

Thurrock Council

Level 1 Strategic Flood Risk Assessment
Report Version 1

Appendix G: Tilbury FSR Sensitivity Analysis

Thurrock Council

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Executive Summary

Background

Thurrock Council has commissioned AECOM to undertake an update of their Strategic Flood Risk Assessment to ensure that it contains the most up to date assessment of flood risk from all sources. In accordance with the National Planning Policy Framework (NPPF) a Strategic Flood Risk Assessment (SFRA) should consider the cumulative impact of development on flood risk and identify opportunities to reduce the causes and impacts of flooding.

Planning policy relating to the approach to sustainable drainage systems (SuDS) is evolving quickly, with the initial findings of the latest government review¹ recommending that SuDS be mandatory to all new developments in England to reduce the risk of surface water flooding, pollution and help alleviate pressures on our traditional drainage and sewerage systems. Thurrock Council specifically have a need to understand the potential impact of future development in the West Horndon area and in the Mardyke catchment more generally, to determine the potential cumulative impact of development on flood risk in this area. Thurrock Council also consider it prudent to assess the cumulative impact of development around the Tilbury Flood Storage Reservoir (FSR) to demonstrate the need to preserve this asset.

Thurrock Council and AECOM have agreed a scope of services to undertake indicative modelling to better understand the potential cumulative impact of development on flood risk in these areas. The outcomes of the modelling will form part of the SFRA and may, where required, provide the necessary evidence to support the development of appropriate policies.

This report documents the sensitivity analysis undertaken for Tilbury FSR. It is anticipated that this will form an appendix to the updated SFRA, part of the technical evidence base, which will be used by Thurrock Council in the development of their Local Plan.

Integrated Catchment Modelling

Existing models of the Tilbury FSR and contributing catchment were reviewed to assess their usefulness for an assessment of the potential cumulative impacts from development in the catchment which may increase impermeable surfaces or encroach into the FSR area.

An updated hydraulic model of the Tilbury FSR and surrounding catchment area was then developed. This updated model represents the FSR in 2D (a significant difference from previous modelling) which means it is now possible to visualise how runoff fills the FSR and to map the predicted depth of flooding within it. It is then possible to see how the predicted depth and extent of flooding might change under different scenarios.

The baseline flood modelling and mapping is presented in this report for the 3.33%, 1% and 0.1% AEP design events. Storm duration testing was undertaken, and a 13-hour storm duration (summer profile) was identified as critical in the FSR area and adopted for the mapping and scenario testing.

Scenario testing was undertaken to identify the potential cumulative impact of future development on flood risk in the catchment in the event that future development increased the impermeable surfaces or included land raising.

Three sensitivity tests have been undertaken to represent different scenarios:

Scenario 1: 50% of the potential development site areas are assumed to be covered by impermeable surfaces.

Scenario 2: 90% of the potential development site areas are assumed to be covered by impermeable surfaces.

Scenario 3: One selected development site area is assumed to be raised by 700mm above existing ground level.

¹ Defra, 10th January 2023, Policy paper: Sustainable drainage systems review
<https://www.gov.uk/government/publications/sustainable-drainage-systems-review>

Summary of findings

The modelling results of Scenarios 1 and 2, identify that development which increases impermeable surfacing will result in increased flood depths within the FSR. The greater runoff generated could increase the depth of flooding in the FSRs by more than 0.1m which reduces the capacity of flood protection offered by the FSR.

Results for Scenario 3, demonstrate that development that includes land raising has the potential to displace floodwater and increase flood risk to existing neighbouring development.

It is therefore recommended that Thurrock Council implement policies that prevent land raising within the FSR. It is recommended that Thurrock Council retain the Flood Zone 3b designation in this area.

It is also recommended that Thurrock Council ensure that existing policies to restrict surface water runoff (to existing runoff rates and volumes) continue to be enforced for all potential development sites in the catchment and where possible opportunities are taken to reduce the surface water runoff.

1. Context

- 1.1.1 The Tilbury Flood Storage Reservoir (FSR) was constructed in 1972 following serious flooding that occurred in September 1958 and September 1968 as a result of intense rainfall. The FSR is designed to reduce flood risk to the town by storing water from the marshland and steep upstream areas. This provides time for runoff generated within the town to discharge into the Thames limited by pump capacity and prevailing tide locked conditions at the gravity sluice outfalls. The FSR is comprised earth embankments that run around the north side of the town.
- 1.1.2 The FSR is designated as a large, raised reservoir under the Reservoirs Act. It is composed of two components, the East FSR and the West FSR, separated by the A126. Outflow from the East FSR is controlled by Fort Road Sluice located on the Pincocks Trough Sewer immediately upstream of the railway line. Flow is regulated through the Fort Road Sluice based on the recorded water level on the Chadwell Cross Sewer in the culvert running underneath the town at Brennan Road. The West FSR drains freely by twin culverts under Dock Road.
- 1.1.3 The FSR provides a vital function for surface water management but is under pressure from new development in the area. In recent years there have been alterations to the FSR to accommodate new development. There is potential that the cumulative impacts of existing and proposed development could result in an increase in flood risk in Tilbury.
- 1.1.4 The existing model of Tilbury FSR has been used to assess the impact on flood risk in the rest of the catchment if new development increases runoff in the catchment or encroaches into the FSR through land-raising.
- 1.1.5 This modelling provides Thurrock Council with an indication of what the flood risk impacts could be if all the potential development sites came forward, resulting in an increase in runoff towards the FSR or a loss of volume in the FSR.

2. Existing models

- 2.1.1 The Environment Agency provided two existing models that included the Tilbury FSR from previous studies.
- FMP-TUFLOW Model, (Mott MacDonald, April 2015, Tilbury Flood Storage Reservoir Study Phase 1 Final Report)
 - InfoWorks ICM Model (JBA Consulting, January 2017, Tilbury Integrated Flood Strategy PS/2015/994).
- 2.1.2 Both models had taken a similar 1D approach to representing the Tilbury FSR, using a stage-area storage relationship.
- 2.1.3 Originally, it was considered whether there was a way that the 1D representation of the FSR could be adjusted, to represent possible increases in runoff or encroachment from development to assess potential flood risk impacts. However, it was decided that it would be preferential to adapt the models so that the storage was represented in 2D, so that the baseline flood risk and potential impacts could be better visualised as flood extents and depths.
- 2.1.4 Furthermore, modifying the model in this way provided a method for addressing some of the issues noted during review of the existing model, which limited confidence in the use of the model(s) as they were for the purposes of this assessment.
- 2.1.5 The model updates described here are considered the essential elements necessary to have confidence in the model for this strategic assessment.

3. Baseline model update

- 3.1.1 Table 3-1 shows the updates made to the existing Environment Agency InfoWorks ICM model of Tilbury FSR for this project, including the replacement of the previous application of rainfall via sub-catchments with a rain-on-mesh method. The main update relevant to this SFRA is the new representation of the FSR within the 2D mesh using the latest available LiDAR DTM to define the topography.
- 3.1.2 This 2D approach to representing the FSR provides a mechanism for adjusting runoff coefficients to represent development in the catchment and provides greater flexibility for representing alterations to the topography (and volume) of the FSR. The 2D approach allows for easier visualisation of the model results and of the impacts of increased runoff towards the FSR or encroachment into it.

Table 3-1 Key updates to InfoWorks ICM model

Updates made	Assumptions / limitations
The representation of flood storage reservoir (FSR) has been changed from 1D to 2D. To facilitate this change, the extent of the 2D mesh has been increased to cover the entire catchment including FSRs (including parts previously represented in 1D only). Figure 3-1 shows the differences between the previous and new extent of the 2D mesh. To change to a 2D approach for representing the FSR, the previous 1D representation of the FSR was entirely removed from the model, including all associated inline banks connected to the river reaches and outfalls and weirs. 1m resolution LiDAR DTM (Digital Terrain Model) data flown in 2020 was used for the 2D mesh.	
OSMM (Ordnance Survey MasterMap) data was used to define land use types across the 2D mesh for applying roughness values and fixed runoff coefficients via roughness zones (RZ) and infiltration zones (IZ), respectively. The Manning's roughness values and runoff coefficients are based on the standard guidance² and are shown in Table 3-2. In consultation with Thurrock Council, the roughness and infiltration zones for the baseline model were altered from those initially derived from the OSMM at two locations where new development has already occurred, see Figure 3-2. Figure 3-2 shows where the roughness and infiltration zones were modified by polygons representing the buildings and roads in the new developments. The same roughness values and runoff coefficients used for roads and buildings in the existing model were used to represent the new features.	The roughness values and fixed runoff coefficients for different landuse types are based on previous experience and are applied to Roughness Zones (RZ) and Infiltration Zones (IZ), respectively.
The maximum triangle area (100m²) and minimum element area (25m²) has not been changed from the previous study, but the maximum height variation has been reduced from 1m to 0.25m to increase mesh definition, especially representation of the drains in the FSRs. The finer resolution mesh zone (MZ) applied in the previous study for Tilbury has been deleted and the porous polygons previously used to represent the threshold of buildings (raised by 0.1m above ground level) have been deleted from the model. For this modelling, buildings, roads, railways, and drains (feature codes 10021, 10172, 10167 and 10089) have been forced to align with the mesh. Mesh level zones (MLZ) have been used to digitise the open watercourses on main flood routes only, and within the storage reservoir (including the ditch network within the storage reservoir)	Any smaller elements less than 0.1m² are removed by adjusting the geometry in RZ, MZ, MLZ. Mesh resolution could be further improved by modelling in a finer resolution (e.g. drains, roads, buildings, and railway) but this is not considered essential for this strategic modelling. Away from the main flow routes / areas of interest, roughness zones have been used in the mesh to represent watercourses.
Rainfall is applied to the whole of the 2D mesh area (previously direct-to-mesh rainfall was only used outside of the sub-catchments linked to the 1D network). Runoff coefficients have been applied in the infiltration zones (IZ) to account for rainfall losses.	
Tidal boundaries are applied where the network discharges into the River Thames (Botney Outfall, Hotel Gardens Outfall and Worlds End Gravity Outfall). At other locations where there are network outfalls, normal depth boundaries are applied.	These boundary assumptions are in line with assumptions made in the existing model and appropriate for a direct rainfall model like this.

