



Southleigh, Havant

Hydraulic Modelling Report

On behalf of **Bloor Homes**

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1 Introduction

1.1 General

- 1.1.1 Stantec UK Limited (Stantec) has been appointed by Bloor Homes to undertake hydraulic modelling to assess the flood risk to a proposed development site at Southleigh, Havant.
- 1.1.2 A hydrological assessment of the catchment has been undertaken, as well as fluvial and surface water modelling, to assess flood risk at the site as the existing datasets are based predominantly on broadscale modelling undertaken by the Environment Agency (EA).
- 1.1.3 The development proposals include a residential development consisting of approximately 48 ha of residential homes within the overall development site of approximately 105ha. The hydraulic modelling is required to determine the extent of fluvial and surface water flooding in the present day, and to consider the impacts of climate change for the lifetime of the development. The results of this assessment will define any fluvial or surface water flood risk constraints on development and evidence the requirement for any flood mitigation.

1.2 Purpose and Hydraulic Modelling Approach

- 1.2.1 This hydraulic modelling report describes the approach taken to assess fluvial and surface water flood risk at the proposed site, as the EA Flood Zones for the site and surrounding area are predominantly based on national scale hydraulic modelling which are not considered sufficient to support a detailed understanding of the flood risk to the proposed development.
- 1.2.2 The scope of the hydraulic modelling at Southleigh, Havant, includes the following:
- Collection of watercourse and structure survey data to inform the development of the hydraulic model of the Nore Farm Stream, West Brook and unnamed watercourses on site. The survey data was collected in accordance with the latest EA National Survey Specification at the time of the survey. .
 - A hydrological assessment of the catchment using FEH Statistical and ReFH2 methods to provide inflow hydrographs and rainfall to the hydraulic models.
 - Development of a 1D-2D hydraulic model and a site specific model using the industry standard TUFLOW-ESTRY software packages to assess fluvial flood risk and surface water flood risk respectively.
 - Preparation of a hydraulic modelling report to inform flood risk to the site and outline any mitigation measures required to protect the development from fluvial or surface water flood risk.

1.3 Site Location

- 1.3.1 The site of interest consists of land bounded by the A27 to the south, Bartons Road to the North and Horndean Road to the east, as shown in **Figure 1.1.1**. Within the site boundary, an unnamed watercourse runs along the western boundary of the site in a north west to south east direction before running underneath the A27, at which point it becomes the Nore Farm Stream (an EA main river). The Nore Farm Stream drains to the Nore Rithe. There are some unnamed ditches running through the site under Southleigh Road. The West Brook lies just outside the eastern boundary of the site and eventually drains to the Emsworth Mill Pond.
- 1.3.2 The West Brook is an EA Main River, and the Nore Farm Stream and unnamed watercourses on site are classified as ordinary watercourses.

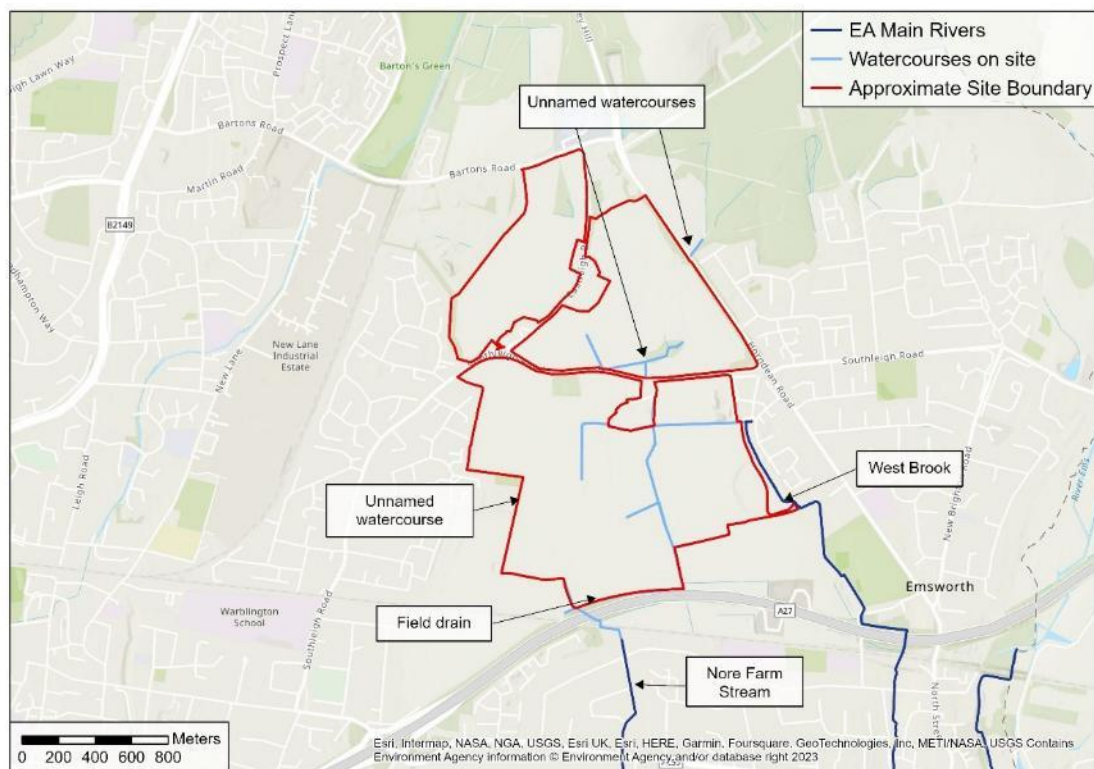


Figure 1.1.- Site Location

1.4 Background Information

- 1.4.1 In April 2014, a planning application was submitted for the Nore Farm Stream FAS, which included water storage ponds to provide flood water attenuation as well as slowing discharge into the existing culvert under the A27. The flood storage area was designed to include a control structure to restrict flow leaving the flood storage areas and entering the culvert under the A27. The Nore Farm Stream FAS planning application also included a new ditch to the north of the A27.

1.5 EA Flood Map for Planning

- 1.5.1 An initial assessment of flood risk at the site of interest was made using the EA Flood Map for Planning. The flood risk from fluvial, surface water and tidal flood risk are outlined below.

Fluvial Flooding

- 1.5.2 The EA Flood Map for Planning shows the extent of fluvial flooding across the site (note this is – and all references to the EA Flood Zones – are based on the 2023 version of the Flood Zone map, which was the applicable point of reference when the modelling was undertaken). We know the Flood Zone mapping was updated in March 2025 as part of the NaFRA update and later revised in November 2025 – these were reviewed and notably they are less extensive over the site, so the modelling and associated comparison remains a conservative approach. The Flood Map for Planning shows areas of the site lie within each of the three Flood Zones:

- Flood Zone 3 'High Probability', which means the land has a 1 in 100 or greater Annual Exceedance Probability (AEP) of river flood risk.

- Flood Zone 2 'Medium Probability', which means the land has between a 1 in 100 and 1 in 1000 AEP of river flood risk.
- Flood Zone 1 'Low Probability', which means the land has a 1 in 1000 or less AEP of river flood risk (land outside of Flood Zones 2 & 3).

1.5.3 The Flood Zones are presented on **Figure 1.2**, in relation to the site. It should be noted that the majority of the site lies within Flood Zone 1, at low risk of flooding and the areas of higher fluvial flood risk are located to the west and south of the site, with associated areas in Flood Zones 2 and 3, at the unnamed water course which drains to the Nore Farm Stream. There is also an area of higher fluvial flood risk to the east of the site at the West Brook flood storage area (a Flood Alleviation Scheme (FAS)).

1.5.4 The Flood Map for Planning at the unnamed watercourse which drains to the Nore Farm Stream is broadly based on an existing model that predates the FAS, the West Brook is based on an adjustment of the Flood Zones based on topography and has not been informed by detailed site modelling.

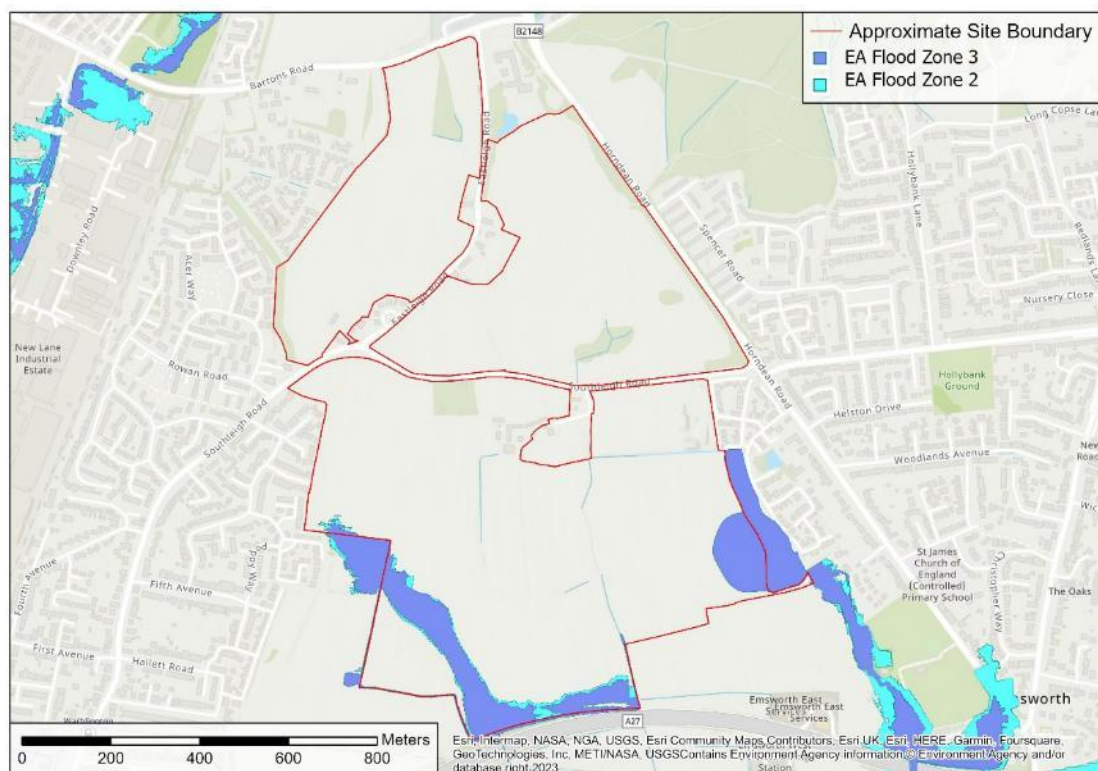


Figure 1.2 - Fluvial Flood Zones (2023)

Surface Water Flooding

1.5.5 The EA 'Risk of Flooding from Surface Water' (RoFSW) mapping identifies areas that could be susceptible to surface water flooding in various rainfall events (note this is – and all references to the EA Risk of Flooding from Surface Water– are based on the 2023 version, which was the applicable point of reference when the modelling was undertaken). We know the Risk of Flooding from Surface Water mapping was updated in January 2025 as part of the NaFRA update, and later revised in September 2025 – these were reviewed and notably they are broadly comparable over the site. The latest mapping assesses flooding resulting from severe rainfall events based on the following scenarios:

- 'High' Risk: 1 in 30 (3.3%) or greater AEP rainfall event;
- 'Medium' Risk: Between a 1 in 100 (1%) and 1 in 30 (3.3%) AEP rainfall event;
- 'Low' Risk: Between 1 in 1000 (0.1%) and 1 in 100 (1%) AEP rainfall event;
- 'Very Low' Risk: Lower than 1 in 1000 (0.1%) AEP rainfall event.

1.5.6 The RoFSW flood risk outputs are presented on **Figure 1.3**, the majority of the site is at 'Very Low' risk of surface water flooding at less than a 1 in 1000 year rainfall event. However, there are areas of 'High', 'Medium' and 'Low' Risk located in the northwest parcel of land with a flow route running north to south as well as an area of flooding in the southwest corner. There is a large flow route running through the centre of the site from Southleigh Road, running southeast towards the West Brook. There is an area of surface water ponding at the south of the site along the southern field drain, located upstream of the A27.

