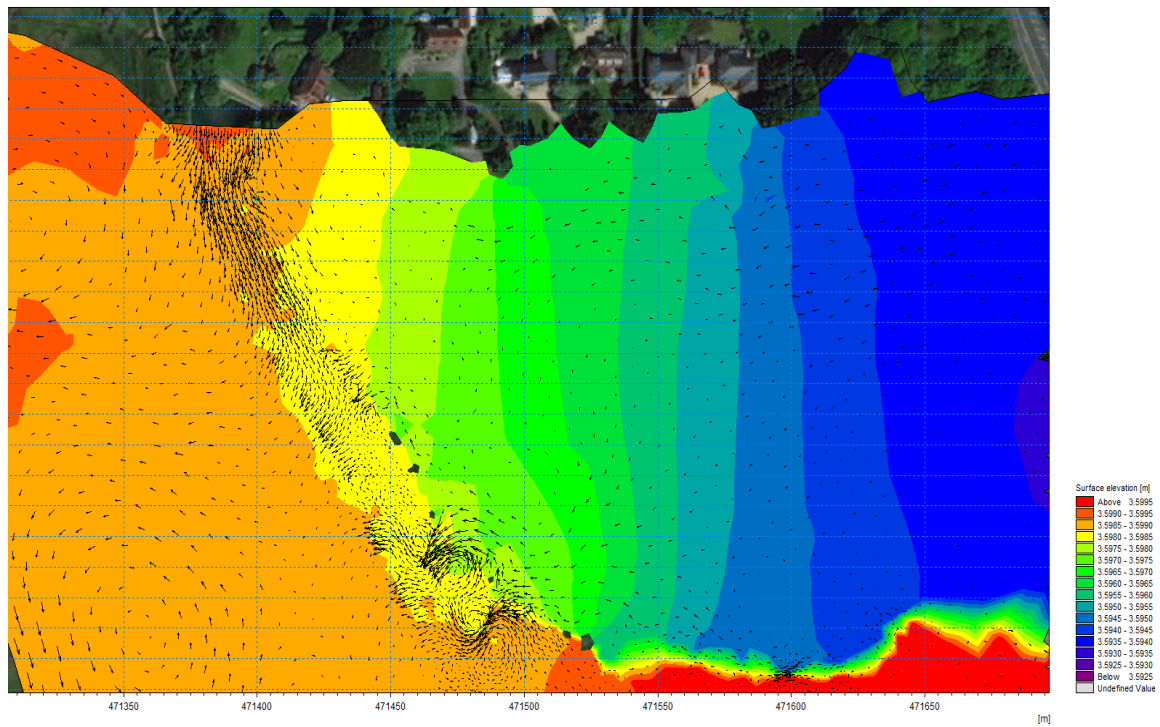


Timestep 216 (3.6m AOD Peak)

Baseline

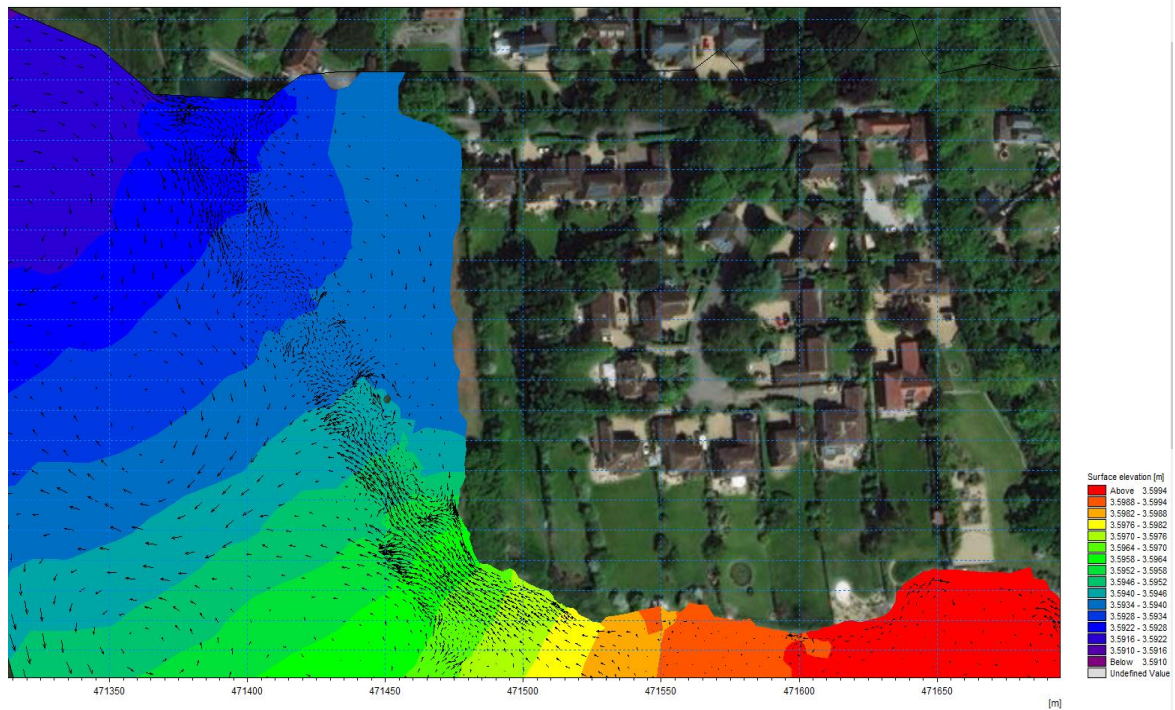


Tidal + Fluvial



Defences Included

Baseline



Tidal + Fluvial