² http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Mannings_n_Tables.htm

Updates made

1D network – The representation of the stormwater network has not been significantly changed from the previous model except where some model updates were considered essential for model stability or confidence before it was used for the strategic assessment:

- Where there were parallel pipes with the same pipe dimensions and inverts, this has replaced by a single pipe with 2 barrels;
- Sub-catchments connected to the gullies and manholes, and to Infiltration Zones (IZ) on roads have been deleted. The previous method of rainfall application has been replaced with a direct rainfall (rain-on-mesh) approach across the whole 2D area, using OSMM to identify landuse types for the application of runoff coefficients;
- The ground level of all nodes in the 2D zone has been updated to match the ground level in 2D mesh (this is to reduce the risk of model instability resulting from discrepancies in model topography);
- Manholes connected to the gullies have been marked as 'sealed'. Therefore, water can only flow through gullies to enter and exit the drainage network;
- Where there are of no gullies, the flood type of 'Stored' manholes has been changed to 'Gully 2D' and a HQ curve (assuming 2 gullies) has been applied based on the shaft plan area of the manhole to allow for a 1D/2D connection in the model;
- An 'Outfall' node type has been applied wherever the network appears to be unconnected to the main surface water network in the model and cannot be discharged directly to the surface water due to significant differences between the ground elevations and pipe inverts. At these outfalls, normal depth boundaries have been applied;
- As noted above, all 1D model elements previously used to represent the FSRs have been deleted (now represented in 2D); and
- The 1D-2D linkage has been changed to 'Depth' wherever applicable to avoid oscillations and model instabilities.

Assumptions / limitations

The previous model setup of applying rainfall through sub-catchments passing flows from the rural areas to the network seems to overwhelm the pipes. The model review for this assessment considered that this was likely to result in an over-estimate of the flow reaching the network and therefore an over-estimate of the modelled water levels in the pipes.

There are some residual limitations of the modelling after these updates;

- There appear to be structures missing on surface flow paths underneath the embankment, and
- The urban area does not appear to be not completely covered by the drainage network.

Neither of these limitations prevent the model being used for this strategic assessment of impacts on the FSR.

1D River Reach – The representation of the stormwater network has not been significantly changed from the previous model except where some model updates were considered essential for model stability or confidence before it was used for the strategic assessment:

- Where the model needs to represent a transfer of flow from a 1D river reach to the 2D mesh, the existing 1D spill units have been deleted and replaced with inline banks. The levels for the inline banks have been assigned based on inspection of the 1m DTM data (at every 10m interval). A discharge coefficient of 1 and a modular limit of 0.9 have been used on the inline banks;
- The modular limit for the river reach bank lines have been changed to 0.6;
- Conveyance within the river sections has been smoothed at a few locations by adding panel markers to improve model stability.

Hydrology –

The change in model setup to a 2D representation of the FSR for this assessment requires rainfall hyetographs of various storm durations to be applied directly to the mesh elements within the surface model. FEH 2013 rainfall data was used to estimate rainfall depths for the 3.33%, 1% and 0.1% AEP events, for the 3-hours, 9-hours, 13-hours, and 15-hours storm durations. ReFH2.3 was then used to generate the storm profile (hyetograph) with a summer storm profile shape selected because most of the catchment is urbanised.

Critical storm duration testing was undertaken, given the significant changes to model schematisation from previous work. The critical storm duration selection undertaken here is specific for this SFRA modelling. Any future studies using this model should re-consider the selection of critical storm duration, especially if/when any

Updates made

For this study, a set of catchment descriptors was purchased from the FEH web service at the 4 outfall locations at the River Thames (outfall co-ordinates shown in Table 3-3). The total area of the 4 catchments is 13.88km² with a Standard Average Annual Rainfall (SAAR) of 546mm. A single design event rainfall hyetograph has been applied across the whole model, using catchment descriptors averaged from the four outfall catchments. Areal and seasonal reduction factors were different for different storm durations.

The total rainfall depths for all the AEP events and storm durations are summarised in the Table 3-4. The typical hyetographs for the summer season 13-hour storm duration for all the three AEP events are shown in Figure 3-4.

Assumptions / limitations

other structures have been added to the model or if there is a different focus to the assessment.

In the present study, the summer season storm profile was selected based on the urbanisation of the catchment. A winter storm profile simulation has not been undertaken for comparison.

Figure 3-1 Updated Model Schematic

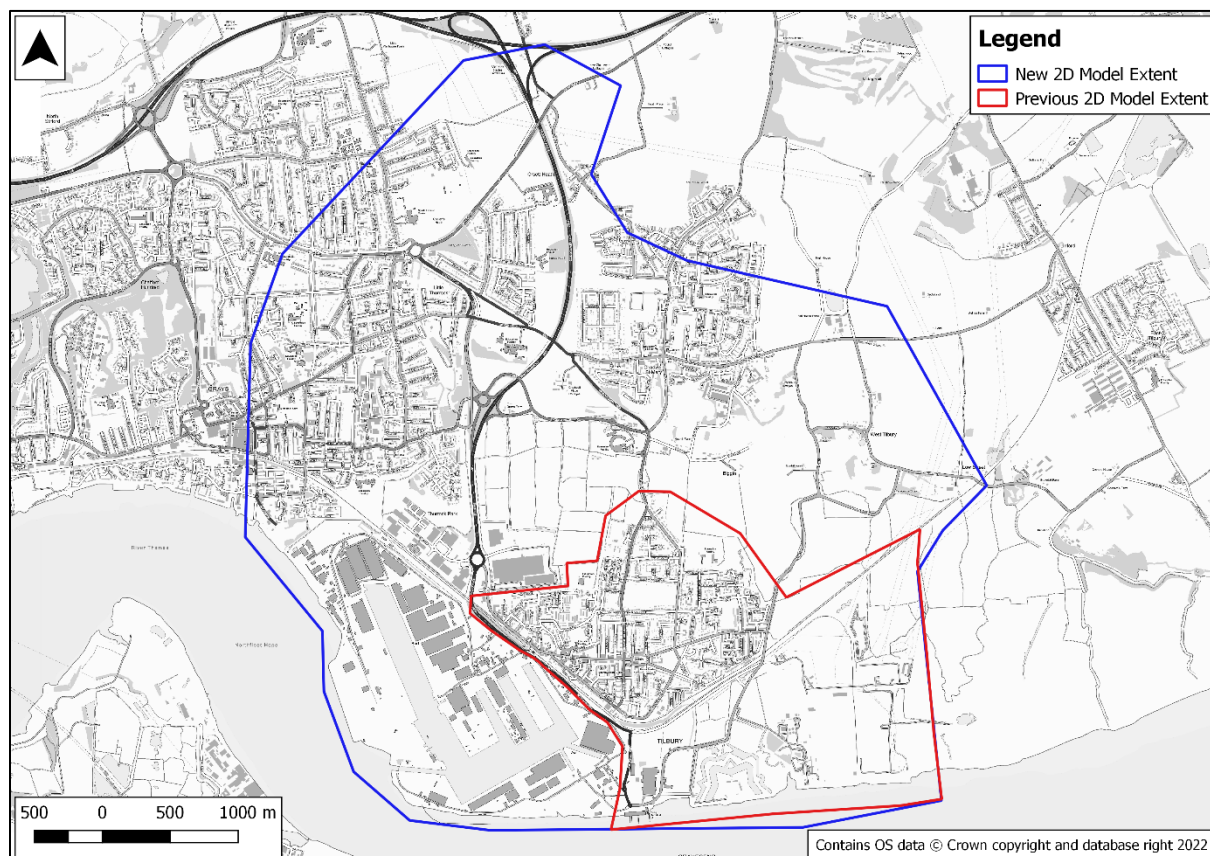


Figure 3-2 Refined Roughness and Infiltration Zones for new development

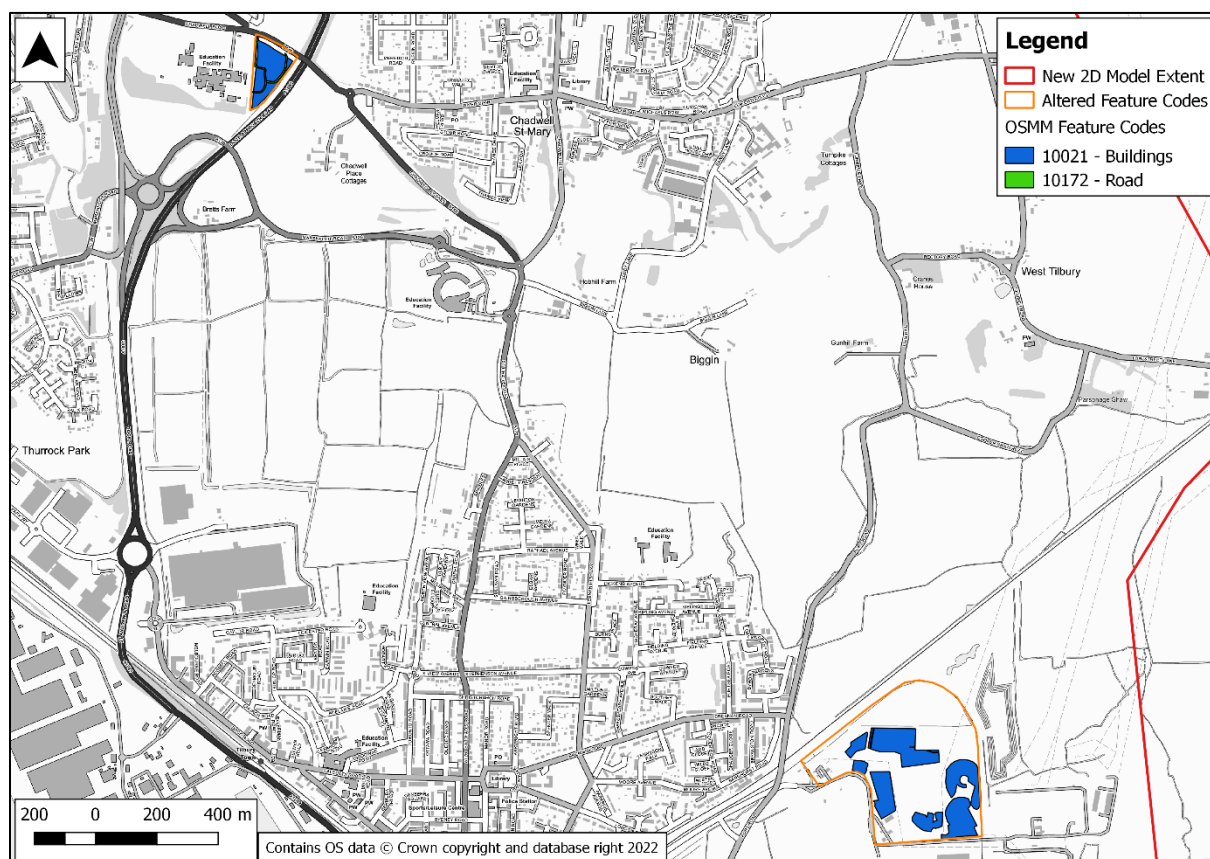


Table 3-2 Manning's 'n' and Runoff Coefficients, assigned by OSMM landuse type

Feature Code	Landuse Type	Manning's 'n'	Runoff Coefficient	Type of Surface
10021	Building	1	0.9	Impermeable
10053	General Surface (Multi Surface)	0.05	0.5	Impermeable
10054	General Surface (Step)	0.025	0.8	Impermeable
10561	General Surface (Grass, parkland)	0.035	0.2	Permeable
10562	General Surface (Manmade)	0.025	0.85	Impermeable
10062	Glasshouse	1	0.9	Impermeable
10089	Inland Water	0.02	1	Impermeable
10096	Landform (Slope)	0.05	0.4	Impermeable
10099	Landform (Cliff)	0.05	0.4	Impermeable
10111	Natural Environment	0.07	0.2	Permeable
10119	Path (Step)	0.025	0.85	Impermeable
10123	Path	0.025	0.75	Impermeable
10167	Rail	0.035	0.35	Permeable
10172	Road or Track	0.025	0.85	Impermeable
10183	Roadside	0.025	0.85	Impermeable
10185	Structure	0.025	1	Impermeable
10203	Tidal Water (Foreshore)	0.02	1	Impermeable
10210	Tidal Water	0.02	1	Impermeable
10217	Unclassified	0.025	0.85	Impermeable