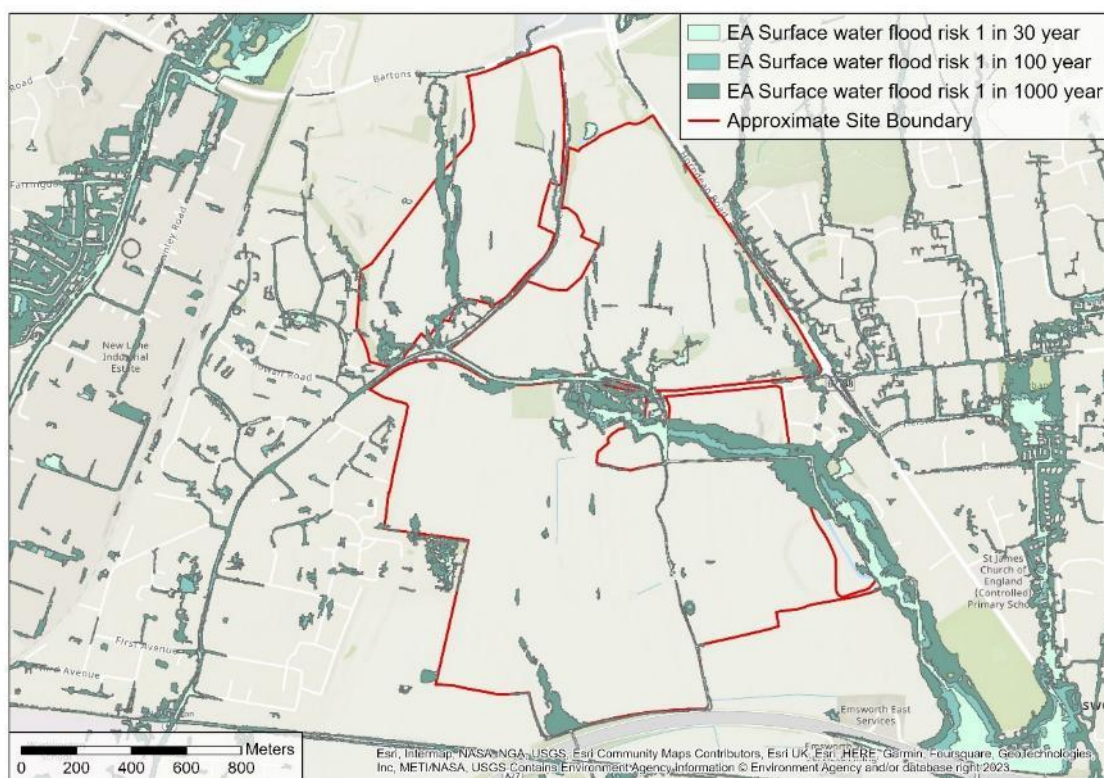


Figure 1.3 - Surface Water Flood Risk Areas

Tidal Flooding

- 1.5.7 The risk of tidal flooding to the site is considered to be low. Based on the EA coastal boundary conditions, the 1 in 1000 year tidal level is 3.41mAOD at the Solent Downs Estuary.
- 1.5.8 According to the extent of tidal Flood Zone 2, the LiDAR level at the edge of the tidal floodplain is 3.94mAOD at Victoria Road. The West Coast Railway line and A27, lie at an elevation of 8.34mAOD at minimum. There is an underpass for pedestrians under the A27 and West Coast Railway line which lies at a minimum elevation of 4.97mAOD.
- 1.5.9 The site is within the South East River Basin District where the sea level rise allowance is 1.6m under the upper end emissions scenario to 2125. The lowest ground level at the site is

8.68mAOD which is above the extreme tidal flood levels in the present day and when the impacts of climate change are considered.

- 1.5.10 Based on the low risk of tidal flooding at the site, tide locking is not directly represented in the hydraulic model. However, a tidal boundary at the downstream of the fluvial model has been applied to represent Mean High Water Spring levels. This approach is described further in **Section 4**.

2 Model Data Sources

2.1 Existing Models

- 2.1.1 There is an existing detailed fluvial model of the Nore Farm Stream including the FAS. However, this data could not be supplied by the EA and is discussed further in **Section 2.6**.
- 2.1.2 There are no existing detailed surface water models of the area to assess surface water flood risk at the site.

2.2 Watercourse Survey

- 2.2.1 A watercourse survey was undertaken in July 2023 by Precision Point Surveys Ltd, to provide data in order to develop fluvial and surface water models for the site. This includes channel and structure cross-sections for 13 reaches of watercourse in the vicinity of the site, as shown in **Figure 2.1**. The data was collected in accordance with the EA survey specification and is therefore considered to be of a high quality and suitable for use in developing fluvial and surface water models.
- 2.2.2 Existing survey of the West Brook, downstream of the site of interest to the Mill Pond, was undertaken in April 2006 by Longdin and Browning. This data was considered to be suitable for use in the development of the fluvial and surface water models downstream of the site of interest.

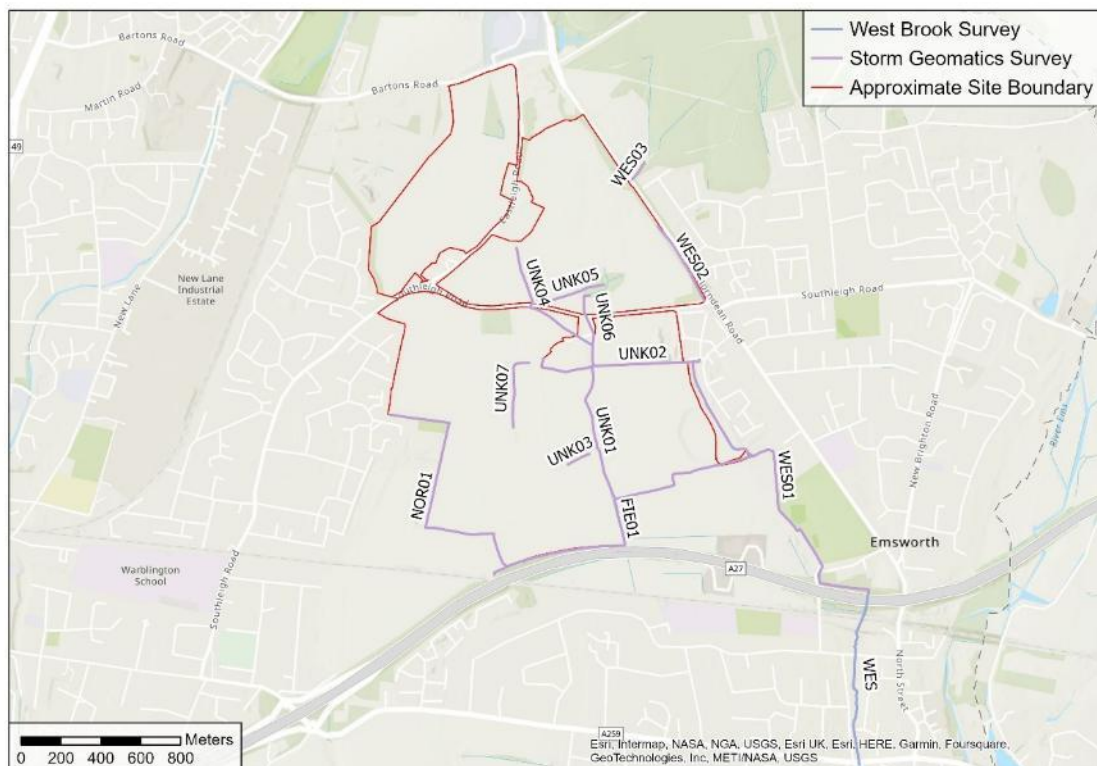


Figure 2.1 - Survey Location

- 2.2.3 A copy of the survey data is included in **Appendix A**. Based on the survey report and a review of the survey data the data was determined to be fit for purpose, with several observations made as follows:

Unnamed Drain 1 (UNK01)

- Along Unnamed Drain 1, there are two culvert exits downstream of Southleigh Road (UNK01_0160), however only one culvert entrance pipe could be found (UNK01_0174).

Unnamed Drain 2 (UNK02)

- The most upstream extent of Unnamed drain 2 is a wall with no opening that could be located, therefore connectivity to this drain is unknown (UNK02_0488).

Unnamed Drain 3 (UNK03)

- Unnamed drain 3 was found to be unconnected to any surrounding drains and rises back to ground level.

Unnamed Drain 4 (UNK04)

- Upstream of Southleigh Road Unnamed drain 4 drain rises to ground level and back to drain level.
- Downstream of Southleigh Road there are three culvert exits (UNK04_0235), connectivity sound tests confirmed that the culvert entrance was the left pipe of the three. The upstream source of the other two pipes could not be identified.
- It is assumed that this watercourse is connected to Unnamed Drain 6 (UNK06) via a culvert at UNK04_0160, as a concrete pipe was located on the right bank of UNK06. However, sound tests could not confirm the connectivity of these pipes.

Unnamed Drain 5 (UNK05)

- Unnamed drain 5 did not appear to be connected to any surrounding drains and rises back to ground level.
- The upstream of UNK05_0178 has a slight dip in the left bank which appears to feed a channel which could have connectivity with UNK06.

Unnamed Drain 6 (UNK06)

- The connectivity between cross-sections UNK06_0225 and UNK06_0101 could not be confirmed despite sound tests being carried out along Unnamed drain 6.

Unnamed Drain 7 (UNK07)

- Unnamed drain 7 was found to be disconnected from any surrounding drains and rises back to ground level.

West Brook Reach 1 (WES01)

- The connectivity upstream of WES01_1102 is unknown.
- Within the pipe at WES01_0000 an additional pipe enters the culvert from the left side, the connectivity of this pipe is unknown.

West Brook Reach 2 (WES02)

- A shallow ditch running north south along the west of Horndean Road has been surveyed where a ditch appears to be present. The West Brook Reach 2 ditch is very shallow and the connectivity is unknown. A culvert at the upstream of the reach has been found but the connectivity is unknown.

West Brook Reach 3 (WES03)

- The connection between West Brook Reach 3 is uncertain and therefore is considered a separate reach, the manhole indicates that flow is running beneath Horndean Road in a southerly direction.

2.3 Topographic Survey

- 2.3.1 A topographic survey was undertaken in June 2023 by Geomatic Surveyors for the development site (**Appendix B**). This is the best available topographic data for the site and will be used to inform the ground elevations within the hydraulic model.
- 2.3.2 The topographic survey data was compared to the LiDAR within the site of interest at some locations. It was found that the topographic survey has good agreement with the LiDAR in the majority of locations checked with an average difference of 0.07m. The maximum different found was 1.35m, however this is in the location of a building and was likely filtered out of the LiDAR but retained in the topographic survey.
- 2.3.3 It is considered that the topographic survey is of greater accuracy than the LiDAR data as it was collected in June 2023 and therefore is more recent and therefore is appropriate to inform ground levels.

2.4 LiDAR data

- 2.4.1 1m Digital Terrain Model (DTM) LiDAR data was used to inform the topography of the site, this was the best resolution LiDAR data available for the site and wider area and was flown in 2020. LiDAR is available for the full 2D model domain and was downloaded from the DEFRA open source data service platform. **Figure 2.2** shows the extent of LiDAR available for the site and surrounding area.

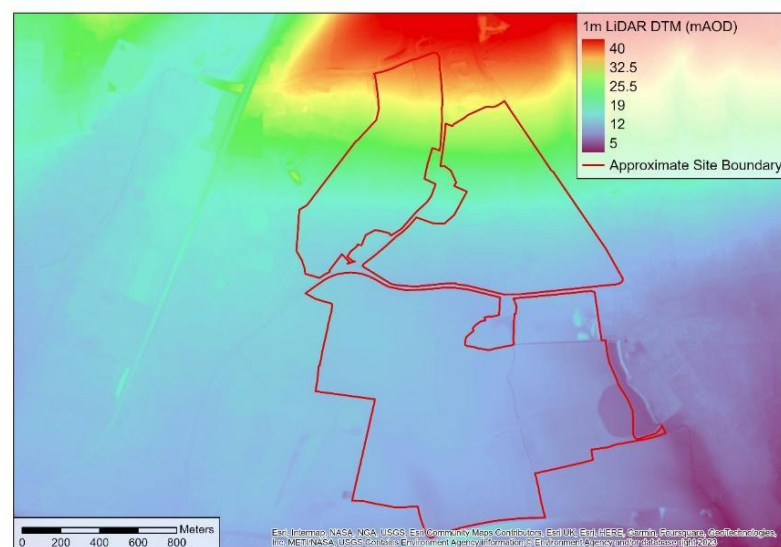


Figure 2.2 - LiDAR Coverage

2.5 Materials Data

- 2.5.1 OS Mastermap data in GIS format was sourced for the project from Emapsite in February 2023. The coverage of data is shown in **Figure 2.3**. This data provided the locations of different land-uses within the model extent, and roughness values were applied to the model in order to represent these different land-uses. Features that are represented include: railways, roads, buildings, inland water, surface water and woodland.

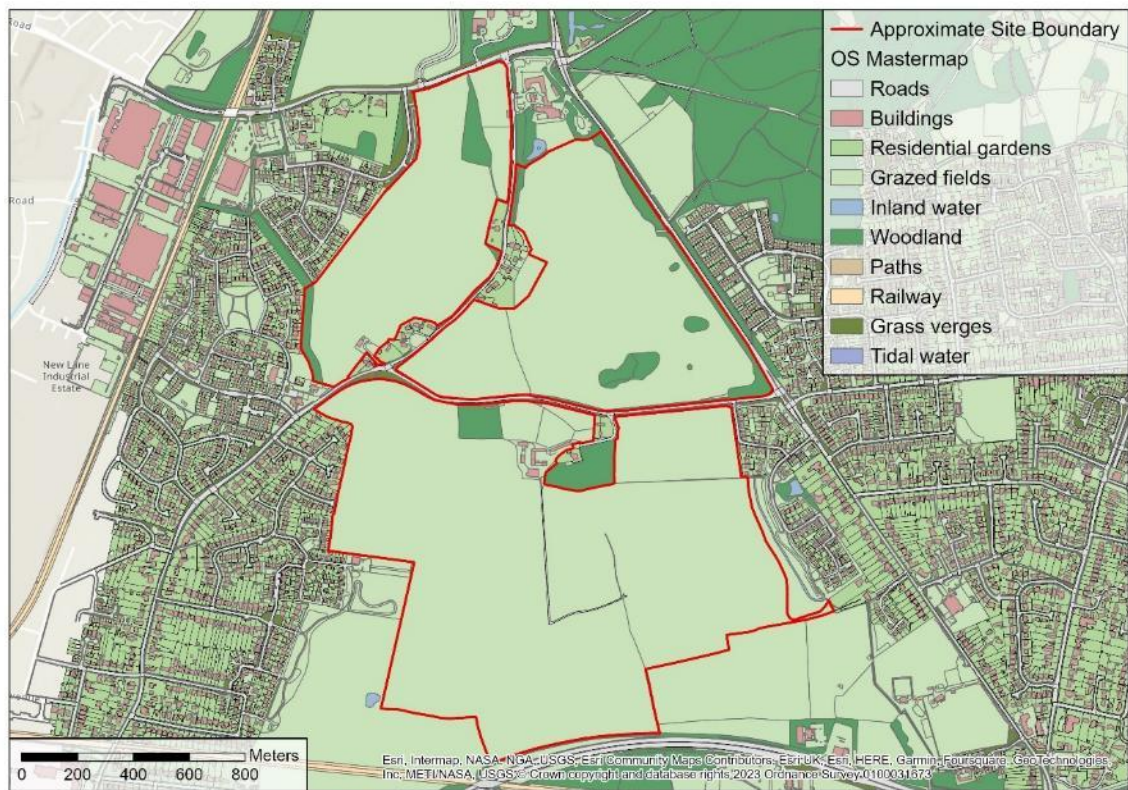


Figure 2.3 - OS Mastermap

2.6 EA Consultation

- 2.6.1 Consultation with the EA was undertaken on 30th March 2023 to discuss the pre-application submission for the development site. An overview of the site along with an indicative masterplan of the development site was presented and a range of information was requested from the EA to understand the constraints to the development.
- 2.6.2 The data requested and dates received are provided in

2.6.3 **Table 2.1.** This data is provided in **Appendix C.**

Table 2.1 - Data requested from Environment Agency

Data Requested	Information received	Comments
Nore Farm Stream hydraulic model.	Information not provided by the EA, would need to have been requested from Mott MacDonald.	Nore Farm Stream reach downstream reach of A27 could not be included in the model.
Nore Farm Stream flood alleviation scheme detailed design information, operational information on the scheme and details of maintenance activities undertaken requested.	Design drawings and as-built information provided on 02/08/2023.	Details of maintenance activities not provided.
West Brook flood alleviation scheme detailed design information, operational information and maintenance activities undertaken requested.	Design drawings from Bellway scheme provided on 20/06/2023.	Details of any EA maintenance activities or arrangement secured with Bellway were not provided.
Emsworth Mill Pond details of the operation of pond and structures used to drawdown the Pond requested.	Operating instructions have been provided including responsibilities of EA and Havant Borough Council on 08/08/2023.	
Details of the connectivity of the Main River along the West Brook and alignment information requested as well as the report.	CCTV plan for this watercourse provided on 19/05/2023.	Report was not provided, discussion of CCTV provided in Section 2.7 .
Gauge data – 15-min flow & level data for any gauges within the catchment were requested.	Data not provided.	We have reviewed the data on the Hydrology Data Explorer and have identified a level gauge at Emsworth (West Brook) which is a level gauge located just before the watercourse enters the Emsworth Mill Pond.
Requested details from asset performance on any maintenance activities undertaken within the site and machinery used within works.	Data not provided.	
Details to be provided on acceptable development within 8m of banktops or information on activities access that needs to be considered within the masterplan design.	Information not provided.	

2.7 CCTV and Sewer plans

- 2.7.1 The EA provided CCTV survey to help identify the connectivity between the reach at Horndean Road, and specifically whether this connects to the West Brook. The CCTV provided was inconclusive, as no report was provided by the Environment Agency. Therefore, CCTV survey was commissioned and supplied by Site Vision Survey and provided on 14th July 2023.
- 2.7.2 This demonstrated that the Horndean Road culvert ran south along the road before running east along Southleigh Road. However, this did not indicate where the flow path continued and therefore the connectivity between the Horndean Road reach and other watercourses on site remained unknown.
- 2.7.3 In order to identify the flow route connectivity sewer plans were procured from Southern Water on 9th August 2023, these are shown in **Appendix D**.

3 Hydrological Assessment

3.1 Fluvial Hydrological Assessment

- 3.1.1 A hydrological assessment has been undertaken for the watercourses that pass through the development site: the Nore Farm Stream and West Brook. Full details of this assessment are provided in **Appendix E**. The purpose of this assessment was to derive model inflows to define fluvial flood extents at the site of interest, including peak flow estimates and hydrographs. The study was completed in line with the latest EA Flood Estimation Guidance (2022¹).
- 3.1.2 The Nore Farm Stream discharges into the Nore Rithe at approximate grid reference NGR 473,923 (E), 105,391 (N). The West Brook discharges into the Emsworth Mill Pond at approximate grid reference NGR 474,823 (E), 105,277 (N). Both watercourses ultimately outfall to Chichester Harbour. **Figure 3.1** shows the catchment areas, the site boundary and the watercourses of interest.
- 3.1.3 Both catchments contain large areas of urbanisation, FEH methods were considered to be appropriate for this study, with careful consideration required due to the urbanised nature of the catchment. The National River Flow Archive (NRFA) and Hydrology Data Explorer indicate that there are no flow gauge stations on the watercourses of interest and are therefore ungauged. There is a level only gauge on the West Brook upstream of the St James' Road culvert (approximately 0.4km south of the A27 crossing). Therefore, the West Brook is continued to be considered ungauged for the purposes of flow estimation calculations.

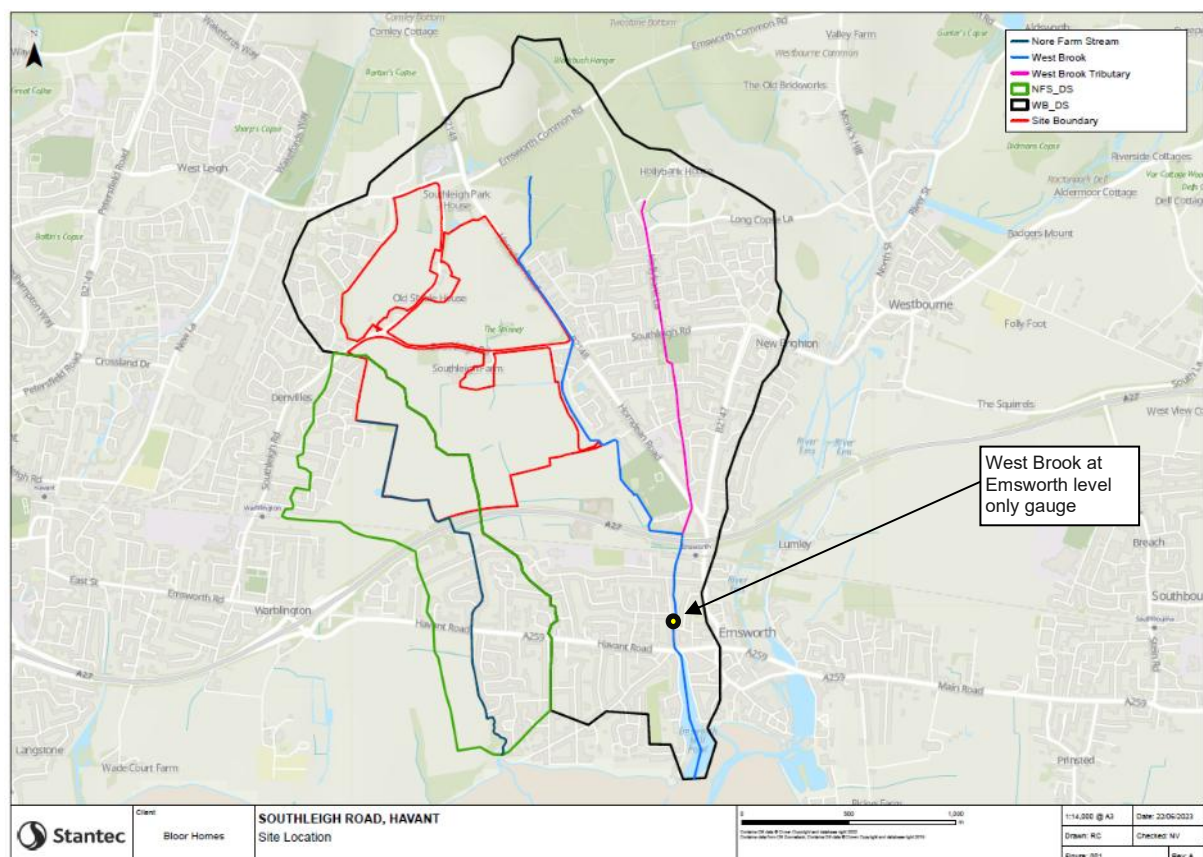


Figure 3.1 - Catchments

¹ EA, December 2022, Flood Estimation Guidelines, LIT 11832

- 3.1.4 The catchment descriptors were downloaded from the FEH Web Service. The catchment areas were reviewed and found to be inconsistent with the ground levels and understanding of flow routes and drainage. Catchment areas were therefore updated using a combination of the FEH Web Service catchment area and LiDAR derived catchment areas.
- 3.1.5 Both catchments were split into sub-catchments, with intervening areas used as inputs to the distributed model – see **Figure 3.2**. NFS_INT is located between the culverted reach of the Nore Farm Stream under the A27 and the downstream extent, and WB_INT is located between the confluence of the tributary at the A27 and the downstream extent. These sub-catchments are based on the key area of interest, which is located between Southleigh Road and the crossing of the Nore Farm Stream and the West Brook under the A27. Furthermore, these intervening areas are classified as very heavily urbanised due to the URBEXT values exceeding 0.3.

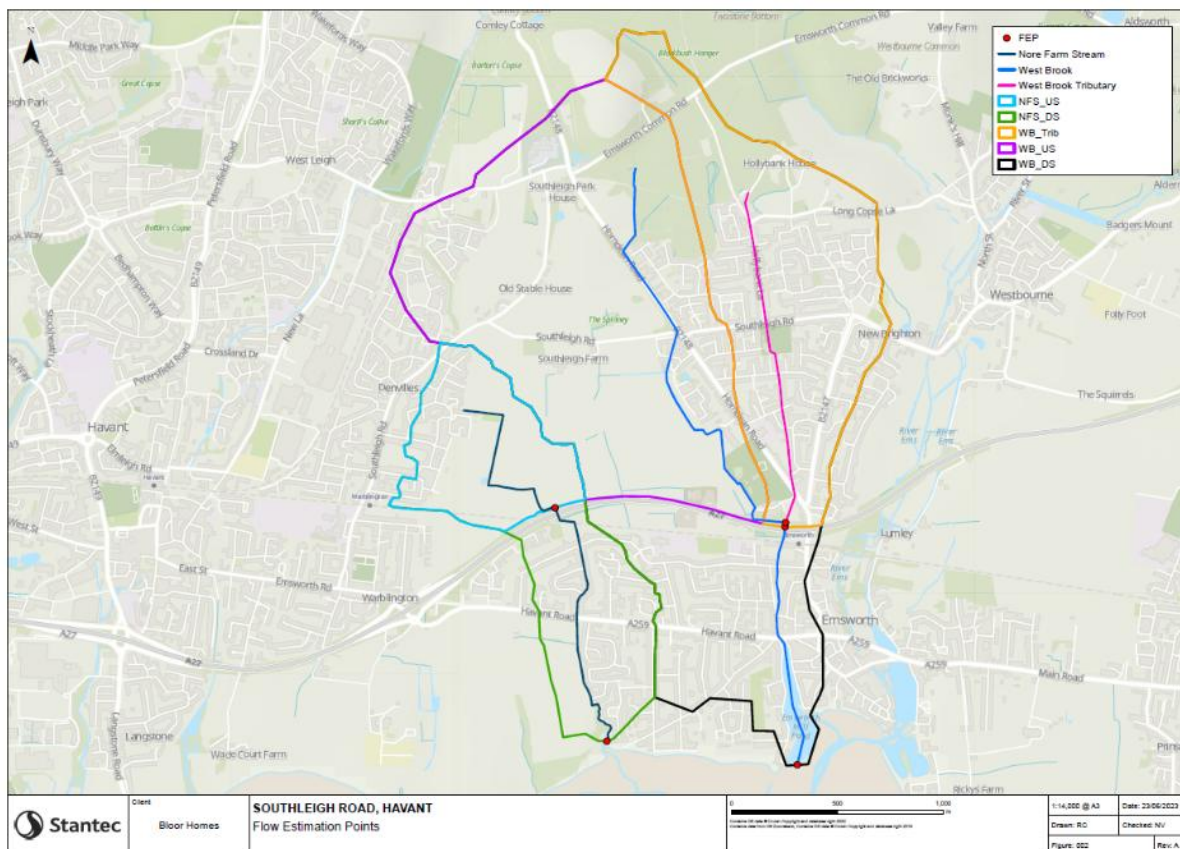


Figure 3.2 - Intervening catchments

- 3.1.6 The catchment descriptors were updated for the revised catchment areas and were manually calculated where possible for the intervening areas. The final catchment descriptors utilised within the assessment are provided in

3.1.7 **Table 3.1** with full details of the reviews completed and changes made provided in **Appendix E**.