Figure 3-3 Combined Catchment

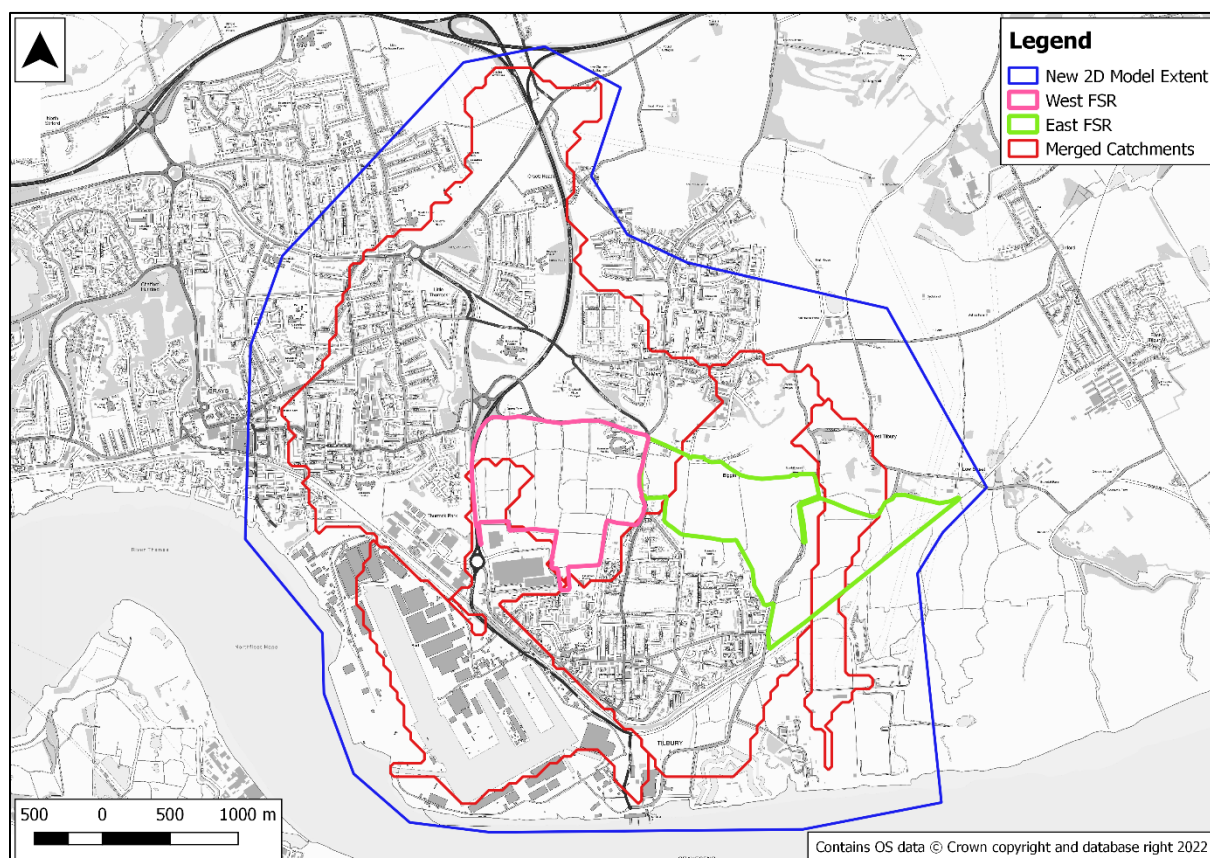


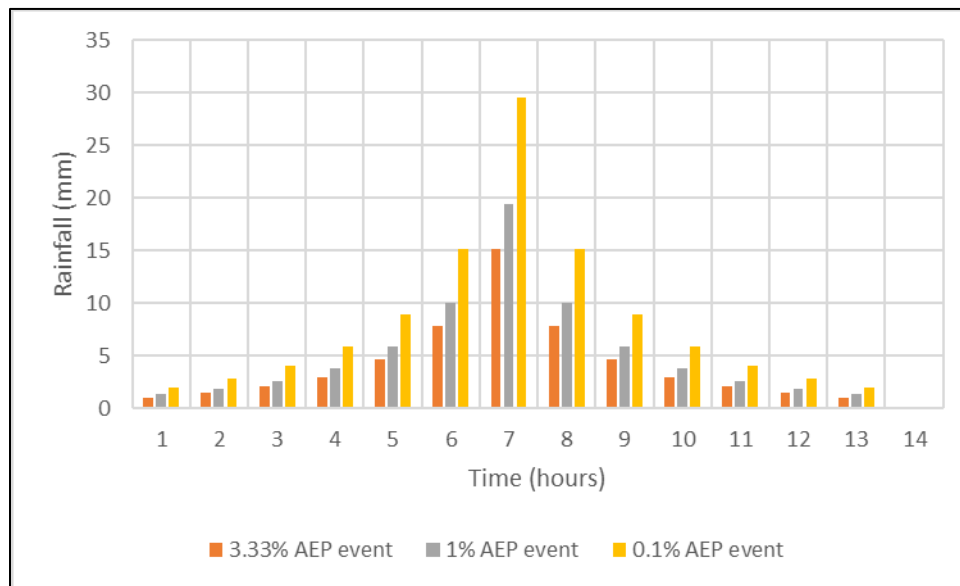
Table 3-3 Outfall coordinates

NGR (National Grid Reference)	Easting	Northing
TQ 62050 77250	562050	177250
TQ 64350 75300	564350	175300
TQ 64800 75450	564800	175450
TQ 65800 75500	565800	175500

Table 3-4 Total rainfall depths (FEH2013 DDF model)

Storm duration	Total rainfall depths in mm for AEP events		
	3.3%	1%	0.1%
3hr	37.51	50.16	83.11
9hr	50.39	65.43	101.30
13hr	55.12	70.69	107.23
15hr	57.02	72.76	109.55

Figure 3-4 13hr storm duration total rainfall depths (summer storm profile)



4. Modelled Events and Scenarios

- 4.1.1 The model has been simulated for the events and scenarios shown in Table 4-1.
- 4.1.2 Four 1% AEP runs were simulated for different storm durations to identify a suitable critical storm duration for the strategic assessment of impacts on the FSR. The 13-hour storm duration (summer profile) was identified as critical in the FSR area and adopted for the mapping and scenario testing.
- 4.1.3 The sensitivity testing scenarios for the strategic assessment of impacts on the FSR were then simulated for 3.33%, 1% and 0.1% AEP design events using the 13h storm duration only.

Table 4-1 Modelled Events and Scenarios

Scenarios/Events	Baseline	Scenario 1	Scenario 2	Scenario 3
3.33%, S13hr	√	√	√	√
1%, S13hr	√	√	√	√
0.1%, S13hr	√	√	√	√
1%, S03hr	√			
1%, S09hr	√			
1%, S15hr	√			

5. Model Performance and Results

5.1 Model Performance

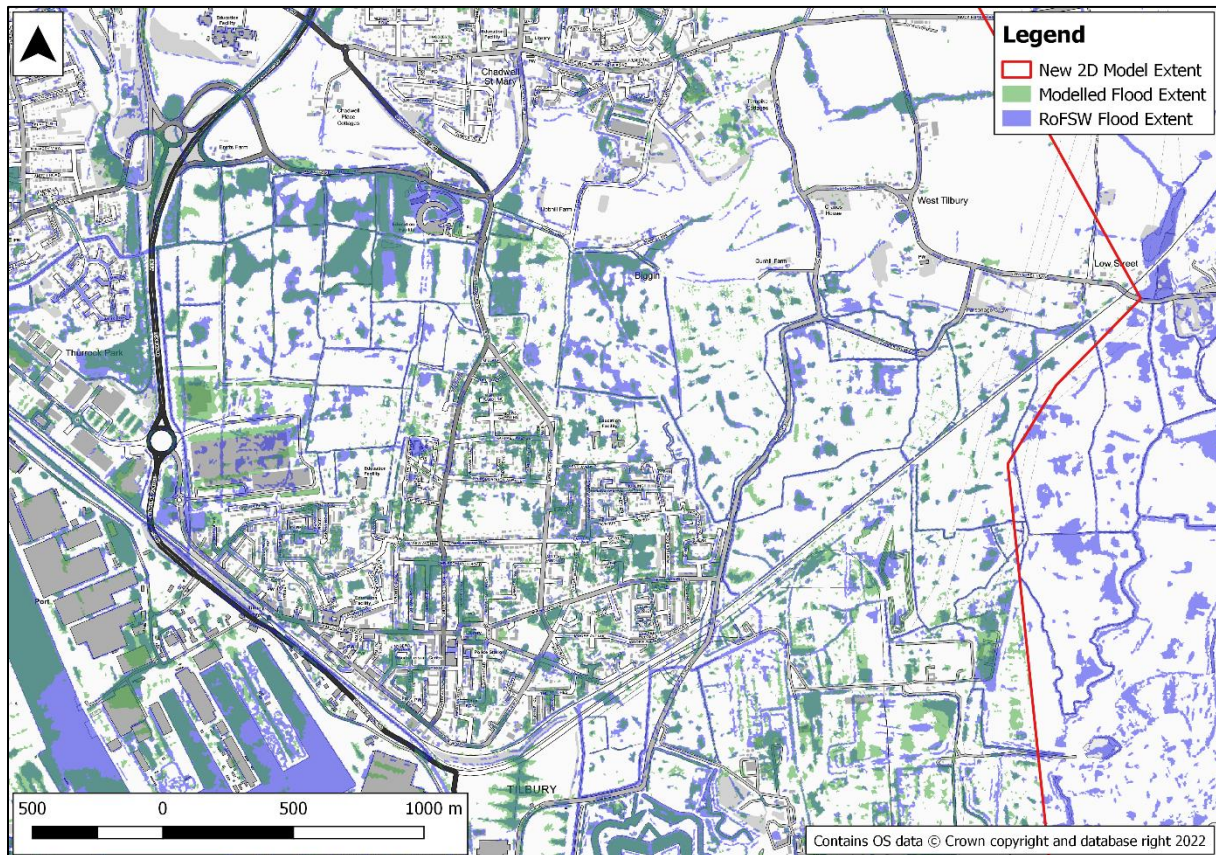
- 5.1.1 For 1D-2D models, InfoWorks ICM software developers³ recommend the Volume Balance Error Percentage (VBEP) should be within +/-5% for a model to be considered 'healthy'. The numerical performance of the updated model has been checked for all the AEP events and the model Log Results show that the VBEP is within +/-5%, except for the 0.1% AEP event for Scenario 2. For example, for the 1% AEP event simulated for a 13-hours storm duration (summer profile), a VBEP of -0.85% was achieved for the baseline scenario.
- 5.1.2 Additionally, the node results grid was checked for maxima error, and it was observed that there were a small number of model nodes where the Volume Balance (%) was greater than +/-1% for all the AEP events. This is not considered a significant limitation on the use of this model for the strategic assessment because the volumes (m³) in those nodes are less than 1m³ for all the AEP events.