Table 3.1 - Catchment Descriptors

Site code	Area (km ²)	FARL	PROP WET	BFIHO ST19	DPLB AR (km)	DPSB AR (m/km)	SAA R (mm)	URBEX T 2000	FPEXT
NFS_US	0.48	1	0.34	0.68	0.88	14.10	754	0.16	0.18
NFS_DS	0.99	1	0.34	0.68	1.13	11.40	742	0.24	0.18
NFS_INT	0.51	1	0.34	0.68	0.69	11.40	742	0.32	0.18
WB_US	2.10	1	0.34	0.48	1.93	20.10	762	0.10	0.12
WB_TRIB	1.29	1	0.34	0.51	1.52	23.40	765	0.31	0.18
WB_DS	4.21	1	0.34	0.54	3.16	19.30	758	0.24	0.18
WB_INT	0.82	1	0.34	0.68	0.90	19.30	758	0.51	0.18

FEH Statistical Method

- 3.1.8 The FEH Statistical method was undertaken for the catchments. A donor search was undertaken in WINFAP5 and a suitable donor selected (NRFA gauge reference 42017). The URBEXT limit was raised to 0.3 due to the urbanised nature of the catchment and, to enable inclusion of other local and urbanised gauges. The QMED values were adjusted within WINFAP5, which resulted in a marginal increase in the QMED estimate compared to catchment descriptor derived values.
- 3.1.9 Two pooling groups were derived based on NFS_DS and WB_DS, stations with poor quality and similarity were removed and appropriate stations added to provide pooling groups with approximately 500 years of data. The effect of increasing the URBEXT value to 0.3 on pooling group composition was investigated due to the urban nature of both catchments. There were five changes to the recommended stations for both the NFS_DS and WB_DS pooling groups, with all recommended stations located a significant distance from the subject catchments (largely northern England). Both watercourses are ungauged, with no NRFA stations available for use, therefore raising the URBEXT limit would not allow for the inclusion of watercourse-specific or local gauges. The default URBEXT limit of 0.03 was therefore retained for both pooling groups. The final FEH Statistical method peak flow estimates are provided in **Table 3.2**, full details of stations removed and added are provided in **Appendix E**.

Table 3.2 - Peak Flow Estimates Statistical Method

Site code	Peak flow estimates (m ³ /s) for return periods (years)				
	30	100	100cc25	100cc36	1000
NFS_US	0.30	0.41	0.51	0.56	0.72
NFS_DS	0.58	0.79	0.99	1.07	1.40
NFS_INT	0.22	0.31	0.39	0.42	0.54
WB_US	1.80	2.46	3.08	3.35	4.50
WB_TRIB	1.38	1.89	2.36	2.57	3.46
WB_DS	3.21	4.39	5.49	5.97	8.04
WB_INT	0.73	1.00	1.25	1.36	1.84

ReFH2 Method

- 3.1.10 The ReFH2 method was completed using the updated ReFH2.4 method with FEH22 rainfall data. Adjustments for urbanisation were applied in accordance with the guidance set out in the EA guidance¹, Section 4.3 (pages 101-102). Durations and storm profiles were derived for NFS_DS and WB_US and were applied to the remaining catchments and intervening catchments to represent a consistent storm over the total watercourses. A 4.5 hour duration summer storm was applied to Nore Farm Stream catchments, and an 8.5 hour duration winter storm was applied to West Brook. The peak flow estimates for these storms are provided in **Table 3.3**.

Table 3.3 - Peak Flow Estimates ReFH2 Method

Site code	Peak flow estimates (m3/s) for return periods (years)				
	30	100	100cc25	100cc36	1000
NFS_US	0.14	0.19	0.2375	0.2584	0.35
NFS_DS	0.24	0.32	0.4	0.4352	0.60
NFS_INT	0.15	0.20	0.25	0.272	0.38
WB_US	0.87	1.10	1.375	1.496	1.85
WB_TRIB	0.68	0.86	1.075	1.1696	1.44
WB_DS	1.49	1.88	2.35	2.5568	3.22
WB_INT	0.25	0.34	0.425	0.4624	0.66

- 3.1.11 It should be noted that the duration and storm profiles were updated as part of the hydraulic modelling exercise, details of which are provided in **Section 5.1**.
- 3.1.12 The ReFH2.4 peak flow estimates are selected for use in the hydraulic model. It is suitable for use deriving peak flows and hydrographs for small and urban catchments.
- 3.1.13 While the FEH Statistical method provides more conservative flow estimates than the ReFH2 method (see **Figure 3.3** and **Figure 3.4**), a review of the pooling groups showed that there was low confidence in the hydrological similarity of the pooling group composition. This would result in removing many years of data and increasing the distance values of those stations added to provide a pooling group with 500 years of data. This is likely due to the small catchment areas of the subject sites and the NRFA dataset does not contain many small catchments. Hence, the overall confidence level in the pooling groups and their resultant peak flow estimates is low. The ReFH2 method was therefore considered to be the preferred method for deriving peak flow estimates for the subject catchments.

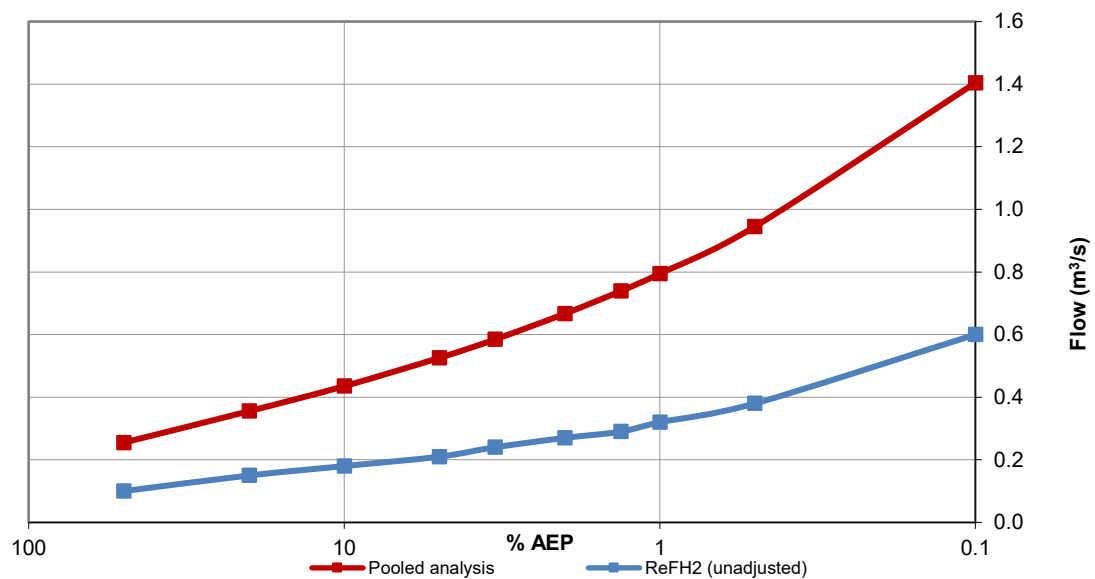


Figure 3.3 – ReFH2 Method

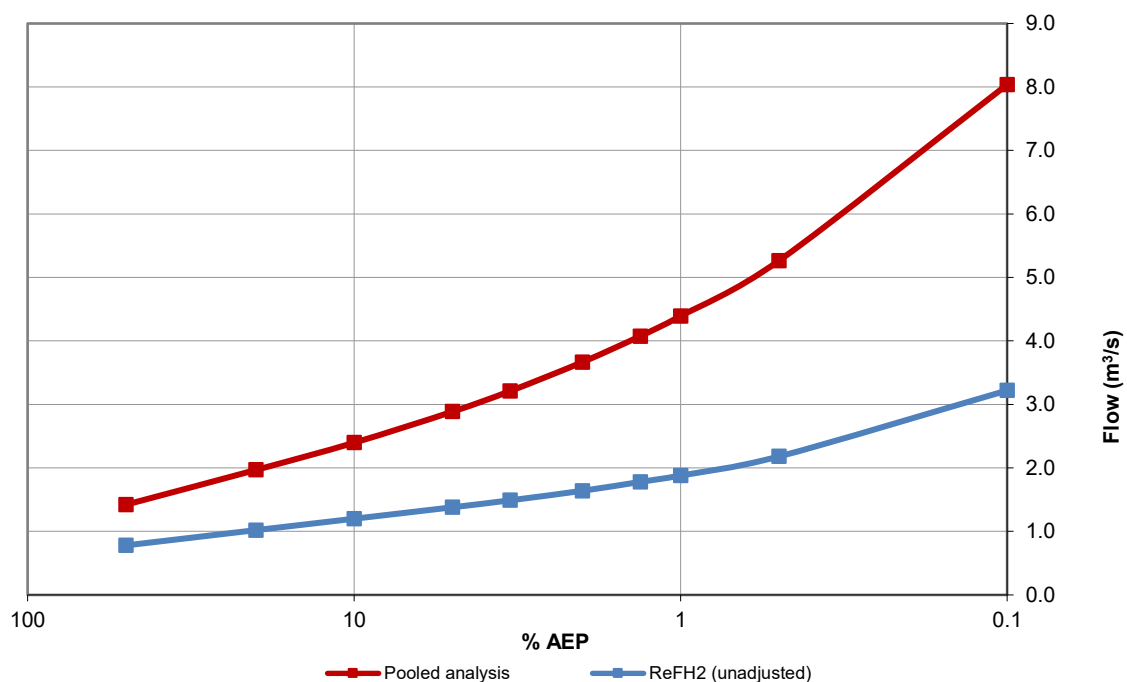


Figure 3.4 – Statistical Method

Inflow Preparation

- 3.1.14 To provide upstream inflows for the fluvial model the flows for WB_US were split to take account of the two open channels of the West Brook, north of Southleigh Road, the area south of Southleigh Road, and to take into account pipe and culvert influence within the upper reaches of the WB_US catchment.
- 3.1.15 Flows for WB_TRIB and WB_INT are not required to be split and are applied in the appropriate locations.
- 3.1.16 Flows for NFS_US and NFS_INT were also not required to be split.

- 3.1.17 The West Brook is open channel to the north-east of Horndean Road where it enters a culvert and flows under Horndean Road. At this point the alignment of the watercourse was not clear, and a CCTV survey was undertaken, and sewer plans obtained, as discussed in **Section 2.7**. CCTV survey indicated that there is a 600mm pipe which flows beneath Horndean Road from the residential area to the east of Horndean Road, and outfalls to the West Brook south of the A27.
- 3.1.18 A second surface water sewer pipe also drains the West Brook catchment, which flows beneath Horndean Road in a 225mm pipe and then flows east along Southleigh Road to Southleigh Park. The sewer then flows south from Southleigh Park and outfalls to the West Brook between the A27 and railway line. The inflows for the WB_US have therefore been updated to take account of this additional information and better represent the inflows to the hydraulic model.
- 3.1.19 **Figure 3.5** shows the inflow splits, **Section 4.3** shows the location of all the 1D inflows to the hydraulic model.

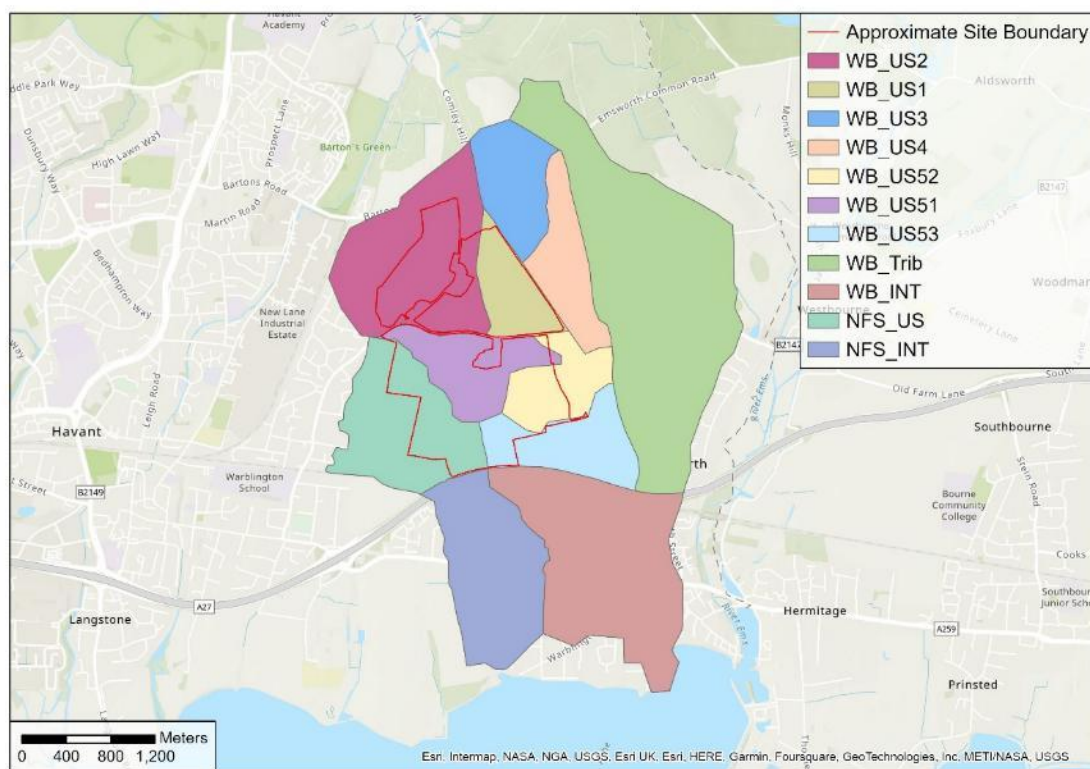


Figure 3.5 – Catchment Splits

- 3.1.20 The peak flow estimates for WB_US have been area-weighted to represent the areas shown in **Figure 3.5** and provide inflows to the hydraulic model. Stream analysis was undertaken in order to split the WB_US catchment into representative areas for inflow points.
- 3.1.21 As shown in **Figure 3.5**, WB_US1 (red) and WB_US2 (gold) are the topographic areas that drain to the open channels north of Southleigh Road. These areas will be applied as upstream inflows to the two open channels north of Southleigh Road.
- 3.1.22 WB_US3 (blue) is the topographic area that drains to the culvert which flows beneath Horndean Road and outfalls to the West Brook near West Brook View. WB_US4 (orange) is the area that is served by the surface water sewer that outfalls to the West Brook just upstream of the A27. WB_US51 to WB_US52 are the remaining catchment area of WB_US that was applied to the

model and was split using stream analysis undertaken using LiDAR to inform the inflow locations. The weightings used are provided in **Table 3.4**.

Table 3.4 - Area weightings for the West Brook upstream catchment

Area reference	Weighting applied
WB_US1	0.09
WB_US2	0.31
WB_US3	0.12
WB_US4	0.11
WB_US51	0.13
WB_US52	0.096
WB_US53	0.14

3.2 Surface Water Hydrological Assessment

- 3.2.1 To inform the surface water model of the catchment, a hydrological assessment was completed for the catchment of interest, to derive rainfall hyetographs to apply in the hydraulic model and estimate surface water flood risk.

Surface Water Catchment Area

- 3.2.2 The surface water catchment area has been obtained using the LiDAR derived catchments previously utilised in the fluvial hydrological assessment (**Appendix E**). The A27 road, south of the site, is a key topographic feature which is considered to influence surface water flow routes in the catchment. Consequently, the LiDAR-derived catchment areas north of the A27, which encompasses the site, are used to inform the surface water catchment area in this study (**Figure 3.6**). The catchment area for the surface water catchment analysis is approximately 3.87km².



3.2.3 The total catchment area for West Brook (WB_DS) spans much of the site and surface water catchment area (**Figure 3.7**). Consequently, the FEH22 depth-duration-frequency (DDF) data associated with the total catchment area for West Brook (WB_DS) has been used to inform the rainfall hyetographs for the model.

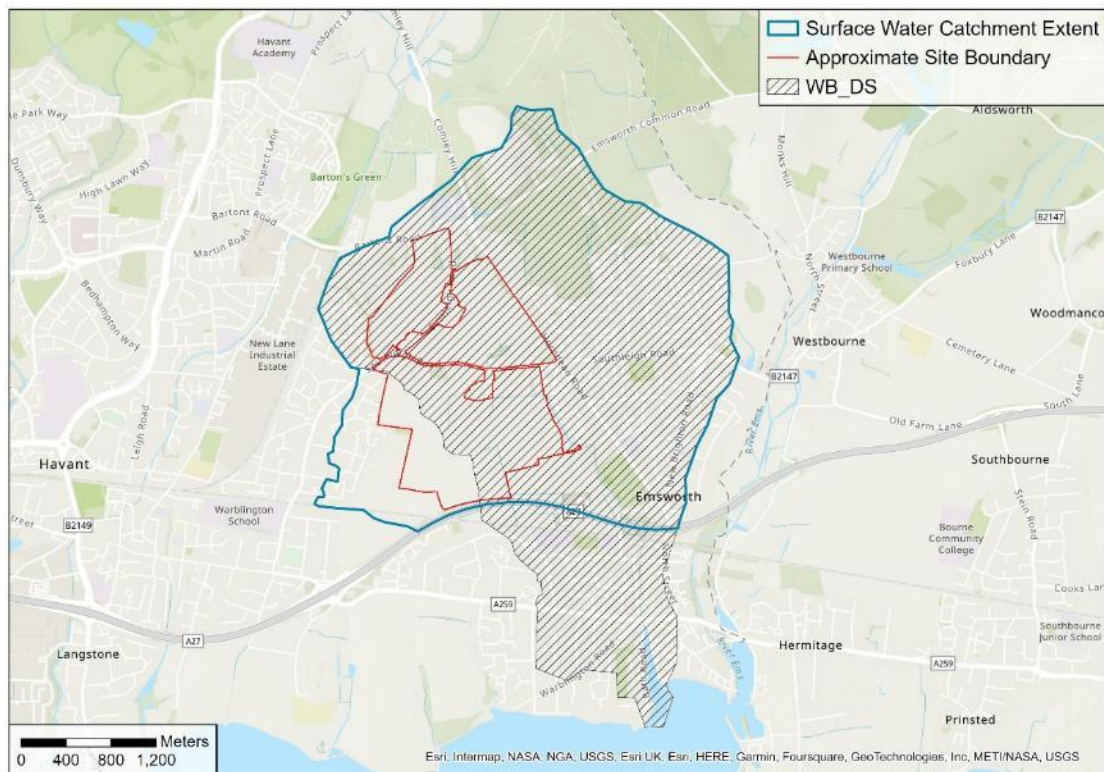


Figure 3.7 – Surface water catchment and West Brook catchment

- 3.2.4 FEH22 rainfall data and catchment descriptors for WB_DS have been used within the latest version of the ReFH2.3 software (version 4.0) to inform hyetographs. The catchment descriptors were checked and updated accordingly as part of the fluvial hydrological assessment (**Appendix E**). The catchment area (3.87km²) and urban area (1.5km²) were updated to reflect the revised surface water catchment area (**Figure 3.6**).

Applying losses to rainfall

- 3.2.5 According to the EA guidance on surface water flood risk mapping², design rainfall should be used with losses applied to represent the rainfall that is lost through infiltration, evaporation and drainage systems. The losses applied differ depending on whether areas are urban or rural. The guidance recommends that in rural areas losses should be applied using the soil characteristic loss model in ReFH2.
- 3.2.6 In urban areas, a 70% imperviousness factor should be applied to represent reduced infiltration due to impermeable surfaces in urban areas. Furthermore, a rainfall reduction of between 5mm/hr to 54mm/hr should be applied to represent the loss of rainfall into drainage systems. In this study a drainage loss of 5mm/hr is applied as a conservative approach. This was applied in the ReFH2 model by adjusting the sewer capacity input.
- 3.2.7 Urban areas within the model have the urban hyetographs applied to include the correct losses, and rural areas have rural hyetographs applied. The split of urban and rural areas is shown in **Section 6**.
- 3.2.8 Design rainfall hyetographs were exported from ReFH2 for the 1 in 30 year, 1 in 100 year and 1 in 1000 year events for the 1 hour, 3 hour and 6 hour durations. This is in accordance with the

EA guidance on surface water flood risk mapping². A summer rainfall profile is of shorter duration and therefore greater intensity than the winter profile and likely to be critical for surface water flooding. As such, a summer rainfall profile has been selected in the ReFH2 model, which is in accordance with the latest EA guidance. It should be noted that the summer profiles have been applied for the fluvial model as well as these presented the worst case scenario.

- 3.2.9 An overview of the total and maximum rainfall values from the derived hyetographs are shown in **Table 3.5** below.

Table 3.5 Total rainfall hyetographs

Total Rainfall (mm)						
Duration	1 in 30 year		1 in 100 year		1 in 1000 year	
	Rural	Urban	Rural	Urban	Rural	Urban
1hr	1.61	4.32	2.22	6.40	3.98	11.90
3hr	2.27	6.80	3.07	9.41	5.73	17.05
6hr	2.86	8.79	3.84	11.84	7.47	21.48

Max Rainfall (mm)						
Duration	1 in 30 year		1 in 100 year		1 in 1000 year	
	Rural	Urban	Rural	Urban	Rural	Urban
1hr	0.50	2.20	0.69	2.96	1.23	4.82
3hr	0.33	1.49	0.45	1.91	0.83	3.06
6hr	0.23	1.03	0.32	1.29	0.61	2.10

Climate Change

- 3.2.10 The NPPF and PPG place emphasis on the need to fully consider, and design for, the impacts of climate change. The EA 'Flood Risk Assessments: Climate Change Allowances' guidance (May 2022) provides contingency allowances for potential increases in rainfall intensity due to climate change.
- 3.2.11 The appropriate allowances are subject to the management catchment and the proposed lifetime of the development. The site lies with East Hampshire Management Catchment³ and is assumed to have a design lifetime of 100 years. The guidance indicates that the +40% 'upper end, 2070s' allowance should be considered for the 1 in 30 year rainfall event, whilst the +45% 'upper end, 2070s' allowance should be considered for the 1 in 100 year event.
- 3.2.12 A summary of the total and maximum rainfall values are provided below for the two climate change scenarios.

² EA, 2019, What is the Risk of Flooding from Surface Water map? Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/842485/What-is-the-Risk-of-Flooding-from-Surface-Water-Map.pdf

³ <https://environment.data.gov.uk/hydrology/climate-change-allowances/rainfall?mgmtcatid=3034>

Table 3.6 - Total and maximum rainfall hyetographs for climate change

Total Rainfall (mm)				
Duration	30 year +40%		100 year +45%	
	Rural	Urban	Rural	Urban
1hr	2.51	7.38	3.69	11.05
3hr	3.61	11.07	5.22	15.69
6hr	4.60	14.04	6.63	19.44

Max Rainfall (mm)				
Duration	30 year +40%		100 year +45%	
	Rural	Urban	Rural	Urban
1hr	0.78	3.30	1.14	4.54
3hr	0.52	2.16	0.76	2.86
6hr	0.38	1.48	0.54	1.93

Baseflow

- 3.2.13 Baseflow has been generated for all return periods and outputted from ReFH2 software. This has been applied to the model with weightings applied based on catchment area. **Table 3.7** outlines the area reference and the weighting applied to the baseflow.

Table 3.7 Area weightings for baseflow

Area reference	Weighting applied
WB_US1	0.05
WB_US2	0.17
WB_US3	0.06
WB_US4	0.06
WB_US51	0.07
WB_US52	0.05
WB_US53	0.07
NFS_US	0.12
WB_TRIB	0.33

4 Fluvial Hydraulic Modelling Summary

4.1 Model schematisation and approach

4.1.1 The fluvial hydraulic model was developed and run using TUFLOW–ESTRY version 2023-03-AC-iSP-w64 which is the latest version of software at the time of model build.

4.1.2 This model represents the risk of fluvial flooding associated with the watercourses running through the site including the Nore Farm Stream and the West Brook. The model has been run for a range of present day and climate change scenarios, based on the allowances set out in **Section 3.1**. The events assessed are:

- 1 in 30 year;
- 1 in 100 year;
- 1 in 100 year plus 25%;
- 1 in 100 year plus 36%;
- 1 in 1000 year .

4.2 2D model

Digital Terrain Model

4.2.1 A single 2D domain has been used to represent the entire model floodplain with a grid size of 2m. This is appropriate for the representation of detailed flow routes at the site of interest and results in reasonable computational run-times. The area of the 2D domain is approximately 2.08km².

4.2.2 The 2D domain extends south of Eastleigh Road down to Emsworth Mill Pond downstream of the A27. The upstream of the model extent was selected based on the locations of the upstream watercourse inflows, the domain extent is shown in **Figure 4.1**.

4.2.3 The topography of the floodplain was defined using a combination of LiDAR and a topographic survey of the proposed development site. The 1m DTM LiDAR flown in 2020 and downloaded from the DEFRA open-source data service platform provides wider coverage of the floodplain across the catchment. To supplement this, topographic survey was used to define the ground levels on site. Topographic survey data is used in preference to LiDAR data for the majority of the site.

4.2.4 **Figure 4.2** shows the extent of topographic survey applied to the model.