5.2 Model Verification

- 5.2.1 There is limited information available on historical flood events and there was not sufficient data to calibrate the model to previous flood events.
- 5.2.2 The model was verified against the Environment Agency Risk of Flooding from Surface Water (RoFSW) map.
- 5.2.3 Figure 5-1 shows the comparison of flood extents between the new model and RoFSW for the 1% AEP events. The nature of the modelled flood extent in this area (in both the new model results and the Environment Agency RoFSW mapping) is non-continuous and shows small areas of surface water flooding rather than large or connected areas. Therefore, it is not easy to make a direct comparison between the two.
- 5.2.4 Within the model extent, areas predicted to be at risk of flooding in the new model generally align with the areas at risk of flooding on the Environment Agency RoFSW map. The Environment Agency RoFSW map shows areas at risk of flooding that are not predicted from the new model but this is likely due to the fact that the modelling which generated the RoFSW map did not have any representation of the sewer network, nor any representation of the recently developed sites.

³ <https://www.innovyze.com/en-us/blog/troubleshooting-hydraulic-models-in-infoworks-icm>

Figure 5-1 Modelled and RoFSW Flood Extents comparison for 1% AEP event



5.3 Baseline Model Results

- 5.3.1 Figure 5-2 to Figure 5-4 show the maximum flood depths for 3.3%, 1%, and 0.1% AEP events (13-hours critical storm duration) for the entire model extent for the baseline scenario.
- 5.3.2 Flooding is shown in the FSRs in the 3.3% AEP event, but this is not a continuous area of inundation, and the flooding is generally shallow. The surface water flooding is typically accumulating in shallow depths in pockets of lower lying land within the model extent and in the FSR.
- 5.3.3 As expected, the depths and extents of flooding are greater in the higher magnitude event. In the 0.1% AEP event, some of the smaller pockets of flooding 'join' to create larger continuous areas predicted to be at risk of surface water inundation.

Figure 5-2 Maximum Flood Depths for 3.3% AEP event (Baseline)

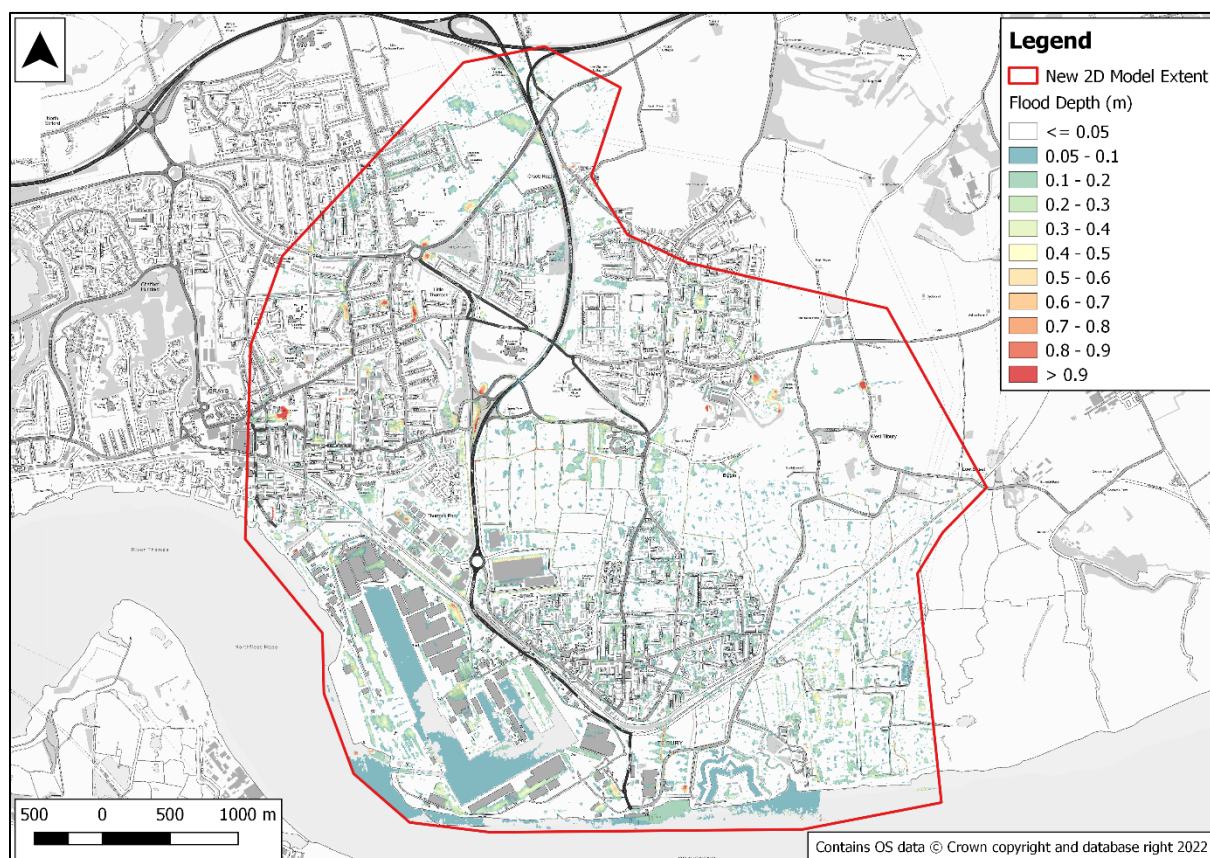


Figure 5-3 Maximum Flood Depths for 1% AEP event (Baseline)

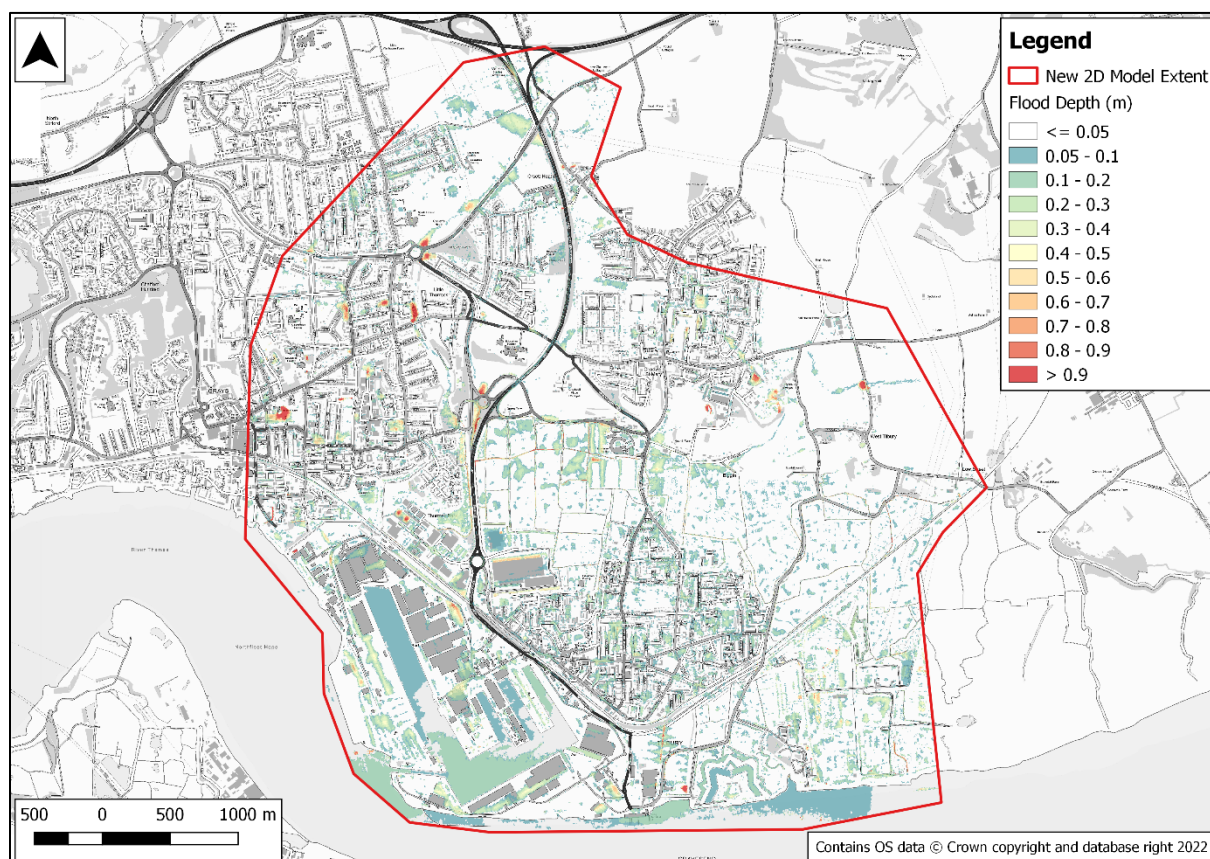
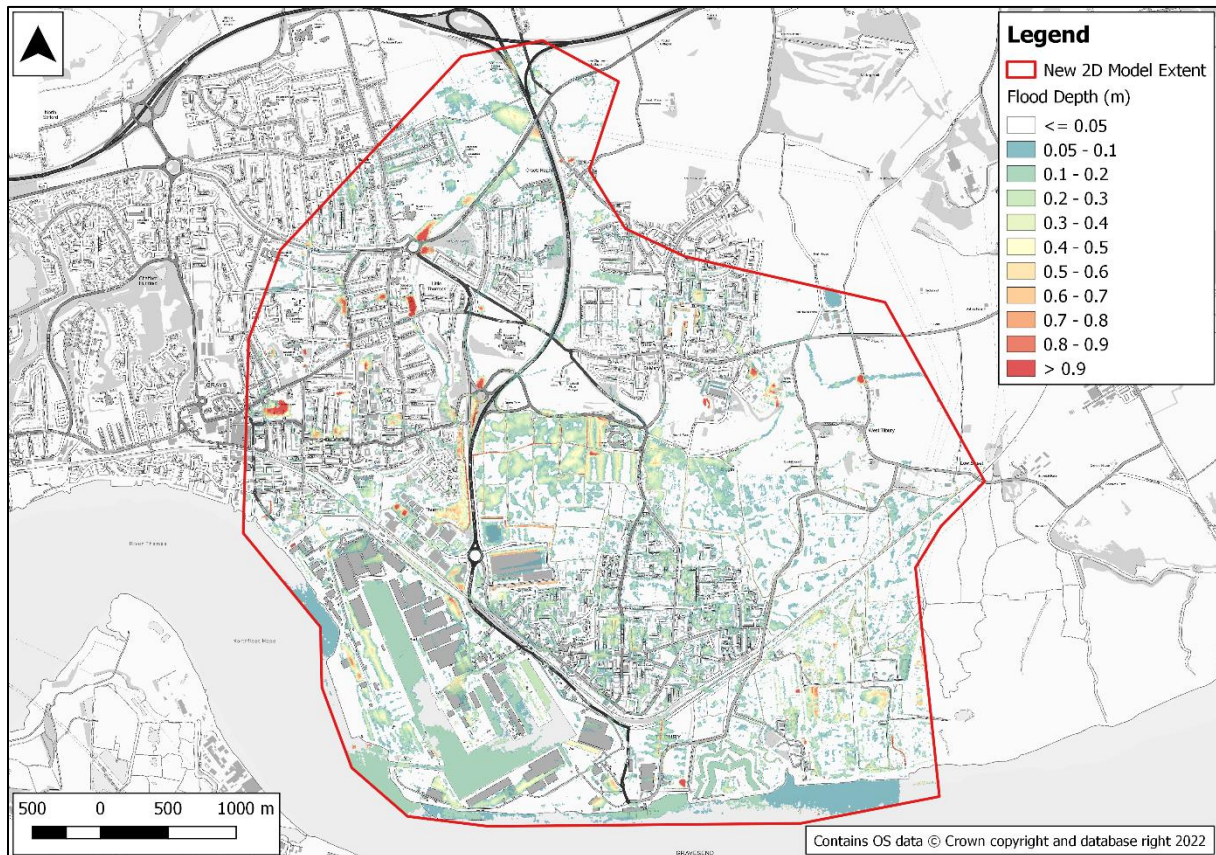