Figure 4.1 - Fluvial Model Domain

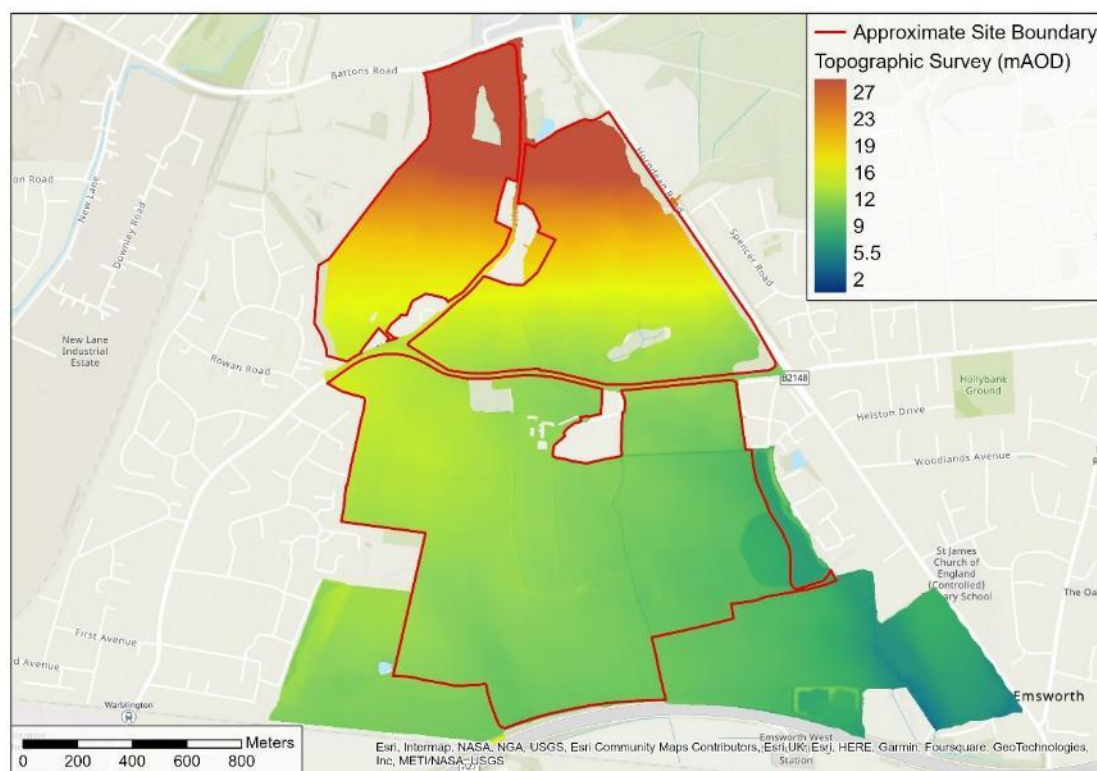


Figure 4.2 - Topographic Survey Extent

DTM Adjustments

4.2.5 Additional changes to the DTM were applied to the model to improve the representation of flow routes and ground levels on site. These changes are summarised below and shown in **Figure 4.3**.

- The 2D domain was connected to the 1D model at all river cross-section units via head-exchange (HX) connection lines. Ground levels at the linkage between the 1D channel and 2D floodplain model domains uses elevations from the cross-section survey to define the top of bank levels, which is the preferred modelling approach. This has been supplemented with topographic survey or LiDAR, where appropriate, between surveyed cross sections. The bank level representation has been informed by the channel survey using a Z line with points and lines (model layer: 2d_zln_SRHF_v11_banklines_L).
- Crest levels on site have been applied explicitly in three locations in order to represent the high ground accurately these include: the right bank of the Nore Farm Stream using top of bank survey data (model layer: 2d_zln_SRHF_v11_banklines_L), the flood storage area west of the West Brook using top of bank survey data (model layer: 2d_zln_SRHF_v01_banktops_L) and the crest levels of the Emsworth mill pond at the downstream extent informed by LiDAR levels (model layer: 2d_zln_SRHF_v12_crest_L).
- Structure decks were represented in 2D where the structure length exceeded three times the cell size in length. Structure deck levels were informed by channel survey and represent the overtopping of the structure (model layer: 2d_zln_SRHF_v03_decks_L).
- Minor ditches on site that have not been represented in 1D have been applied explicitly in 2D using a Z shape with the GULLY command with elevations informed by channel survey (where ditches are unconnected and raise to ground level), and topographic survey (model layer: 2d_zsh_SRHF_v03_ditches_L).
- The small pond to the west of the Nore Farm Stream has been applied explicitly using a 2D Z shape and Z line in order to set elevations for the pond, this has been informed by topographic survey (model layer: 2d_zsh_SRHF_v01_pond_R).

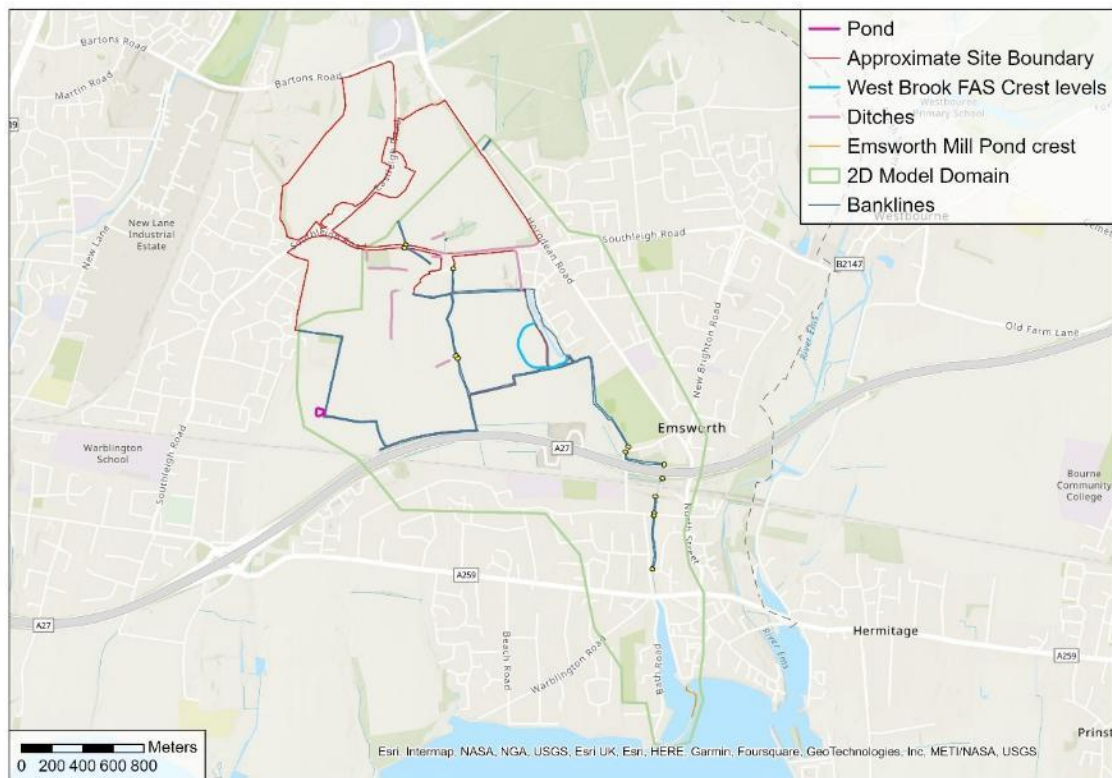


Figure 4.3 - DTM Adjustments

Floodplain Roughness

- 4.2.6 The floodplain roughness was applied using a 2d_mat materials layer to define different land use types. This was linked to the '.tmf' file which was defined using the roughness value for each land-use type. The 2d_mat materials layer (model layer: 2d_mat_SRHF_v01_mastermap_R) is based on the OS Mastermap dataset (as outlined in **Section 2.5**).
- 4.2.7 The Manning's 'n' values used to define the land-use type of the model are included in

4.2.8 **Table 4-1.**

Table 4-1 Manning's 'n' values

Material ID	Manning's 'n' value	Description
10021	1	Buildings
10053	0.08	Residential gardens
10056	0.05	Grazed fields, short grass
10089	0.035	Inland water
10111	0.1	Woodland
10123	0.022	Paths
10167	0.08	Railway
10172	0.022	Roads
10183	0.04	Grass verges
10210	0.04	Tidal water

Model Boundaries

- 4.2.9 An initial water level has been applied to the model at the downstream extent of the model, as shown in **Figure 4.4** – 2D Boundaries
- 4.2.10 , to represent the Mean High Water Spring tide level downstream of Emsworth Mill Pond at a level of 1.97mAOD (model layer: 2d_iwl_SRHF_v12_R). This value has been informed by the Coastal Design Sea Levels Coastal Flood Boundary Extreme Sea Levels dataset, downloaded from the Environment Agency on 1st August 2023. The remainder of the model domain starts dry, as it is assumed that LiDAR accurately represents initial ground levels within the model domain.
- 4.2.11 The 2D domain boundaries are defined by four boundaries applied at the eastern edge, southern edge and downstream model extent of the active model area to allow flow to drain out of the model, **Figure 4.4** – 2D Boundaries
- 4.2.12 . The four boundaries at the southern and eastern edge are HQ (Head/Flow) boundaries with an average gradient applied (model layer: 2d_bc_SRHF_v12_L). The boundary at the downstream model extent is a HT (Head/Time) boundary, within the same model layer, set to the Mean High Water Spring tide level downstream of Emsworth Mill Pond. The downstream boundary of the model is located approximately 2.2km downstream of the site. This is far enough downstream that the selection of the boundary does not impact the flood mechanisms and modelled flood levels at the site.
- 4.2.13 An inflow for the Nore Farm Stream intervening area has been applied in 2D downstream of the A27, **Figure 4.4** – 2D Boundaries
- 4.2.14 . This has been applied as a QT (Flow/Time) boundary (model layer: 2d_bc_SRHF_v13_inflow_sens_P).

- 4.2.15 No hydraulic structures have been included within the 2D domain, a check was undertaken to ensure that linear features were appropriately represented in the model grid.

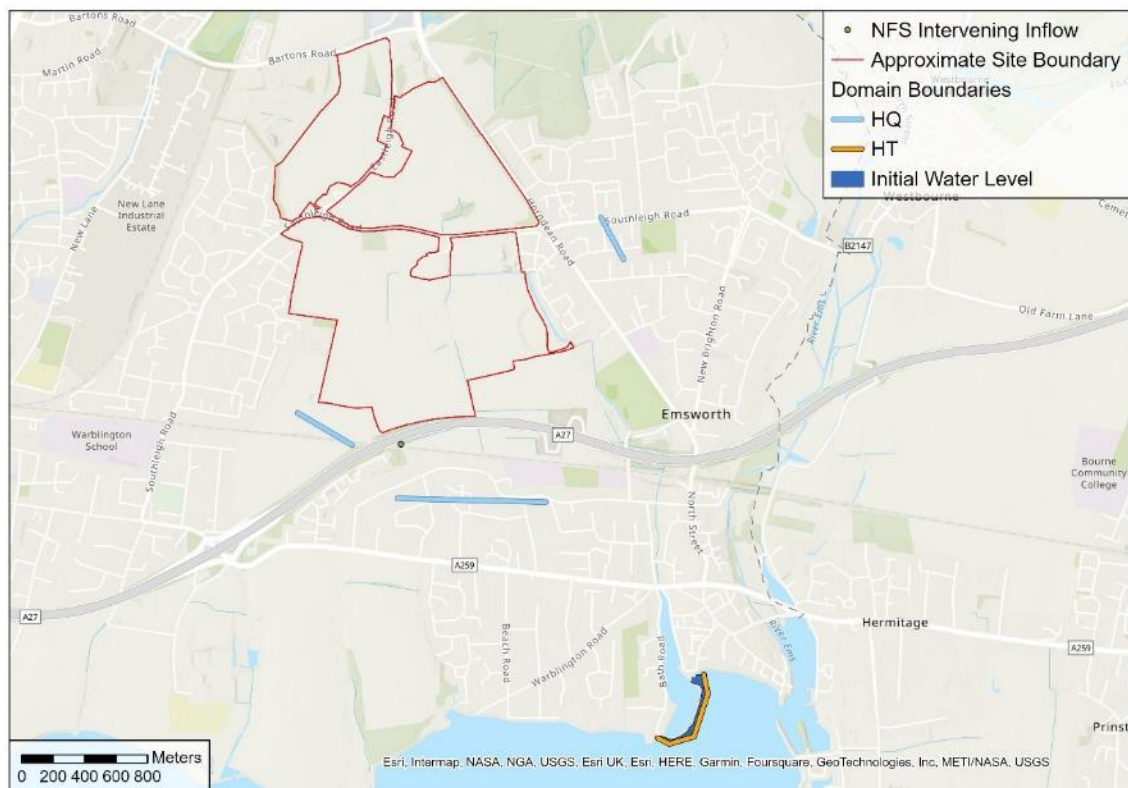


Figure 4.4 – 2D Boundaries

4.3 1D model

- 4.3.1 The conveyance of the watercourse channels is represented in 1D using ESTRY software, based on the watercourse survey data collected by Precision Point Surveys (**Section 2.2**). All hydraulic structures influencing flood flows were also represented in 1D using appropriate ESTRY units.

Model Extents

- 4.3.2 The extent of the hydraulic model is shown in **Figure 4.5**. The upstream boundary of the model furthest north is located upstream of the watercourse at Horndean Lane outside of the site boundary.