Figure 5-4 Maximum Flood Depths for 0.1% AEP event (Baseline)



- 5.3.4 Figure 5-5 shows the surface water flood mechanisms in more detail in the two FSRs and Tilbury area for the 0.1% AEP event (13-hours storm duration).
- 5.3.5 The blue arrows show a general flow direction of north to south, towards the River Thames. The model results do not show a continuous extent of flooding across the FSR (flooding is shown when depths are greater than 0.05m). Deeper areas of flooding are predicted on areas of land that are slightly lower in elevation, i.e., local depressions.

Legend

New 2D Model Extent

Flood Depth (m)

- <= 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- > 0.9

500 0 500 1000 m

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6. Scenario Modelling

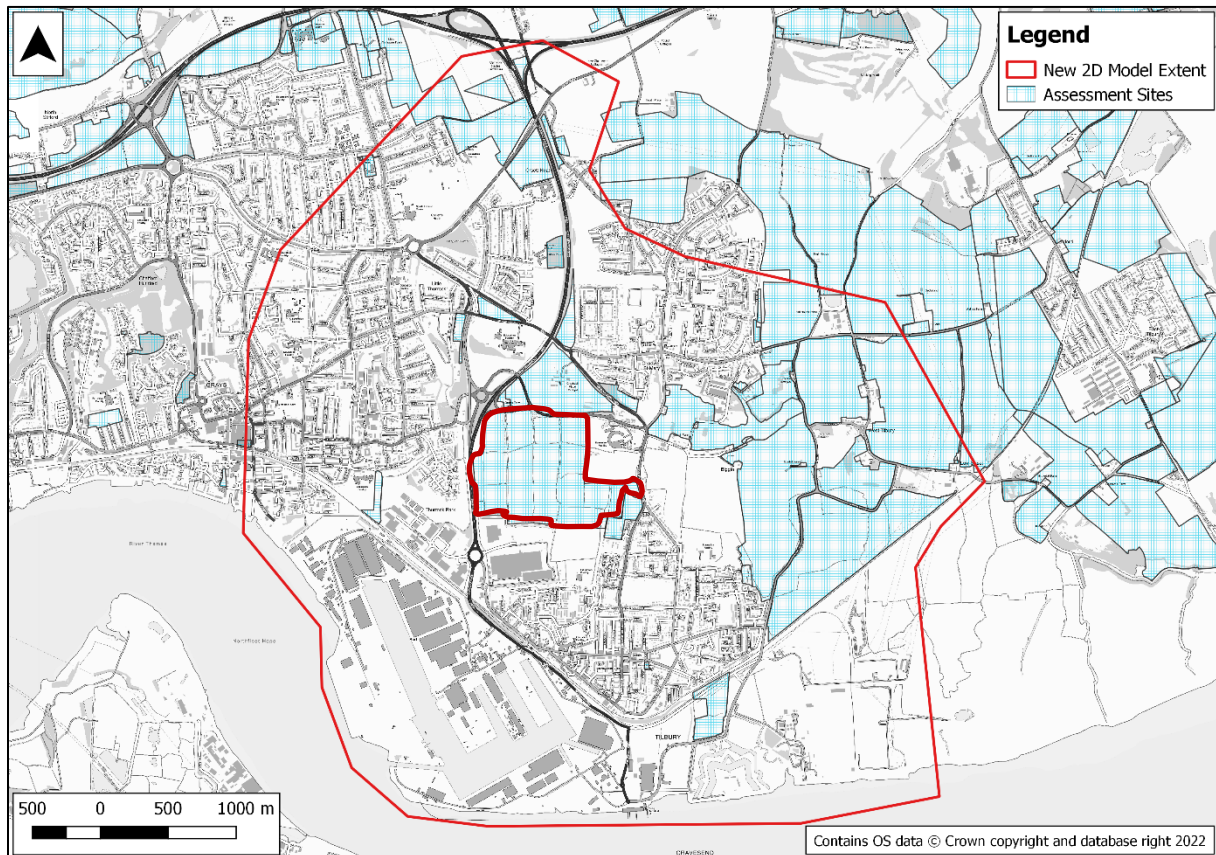
6.1 Overview

- 6.1.1 Three sensitivity scenarios have been modelled to understand the potential cumulative impact on flood risk of development in the Tilbury FSR catchment. This provides Thurrock Council with technical evidence showing the potential flood risk impact of changes in the landuse pattern across the catchment. Figure 6-1 shows the assessment sites included in this modelling, based on landuse planning information provided by Thurrock Council.
- 6.1.2 As this is a strategic assessment (not site scale detail), assumptions have been made in consultation with Thurrock Council about the likely change in landuse pattern on the assessment sites and the effect this has on the permeability / impermeability of the sites and the potential reduction in FSR volume because of land raising. This has been represented in the sensitivity scenarios by changing the roughness and infiltration zones in the model or modifying the mesh to represent land raising in the assessment sites.

6.2 Scenarios

- 6.2.1 **Scenario 1 assumes for each of the assessment sites that 50% of the development would be permeable surfaces and 50% impermeable surfaces.** This is represented in the Roughness Zones (RZ) and Infiltration Zones (IZ) in the model. The roughness and runoff coefficients on these sites have been adjusted to represent these assumption, based on the same values assumed in the baseline scenario (Table 3-2) for impermeable surfaces (roads) and permeable surfaces (grassland).
- 6.2.2 For example, the assumption of 50% permeable surfaces and 50% impermeable surfaces is represented with a runoff coefficient of 0.525 for these development areas. A similar calculation approach was adopted for the estimation of a roughness value for these development sites.
- Runoff coefficients for grassland = 0.2
 - Runoff coefficients for roads = 0.85
 - Overall runoff coefficient for the development area = $[(0.2 * 0.5) + (0.85 * 0.5)] = 0.525$
- 6.2.3 **Scenario 2 assumes for each of the assessment sites that 10% of the development would be permeable surfaces and 90% impermeable surfaces.** As above, this is represented in the Roughness Zones (RZ) and Infiltration Zones (IZ) in the model.
- 6.2.4 For example, the assumption of 10% permeable surfaces and 90% impermeable surfaces is represented with a runoff coefficient of 0.785 for these development areas. A similar calculation approach was adopted for the estimation of a roughness value for these development sites.
- Runoff coefficients for grassland = 0.2
 - Runoff coefficients for roads = 0.85
 - Overall runoff coefficient for the development area = $[(0.2 * 0.1) + (0.85 * 0.9)] = 0.785$
- 6.2.5 **Scenario 3 assumes that all the area contained within one specific assessment site (TC11), outlined in red in Figure 6-1, is raised by 700mm above the current ground surface.** This is represented in the model by creating a new mesh zone which had a value of 0.7m as a 'raise by' attribute in the model. This third scenario has been undertaken because this assessment site is within the FSR and is close to the town, therefore there appears to be potential for an increase in flood risk if this site encroaches into the FSR volume. There are no changes to the Roughness Zones (RZ) and Infiltration Zones (IZ) in the model in this Scenario, i.e., the only difference from the baseline is in the ground elevations within the assessment site.

Figure 6-1 Assessment sites provided by Thurrock Council



Note: TC11 assessment site outlined in red is the single site where ground elevations are raised in Scenario 3

6.3 Model Results

- 6.3.1 Table 6-1 shows the maximum flood depth in the baseline and three sensitivity scenarios for the 1% AEP event for 13-hour storm duration (summer storm profile) for points in the FSR. The difference in maximum depth between the baseline and the sensitivity scenarios is also shown. The location of the inspection points is shown in Figure 6-2, along with the maximum flood depths for the 1% AEP event baseline scenario.
- 6.3.2 The sensitivity scenarios are shown to cause an increase in flood depth at all the inspection points in the FSR during Scenario 1 and Scenario 2 and at some of the inspection points during Scenario 3.

Inspection Points	Peak Depth (m)	Peak Depth (m)	Peak Depth (m)	Peak Depth (m)	Depth Difference (m)	Depth Difference (m)	Depth Difference (m)
	Baseline	Scenario 1	Scenario 2	Scenario 3	Scenario 1 - Baseline	Scenario 2 - Baseline	Scenario 3 - Baseline
1	0.26	0.28	0.31	0.08	0.02	0.05	-0.18
2	0.24	0.27	0.32	0.14	0.03	0.08	-0.10
3	0.26	0.29	0.34	0.12	0.03	0.08	-0.14
4	0.19	0.33	0.34	0.17	0.14	0.15	-0.02
5	0.30	0.36	0.40	0.04	0.06	0.10	-0.26
6	0.21	0.28	0.30	0.22	0.07	0.09	0.01
7	0.32	0.39	0.43	0.12	0.07	0.11	-0.20
8	0.87	0.94	0.98	0.92	0.07	0.11	0.05
9	0.56	0.64	0.70	0.53	0.08	0.14	-0.03
10	0.39	0.42	0.47	0.37	0.03	0.08	-0.02
11	0.14	0.15	0.17	0.15	0.01	0.03	0.01
12	0.12	0.22	0.27	0.13	0.10	0.15	0.01
13	0.15	0.25	0.26	0.16	0.10	0.11	0.01
14	0.09	0.19	0.24	0.10	0.10	0.15	0.01

Legend

- New 2D Model Extent
- Inspection Points

Flood Depth (m)

- <= 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- > 0.9

200 0 200 400 m

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Scenario 1

- 6.3.3 Figure 6-3 to Figure 6-5 shows the difference between the maximum flood level (or depth) in Scenario 1 compared to the baseline for the 3.33%, 1%, and 0.1% AEP events, 13-hour storm duration (summer storm profile) focused on the FSR.
- 6.3.4 These figures provide an indication of how flood levels may increase because of cumulative development in the area. Where the difference in flood level (or depth) is within $\pm 0.02\text{m}$ it is not coloured in these figures. The colour scheme on all difference maps is the same with the red and orange colours particularly highlighting where impacts or differences are greater than $\pm 0.02\text{m}$.
- 6.3.5 Flood levels increase from $+0.01\text{m}$ to $+0.14\text{m}$ across the FSR.

Figure 6-3 Difference in Maximum Stage: Scenario 1 vs. Baseline scenario - 3.33% AEP event

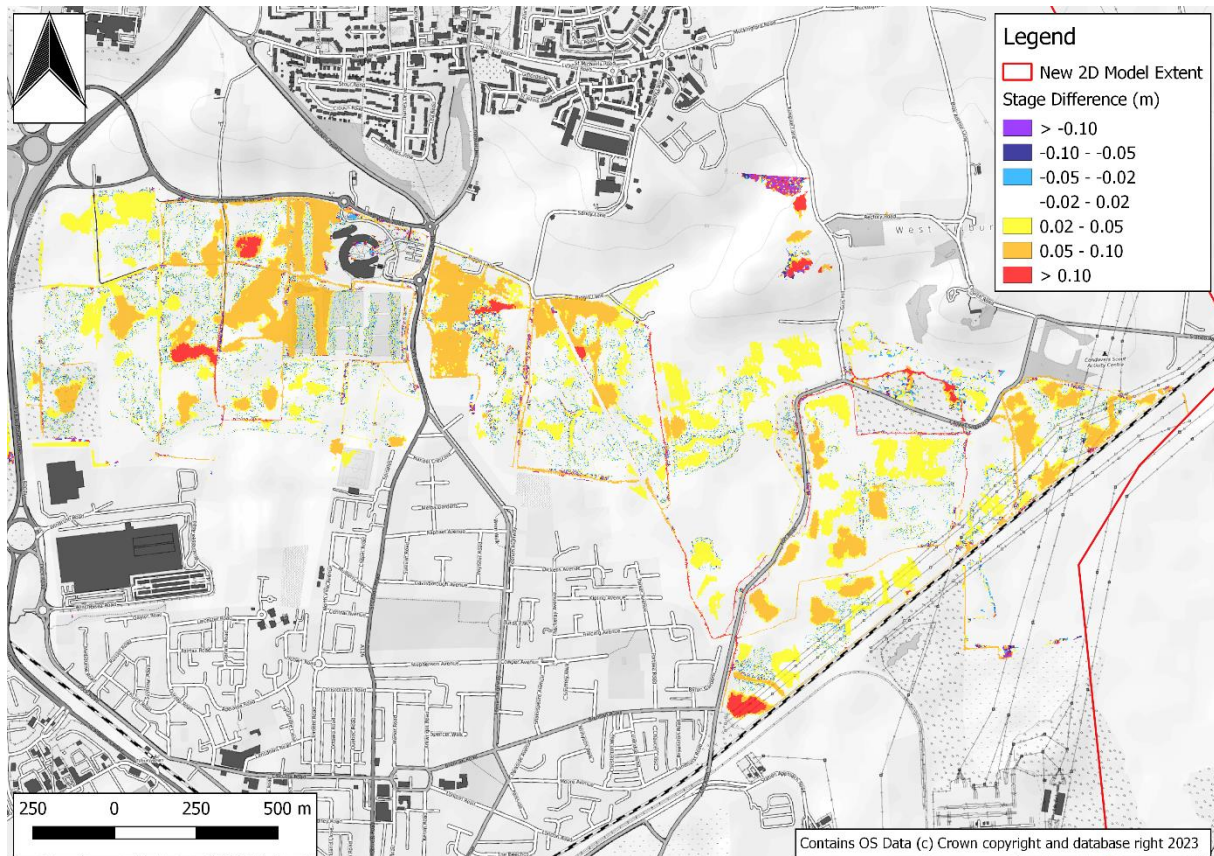


Figure 6-4 Difference in Maximum Stage: Scenario 1 vs. Baseline scenario - 1% AEP event

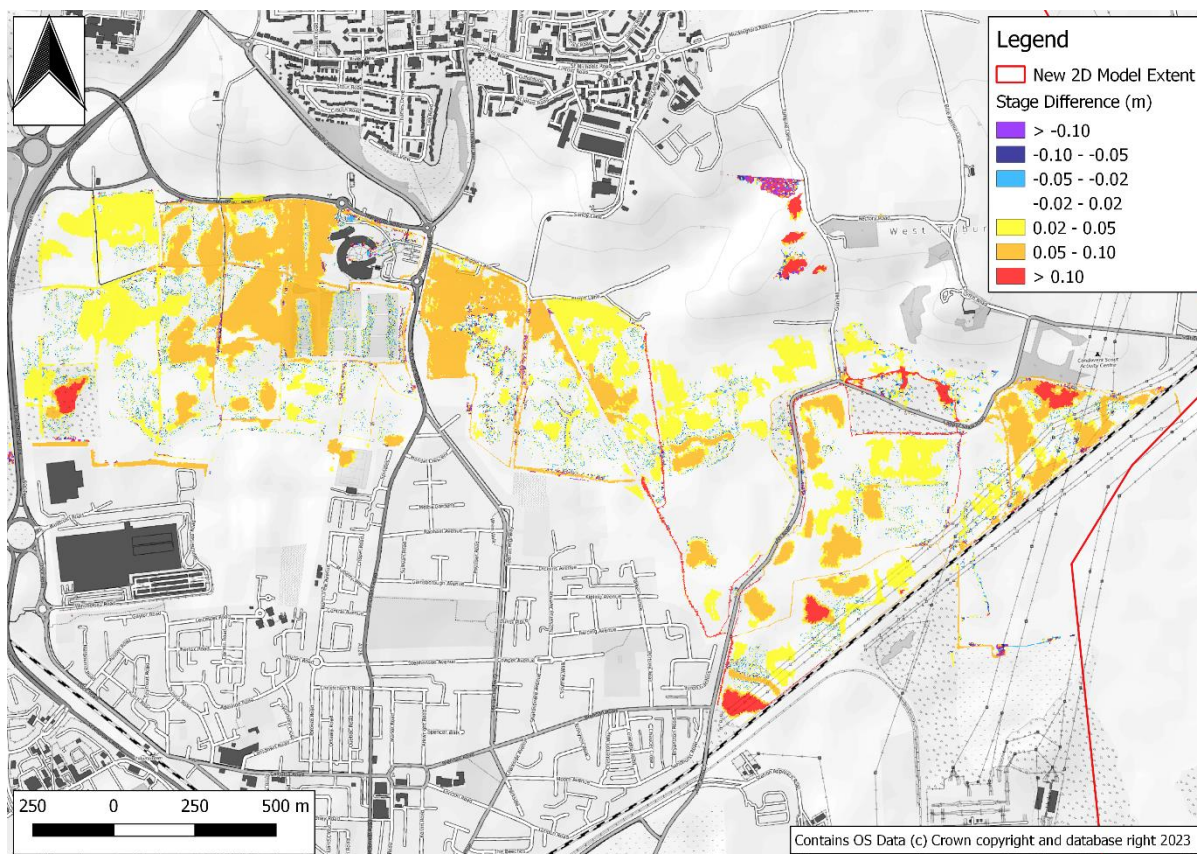
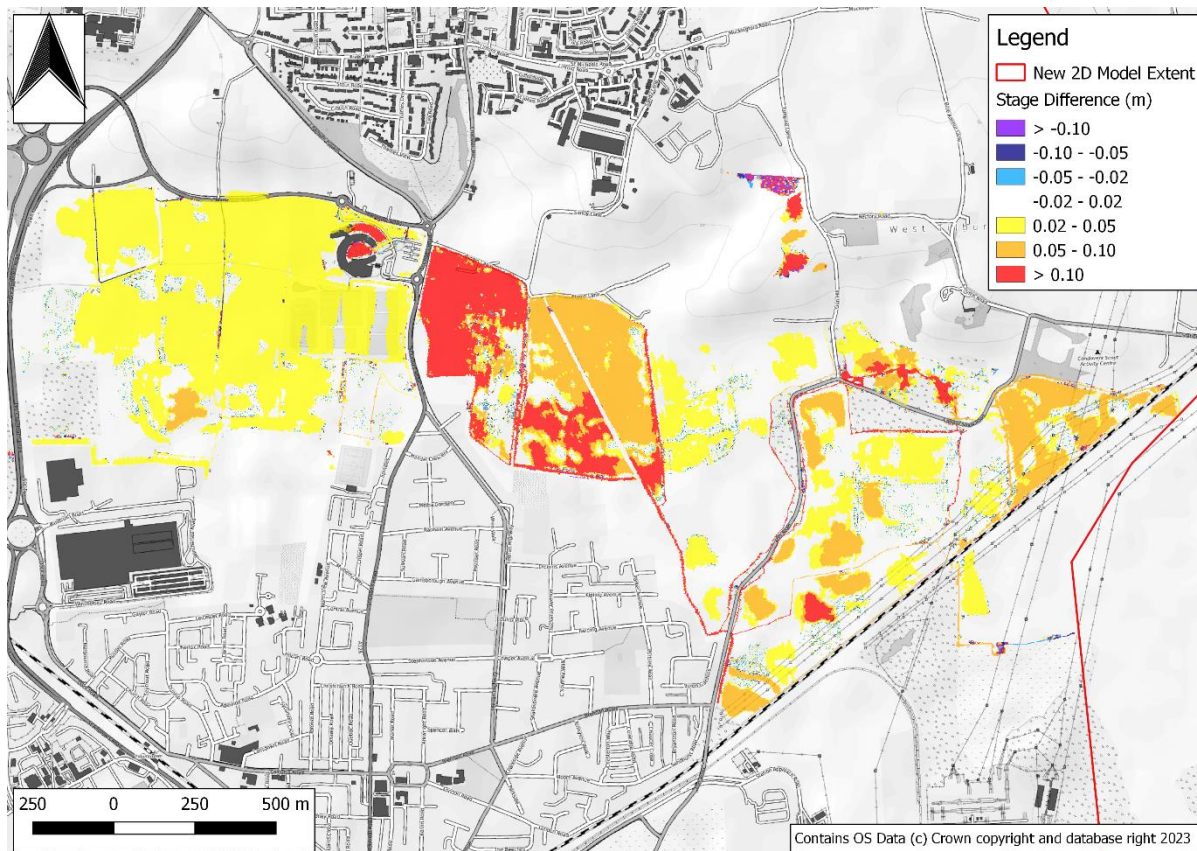


Figure 6-5 Difference in Maximum Stage: Scenario 1 vs. Baseline scenario - 0.1% AEP event



Scenario 2

6.3.6 Figure 6-6, Figure 6-7 and Figure 6-8 show the difference in maximum flood level (or depth) between the baseline model results and the results of Scenario 2 for the 3.33%, 1% and 0.1% AEP events respectively, each for the 13hour storm duration with summer storm profile. The same colour profiles are used as for the Scenario 1 figures so that the results can be compared.