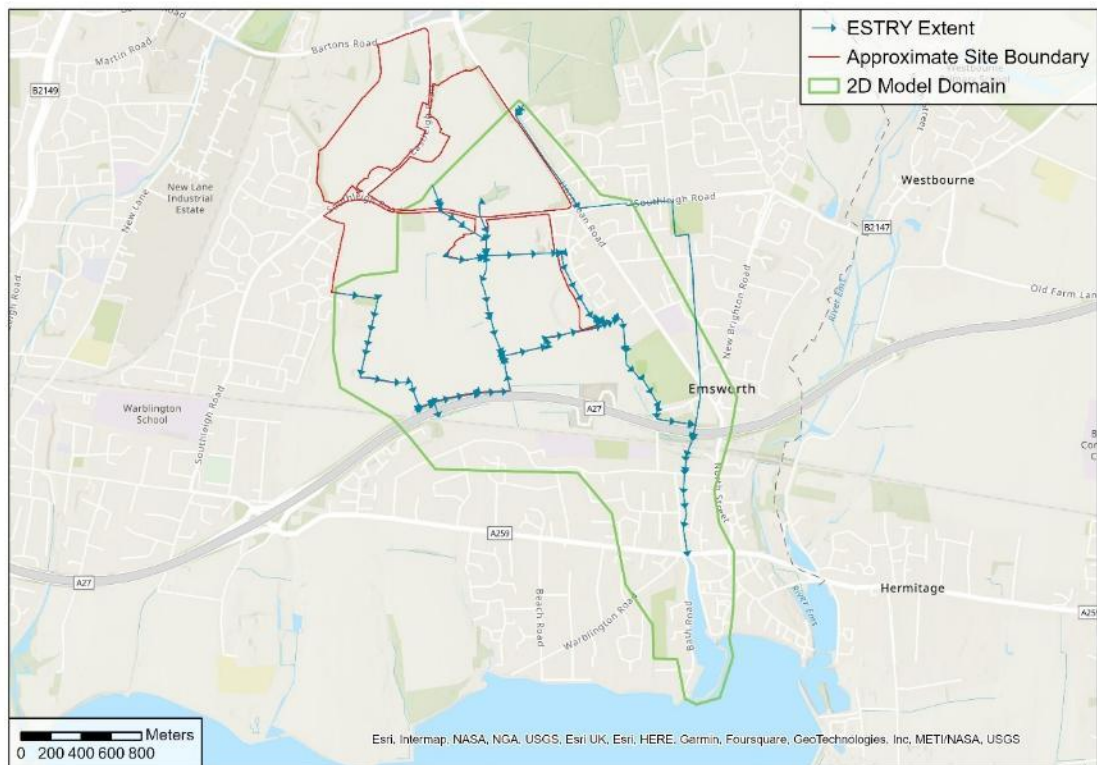


Figure 4.5 - 1D Domain Extent

Channel Roughness

- 4.3.3 The in-channel roughness values (Manning's 'n' coefficients) were reviewed throughout the model using the watercourse channel survey, photographs and satellite imagery to ensure that site specific values were used.

4.3.4 **Table 4-2** summarises the Manning's 'n' roughness values applied in the 1D model.

Table 4-2 Manning's 'n' channel roughness values

Bed - Description	Manning's 'n' Roughness value
Clean straight, no deep pools	0.03
Clean straight, some stones and weeds	0.035
Clean, winding with some pools and shoals weeds and stones	0.04
Sluggish reaches, weedy deep pools	0.05
Banks - Description	Manning's 'n' Roughness value
Gravel bottom with sides of formed concrete	0.025
Scattered brush and heavy weeds	0.05
Light to medium brush and trees	0.06
Medium to dense brush in summer	0.07

- 4.3.5 The Nore Farm Stream has a relatively uniform bed and a rougher right bank compared to left bank for the banks due to grazed crops on the left bank and hedgerows on the right bank.
- 4.3.6 The West Brook is rough for the channel bed upstream of the flood storage control structure due to weeds.
- 4.3.7 The unnamed watercourses have a relatively uniform bed, however bank roughness varies depending on the location of the watercourses.
- 4.3.8 Throughout the model Manning's 'n' values of 0.03 to 0.05 were applied for the channel beds to represent clean straight channels with no rifts or deeps pools to sluggish weedy reaches with deep pools. Manning's 'n' values of 0.025 to 0.07 were applied to the banks throughout the model to represent gravel channels with sides of formed concrete to medium to dense brush.

4.3.9 Example channel sections and their associated Manning's 'n' values are shown in **Figure 4.6** to **Figure 4.11**

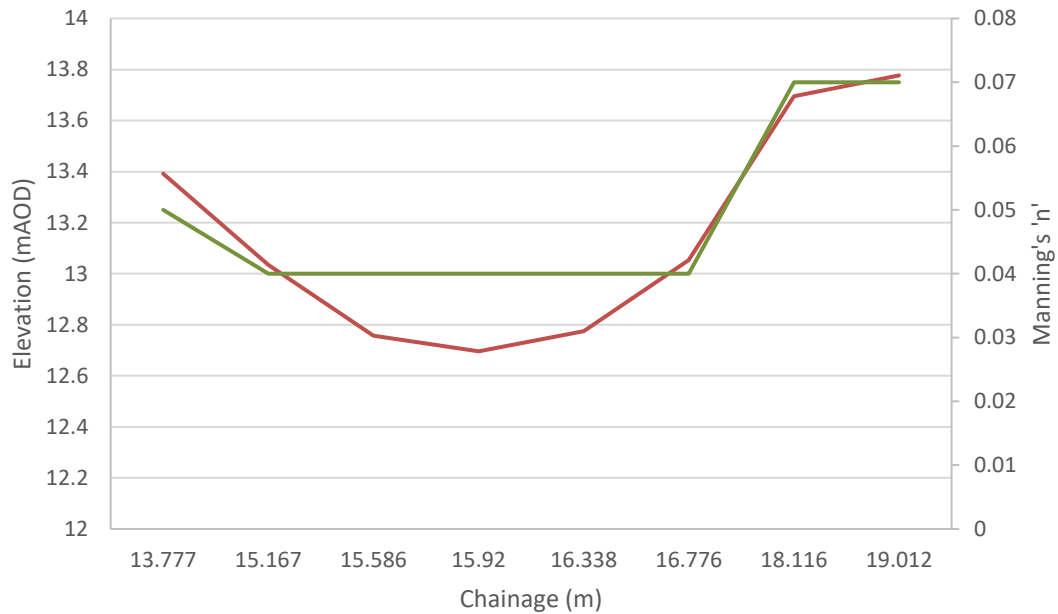


Figure 4.6 NOR01_0671 Manning's 'n' cross section profile



Figure 4.7 - Photograph of NOR01_0760

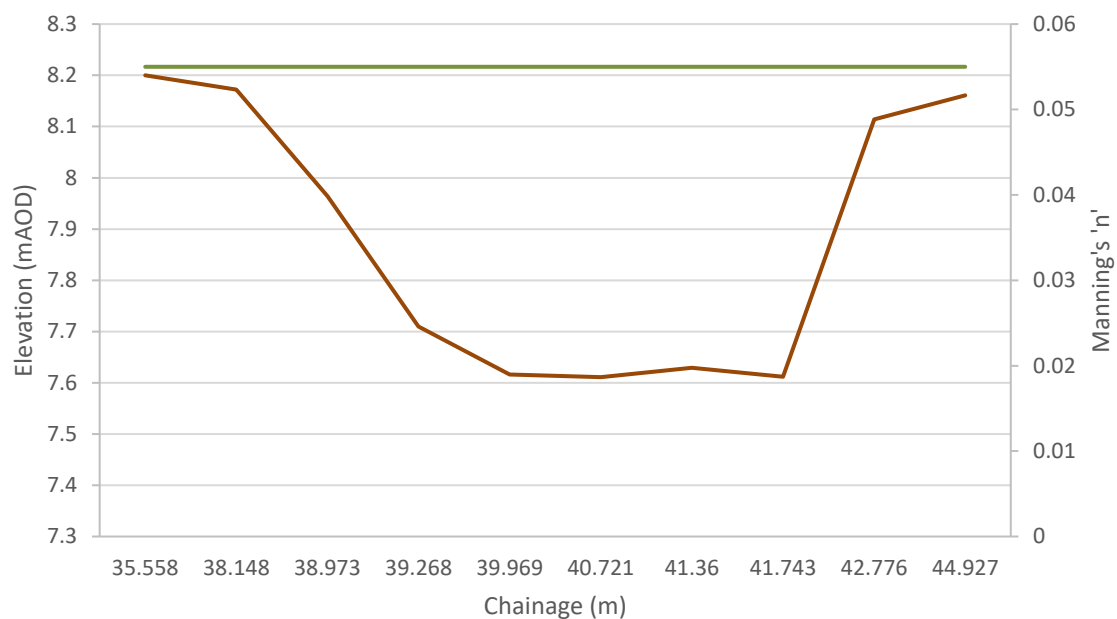


Figure 4.8 - WES01_0860 Manning's 'n' cross section profile



Figure 4.9 - WES01_0860 Survey Photograph

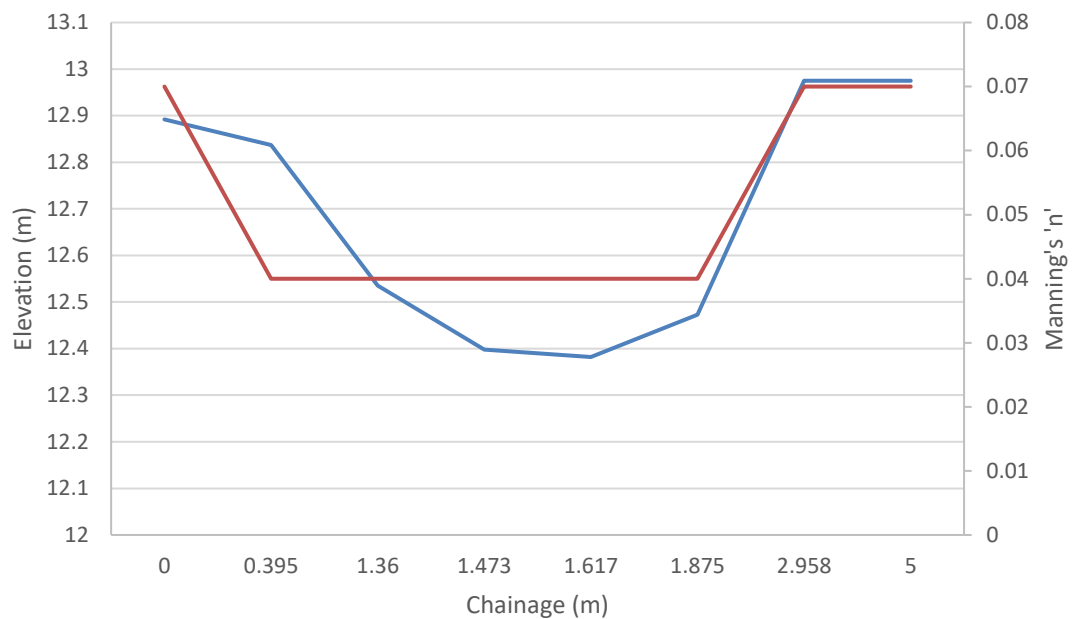


Figure 4.10 - UNK06_0225 Manning's 'n' cross section profile



Figure 4.11 - UNK06_0225 Survey Photograph

4.3.10 1D in-line spill units for structures were included to allow water to overtop in the event of high-water levels, typically where the length of the structure is less than 3 grid cells. Spill units were not used in the 1D model for structures that exceeded 3 grid cells in length, with the spill represented in the 2D model instead.

- 4.3.11 All spill coefficients were set as default according to the TUFLOW manual.
- 4.3.12 The floodplains were deactivated from all 1D sections and represented within the 2D domain.
- 4.3.13 Additional storage was applied to some nodes within the model domain at the location of some localised instabilities (model layer: 1d_nd_SRHF_v14_ANA_P). The storage within the nodes was increased by 10 times the existing storage, and by 20 in one location. Increasing nodal storage is a known fix for instabilities in the 1D domain and is recommended by TUFLOW. It is recommended that a sensitivity is undertaken to ensure that results are not unduly affected. This testing is discussed in **Section 8.4**.

Structures

- 4.3.14 The structures within the 1D modelled reaches within the ESTRY domain are summarised in

- 4.3.16 Table 4-3, including details of whether they have been included in the model and how they have been represented.

Table 4-3 ESTRY Structures

Structure ID	Description and Data Source	Model representation
FIE01_1023	Sluice gate, informed by channel survey	<p>Represented as a rectangular conduit that is uni-directional to prevent backflow from the Nore Farm Stream.</p> <p>Upstream invert 10.57mAOD, downstream invert 10.51mAOD. Height 0.88m and width 0.72m. 2.03m long.</p> <p>Spill represented in 1D.</p>
		

FIE01_0766

Footbridge with stop logs, informed by channel survey.

Represented as a rectangular conduit for the open area underneath the stop logs.

Upstream invert is 10.62mAOD, downstream invert 10.63mAOD. Width 0.31m, height 0.1m. 1.99m long.

Spill represented in 1D.



FIE01_0483

Footbridge, informed by
channel survey.

Represented as a bridge unit,
there is some blockage of the
structure due to vegetation, this
has not been represented.

Upstream and downstream
invert 10.22mAOD. 1.92m long.

Spill represented in 1D.



<p>SLU01_0001</p>	<p>Culvert with sluice gates covering opening, informed by channel survey.</p> <p>Length informed by aerial imagery.</p>	<p>Represented as two conduits, an irregular conduit to represent the open area between the sluice gate and the circular pipe. And a circular conduit to represent the structure under the A27.</p> <p>Irregular conduit upstream invert 10.21mAOD, downstream invert 10.06mAOD. Dimensions applied with a Head/Width table measured from survey data. 0.5m long.</p> <p>Circular conduit upstream invert 10.06mAOD, downstream invert 9.76mAOD. Diameter 1.05m. 97.41m long.</p> <p>Spill over irregular conduit represented in 1D.</p>
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UNK01_0174	Circular conduit, informed by channel survey.	<p>Represented as an irregular conduit to represent the open face of the culvert only given the siltation.</p> <p>Upstream invert 10.26mAOD, downstream invert 10.25mAOD. Dimensions applied in a Head/Width table measured from survey data. 14.22m long.</p> <p>Spill represented in 2D.</p>
		

UNK04_0250

Circular conduit, informed by channel survey.