6.3.7 The results show that the flood levels increase from +0.03 to +0.15m across the FSR and in the surrounding area during Scenario 2.

Figure 6-6 Difference in Maximum Stage: Scenario 2 vs. Baseline scenario - 3.33% AEP event

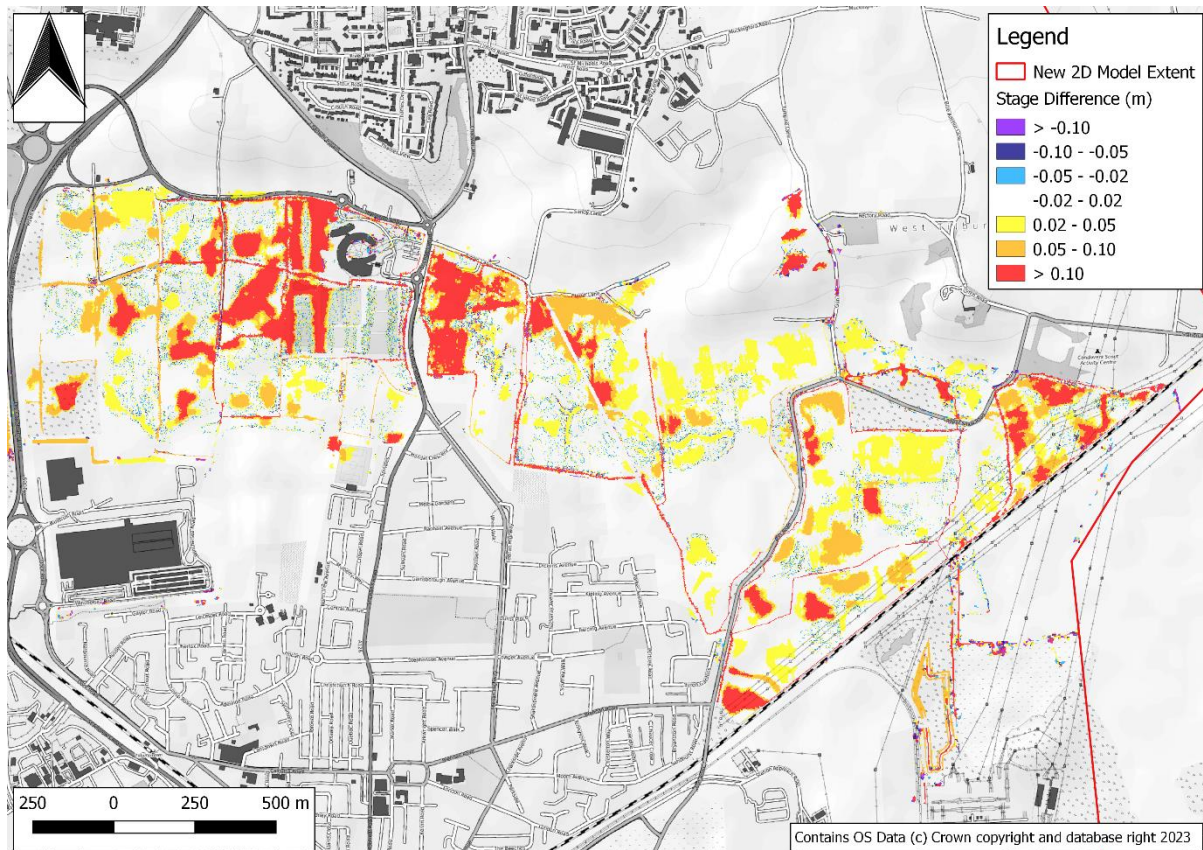


Figure 6-7 Difference in Maximum Stage: Scenario 2 vs. Baseline scenario - 1% AEP event

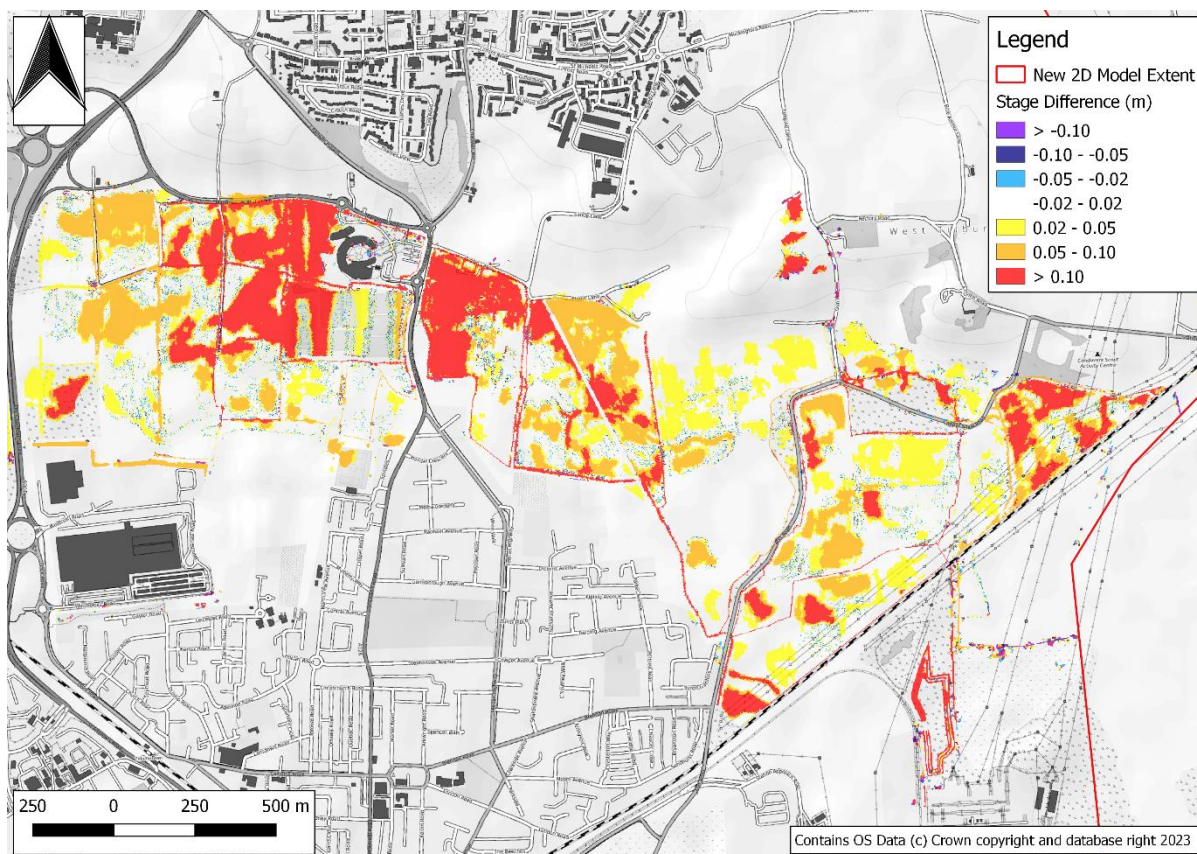
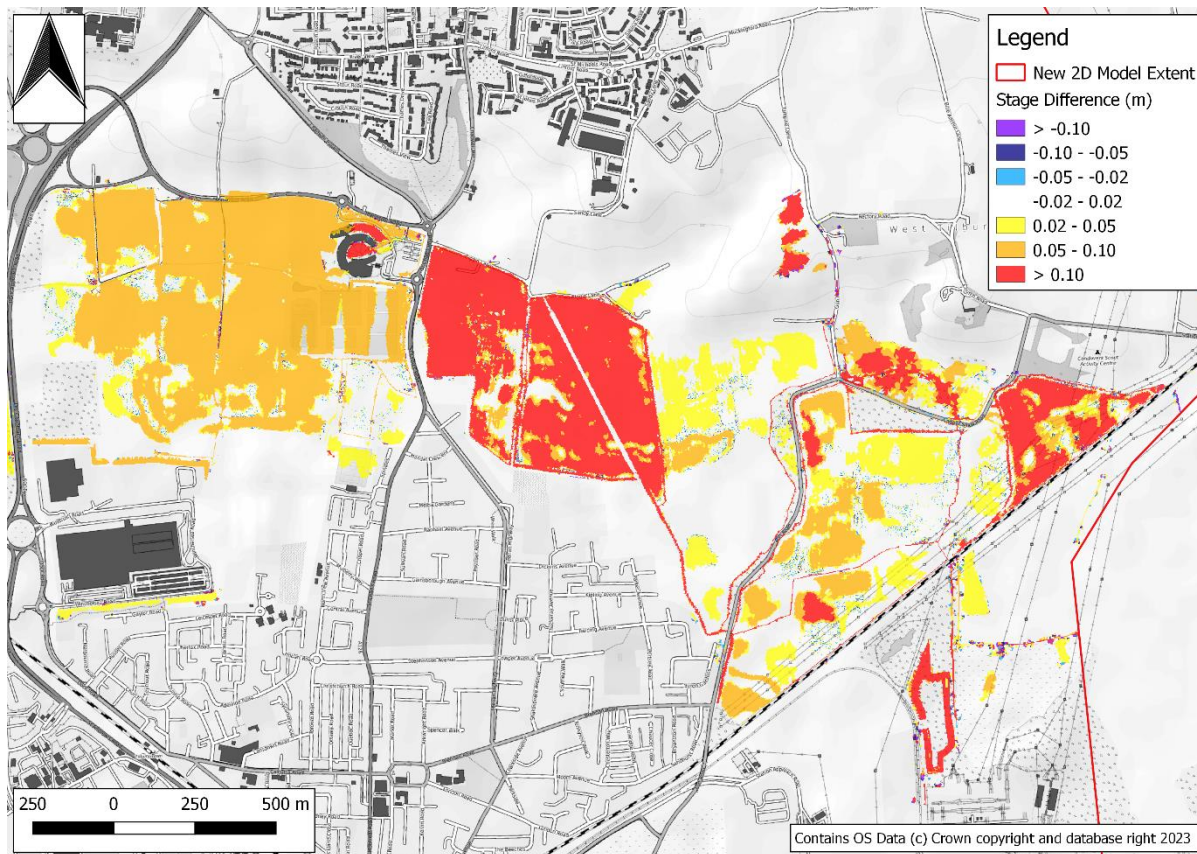


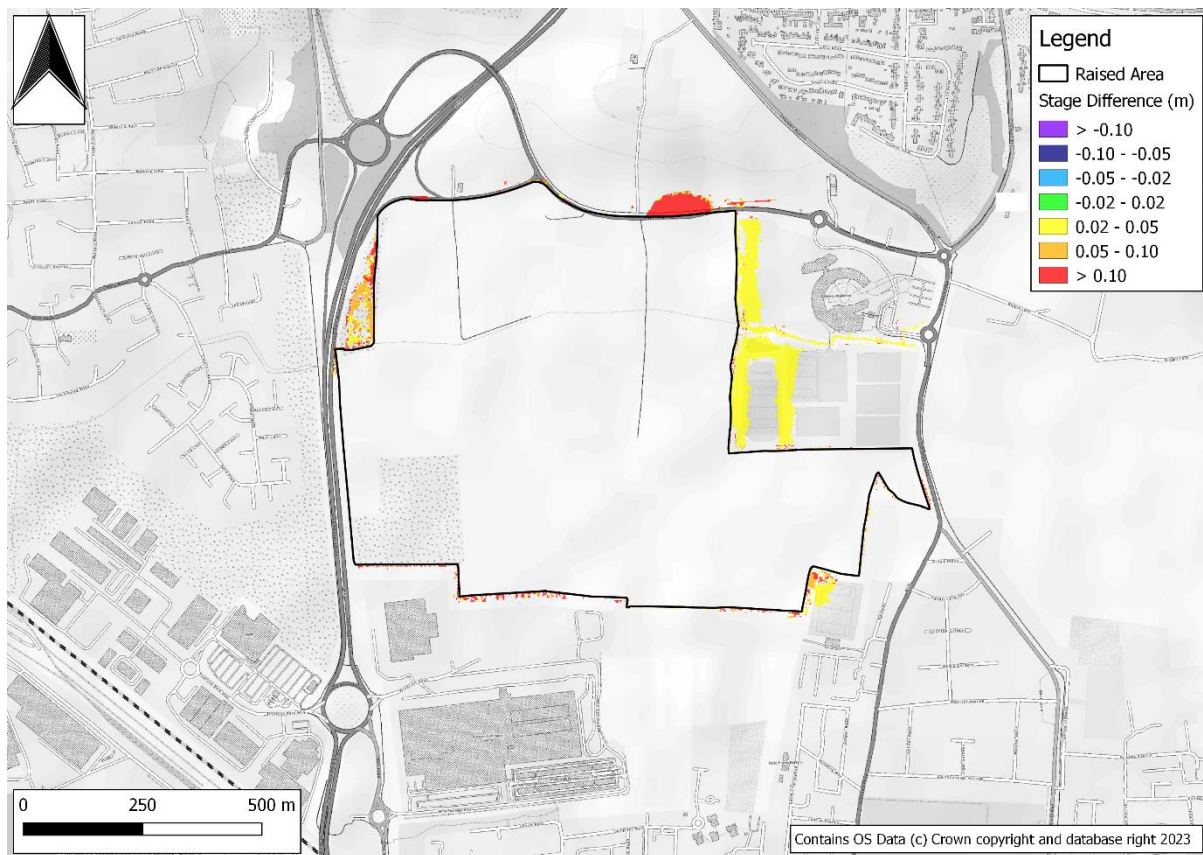
Figure 6-8 Difference in Maximum Stage: Scenario 2 vs. Baseline scenario - 0.1% AEP event



Scenario 3

- 6.3.8 Figure 6-9, Figure 6-10 and Figure 6-11 show the difference in maximum flood level (or depth) between the baseline model results and the results of Scenario 3 for the 3.33%, 1% and 0.1% AEP events respectively, each for the 13 hour storm duration with summer storm profile. The same colour profiles are used as for the Scenario 1 and 2 figures so that the results can be compared.
- 6.3.9 The site area shown in Figures 6-9, 6-10 and 6-11 was raised by an assumed 700mm above current ground level using a mesh zone to assess the impact of potential displacement of FSR volume. (There are no 'stage difference' results shown within the raised area because this area is now above flood level).
- 6.3.10 The model results show that land raising within the FSR has the potential to displace floodwater and lead to greater depth of flooding experienced at existing neighbouring development. The potential impact is shown to be more significant in the 0.1% AEP design event.

Figure 6-9 Difference in Maximum Stage: Scenario 3 vs. Baseline scenario - 3.33% AEP event



0 250 500 m

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Legend

□ Raised Area

Stage Difference (m)

- > -0.10
- 0.10 - -0.05
- 0.05 - -0.02
- 0.02 - 0.02
- 0.02 - 0.05
- 0.05 - 0.10
- > 0.10

0 250 500 m

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7. Discussion

- 7.1.1 An updated hydraulic model of the Tilbury FSR and surrounding catchment area has been developed by AECOM for Thurrock Council as part of their technical evidence basis for the SFRA.
- 7.1.2 The updated model represents the FSR in 2D (a significant difference from previous modelling) which means it is now possible to visualise how runoff fills the FSR and to map the predicted depth of flooding within it. It is then possible to see how the predicted depth and extent of flooding might change under different scenarios.
- 7.1.3 The baseline flood modelling and mapping shown here is for the 3.33%, 1% and 0.1% AEP design events. Storm duration testing was undertaken, and a 13-hour storm duration (summer profile) was identified as critical in the FSR area and adopted for the mapping and scenario testing.
- 7.1.4 It is noted that these results are for present day scenarios and do not include for a climate change allowance on the design event rainfall profiles. The risk of flooding is expected to increase in the future.
- 7.1.5 Scenario testing was undertaken to identify the potential cumulative impact of future development on flood risk in the catchment in the event that future development increased the proportion of impermeable surfaces across the sites or included land raising.
- 7.1.6 Three sensitivity tests have been undertaken to represent different scenarios:
- Scenario 1:** 50% of the potential development site areas are assumed to be covered by impermeable surfaces.
- Scenario 2:** 90% of the potential development site areas are assumed to be covered by impermeable surfaces.
- Scenario 3:** One selected development site area is assumed to be raised by 700mm above existing ground level.
- 7.1.7 The modelling results of Scenarios 1 and 2, identify that development which increases impermeable surfacing will result in increased flood depths within the FSR. The greater runoff generated could increase the depth of flooding in the FSRs by more than 0.1m which reduces the capacity of flood protection offered by the FSR.
- 7.1.8 Results for Scenario 3, demonstrate that development that includes land raising has the potential to displace floodwater and increase flood risk to existing neighbouring development.
- 7.1.9 It is therefore recommended that Thurrock Council implement policies that prevent land raising within the FSR. It is recommended that Thurrock Council retain the Flood Zone 3b designation in this area.
- 7.1.10 It is also recommended that Thurrock Council ensure that existing policies to restrict surface water runoff (to existing runoff rates and volumes) continue to be enforced for all potential development sites in the catchment and where possible opportunities are taken to reduce the surface water runoff.

8. Modelling Limitations

8.1.1 The modelling undertaken and presented in this report is suitable for a strategic assessment of the potential cumulative impacts of development in the Tilbury FSR catchment. As the modelling was undertaken a number of limitations in the methodology and approach were noted, with recommendations as to how the model could be refined in future for a more detailed assessment. These are summarised below but are not considered essential for the purposes of this SFRA. They would be recommended if the model was used for a more local / site specific assessment of flooding or testing of impacts.

- No calibration of the model was undertaken due to a lack of historical event data. The outputs from the model were validated against the Environment Agency RoFSW map and showed general agreement. It is therefore not possible to quantify the degree of confidence in this modelling. Calibration of the model would require more hydrometric and quantitative data of observed flood events that resulted in filling of the FSR.
- The sensitivity testing of the model was limited to the development / permeability scenarios described above. No sensitivity testing of other modelling assumptions (e.g., Manning's n roughness values or roughness coefficients) was undertaken and no sensitivity testing of model inflows or rainfall input was undertaken, apart from the duration testing. Additional sensitivity testing would give more information about the level of confidence in the model but was not essential for the relative impact assessment needed in this SFRA.
- The scenario testing included simple assumptions about the proportion of permeable and impermeable surfaces on the allocated development sites for Scenario 1 and 2. No information about the development layout on those sites was used, rather an average runoff coefficient and Manning's n value was calculated based on the assumed proportion of impermeable surfaces. More detailed information about the development could be represented in the model including the layout of ditches, structures (culverts), roads and buildings, but this was not necessary for this initial strategic assessment.
- Scenario 3 adopted a basic assumption that the whole area of the assessment site was raised by 700mm above the existing ground level. The planning proposals for the site may take a different approach to ground raising which is not as extensive as this basic assumption and would be assessed through a site specific FRA.
- The development / permeability scenarios tests do not account for other types of impact development might have on flood risk, beyond land raising and reducing the permeability area and increasing the runoff. For example, the model does not represent the effects that large buildings might have by changing flow paths or the new flow paths that could be created by the layout of new roads. These effects would need assessing in site specific modelling for FRAs to support planning applications.
- The model geometry is currently based mostly on LiDAR DTM and OSMM data. There are structures in the model e.g., underneath the roads, railways and embankments where additional survey data would help refine the representation in the model which would give a better understanding of flow mechanisms across the area.
- Additional modelling scenarios could be undertaken with alternative assumptions of the permeable / impermeable proportions on the development sites, e.g., varying the proportions between different sites where land uses are known. The model could also be used to identify if there are benefits that could be realised by reducing runoff within the FSR catchment, e.g., through control of surface water runoff.
- This modelling has been undertaken to provide an evidence base suitable for the SFRA. This modelling should not be used in the assessment of specific planning applications and associated FRAs. It is expected that planning applications in these areas would include FRAs supported by modelling that represented the development in a more refined way based on the proposed layouts and levels of each site.