Represented as an irregular conduit due to the siltation build up. Downstream of pipe assumed to be further left in survey photograph based on survey data.

Upstream invert 12.19mAOD, downstream invert 12.05mAOD. Dimensions applied using Head/Width table measured from channel survey. Length 14.7m.

Spill represented in 2D.



UNK04_0105

Circular conduit, informed by channel survey.

Represented as an irregular conduit due to the siltation build up. Location where culvert drains is uncertain, but making same assumption as surveyors that the downstream joins the UNK06.

Upstream invert 11.53mAOD, downstream invert 10.63mAOD. Dimensions applied using Head/Width table measured from channel survey. Length 170m.

Spill represented in 2D.



UNK06_0225	Circular conduit, informed by channel survey.	<p>Represented as a circular culvert, upstream invert at 12.34mAOD and downstream at 10.83mAOD. Diameter 0.22m and 192m long.</p> <p>Connection has been assumed based on survey data, surveyors could not confirm connectivity.</p>
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WES01_1102

Circular Culvert

Culvert not represented in model as unknown where upstream face originates. The downstream face of the structure is the upstream of this reach.



<p>WES01_0749</p>	<p>Sluice, informed by channel survey</p>	<p>Represented as a circular culvert due to lack of operational information regarding the sluice.</p> <p>Upstream invert 7.6mAOD as well as downstream. In reality there is a shallow adverse gradient on this structure, however this caused stability issues therefore represented as flat with the diameter adjusted in order to maintain the soffit level at the downstream. Diameter 0.44m (surveyed diameter 0.49m). Length 0.605m.</p> <p>Spill represented in 1D.</p>
		

WES01_0716

Foot bridge, informed by
channel survey

Represented as a flat deck
bridge with invert at 7.2mAOD.
Cross section applied and
trimmed to soffit level of
7.93mAOD. Length 1m.

Spill represented in 1D.



WES01_0679

Footbridge, informed by
channel survey

Represented as a flat deck
bridge as the arch of the
structure is shallow therefore
not considered to result in
significant losses. Soffit at
7.87mAOD, length 0.7m and
invert 7.11mAOD.

Spill represented in 1D.



WES01_0648

Weir

Not represented as considered little impact on water levels and downstream of the site of interest.



WES01_0646

Foot bridge, informed by
channel survey

Represented as a flat deck
bridge as the arch of the
structure is shallow therefore
not considered to result in
significant losses. Soffit at
8.39mAOD, length 0.9m and
invert 7.45mAOD.

Spill represented in 1D.



WES01_0504

Rectangular Culvert,
informed by channel
survey

Represented as a rectangular
conduit, upstream invert
6.08mAOD, downstream invert
5.96mAOD. 0.79m wide, 0.93m
high. 5.6m long.

Spill represented in 1D.



WES01_0211

Rectangular culvert,
informed by channel
survey

Represented as a rectangular
conduit, upstream invert
4.27mAOD and downstream
invert 4.14mAOD. Width 0.95m,
height 1m. 24m long.

Spill represented in 2D.



WES01_0000	Circular culvert, informed by channel survey	<p>Represented as a circular conduit, 3.3mAOD upstream invert and downstream in 2.93mAOD. 1.06m diameter. 58metres long according to 2006 channel survey.</p> <p>Within the pipe at WES01_0000 an additional pipe enters the culvert from the left side, the connectivity of this pipe is unknown.</p>
		
		

WES_501

Circular Culvert, informed
by 2006 channel survey

Represented as a circular
conduit, upstream invert at
3.01mAOD, downstream invert
at 2.72mAOD. Diameter is
1.33m, with a length of 67m.

Spill represented in 2D.



WES_362	Circular culvert, no photograph available, informed by 2006 channel survey	<p>Represented as an irregular culvert, upstream invert 2.48mAOD downstream invert 2.49mAOD. Diameter specified by Head Width table. Length 11m.</p> <p>Spill represented in 2D.</p>
WES_122	Arch culvert with trash screen	<p>Trash screen not represented, located over 1km downstream from site of interest therefore this trash screen will not impact the flood levels on site.</p> <p>Represented as an irregular conduit with upstream invert at 1.57mAOD and downstream invert at 1.44mAOD. Diameter specified by Head Width table. Length 122m.</p> <p>Spill represented in 2D.</p>



WES02_0000	Culvert located at the upstream of reach WES02.	Culvert not represented as the inlet of the culvert could not be located. WES02 ditch not represented in 1D due to the shallow nature of the ditch and unknown connectivity.
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WES03_0000	Culvert informed by channel survey, CCTV survey and sewer plans.	<p>Represented as four circular culverts. The first culvert represents the inlet to the manhole with upstream and downstream invert at 22.31mAOD. Diameter at 0.3m and 3.7m long.</p> <p>The second culvert runs from the manhole to manhole SW06 where the diameter of the culvert changes according to CCTV survey. The upstream invert of the culvert is 22.12mAOD and downstream 18.5mAOD. Length is 120m with diameter of 0.225m.</p> <p>The third culvert runs down the remainder of Horndean Road and then east. The upstream invert is 18.5mAOD and downstream 11.03mAOD. The downstream invert is informed by sewer plans. Length is 348m and the diameter is 0.3m according to CCTV survey.</p> <p>The fourth culvert is informed by sewer plans and has an upstream invert of 11.03mAOD and downstream of 2.93mAOD which joins the West Brook downstream of the A27. Diameter is 0.375m and length ~1400m.</p> <p>Spills are represented in 2D.</p>
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Boundaries

- 4.3.17 The upstream boundaries applied to the model in ESTRY are QT (Flow/Time) boundaries. These boundaries have been applied in accordance with the hydrological catchment splits, the location of these inflows are shown in **Figure 4.12** and the approach is described in **Section 3.1**.

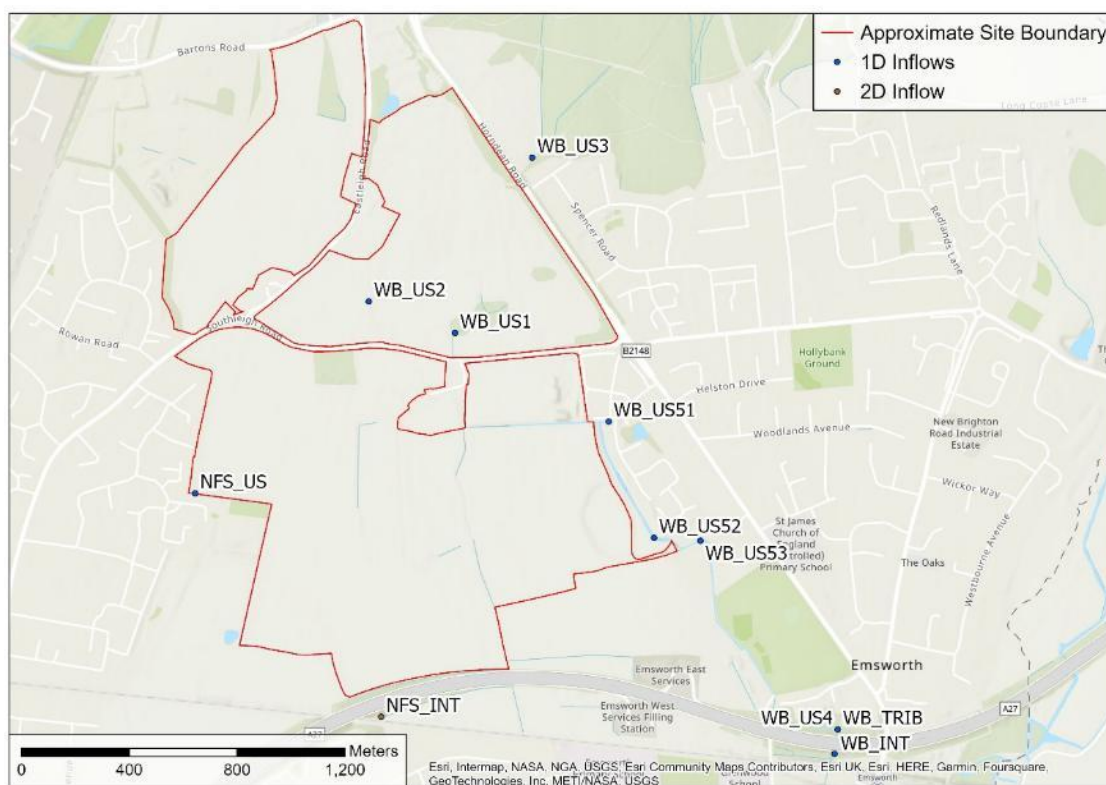


Figure 4.12 - Fluvial inflow locations

5 Fluvial Hydraulic Model Results

5.1 Model run scenarios and parameters

- 5.1.1 The hydraulic model was run for the winter and summer storm for the largest event (1 in 1000 year) in order to determine the worst case scenario for the site of interest. The results demonstrated that the summer storm resulted in a worst case scenario for both the Nore Farm Stream and West Brook catchments, therefore this has been brought forward as the design scenario.
- 5.1.2 The hydraulic model was run for the 1 in 30 year, 1 in 100 year and 1 in 1000 year present day events and the 1 in 100 year with 25% and 36% climate change allowances for the summer storm. These events have been selected to understand the impacts of climate change over the lifetime of the development.
- 5.1.3 The simulation time of 50 hours was adopted to allow sufficient time after the peak water levels for the model to drain on site. Based on the 2m grid size for the 2D domain a 2D timestep of 1 second and a 1D timestep of 0.5 seconds were used.

5.2 Model Simulations

- 5.2.1 The model simulations and the model versions used are summarised in **Table 5-1**.

Table 5-1 Model Simulations

Event	Model File
1 in 30 year	SRH~s1~_v19-~e1~.tcf
1 in 100 year	SRH~s1~_v19-~e1~.tcf
1 in 100 year plus 25% climate change	SRH~s1~_v19-~e1~.tcf
1 in 100 year plus 36% climate change	SRH~s1~_v19-~e1~.tcf
1 in 1000 year	SRH~s1~_v19-~e1~.tcf

- 5.2.2 The ESTRY file is contained within the 1D section of the TUFLOW control file (.tcf), and the TUFLOW geometry and boundary files are named 'SRHF_v19.tgc' and 'SRHF_v19.tbc' respectively.

5.3 Model performance overview

- 5.3.1 The model performance was based on all simulated events. The 1D and 2D mass balance error for all return periods are presented in **Table 5-2** Mass Balance Summary.

Table 5-2 Mass Balance Summary

Event	1D Mass Balance	2D Mass Balance	Negative depths
1 in 30 year	0.08	0.03	0
1 in 100 year	0.06	0.03	0
1 in 100 year plus 25% climate change	0.03	0.02	0
1 in 100 year plus 36% climate change	0.04	0.02	0
1 in 1000 year	0.04	0.01	0

- 5.3.2 The mass balance error is within acceptable limits for both the 1D and 2D domains for all events modelled.
- 5.3.3 For all model scenarios there are no negative depths during the simulations. Warnings prior to the simulation starting are mainly associated with null, SX lowering and ignored objects. The files that warnings are associated with have been reviewed with the conclusion that they do not impact the model results.
- 5.3.4 The 1D outputs indicate that the model is generally stable, with isolated periods of instability after the peak of the event at some locations. These locations are located on the site boundary with the field drain that connects the Nore Farm Stream and West Brook. This is associated with water flowing in and out of the 1D due to proximity to the Flood Storage area. There is also an instability at the peak of the event for the 1 in 100 year within the Field drain running north to south, it should be noted that although this is located within the site boundary there is only 0.002m³/s of flow within the ditch. Therefore, instabilities are associated with the ditch running dry in this location.
- 5.3.5 The long section for all maximum water levels for all modelled events have been reviewed, and the water level is highest for the largest event and lowest for the smallest event, as expected.
- 5.3.6 Based on the above the Southleigh fluvial model produces stable and representative results.

5.4 Baseline Model Results

- 5.4.1 The hydraulic modelling results will be presented for the site of interest, the fluvial modelling should be used in preference over the surface water modelling for 1D results.
- 5.4.2 Mapped results from the model presenting flood extents and flood depths for all modelled events are included in **Appendix F**.
- 5.4.3 At the centre of the site of interest at Southleigh Road for the design event, out of bank flooding occurs within the proposed development site at 0.5hrs after the start of the model simulation. This occurs at the left bank of Unknown drain 4 where the left bank is overtopped. The flows in a south easterly direction before running along Southleigh Road.
- 5.4.4 At 2.5 hours into the simulation out of bank flooding occurs upstream of the culvert which joins Unknown drain 4 to Unknown drain 6 in a south easterly direction. At 4 hours into the simulation

Southleigh Road is overtopped and a flow route runs south into the site of interest and then south east towards Unknown drain 6. Out of bank flooding occurs for Unknown drain 6 at 3.25 hours into the simulation which flows in a south westerly direction to Southleigh Road.

- 5.4.5 Within the site of interest, to the west of Horndean Road, out of bank flooding occurs 4.25 hours into the simulation where the capacity of the pipe under Horndean Lane is exceeded. Flooding runs along Horndean Road before running west and inundating the eastern edge of the site. This flows in a south easterly direction before reaching West Brook View and draining into the West Brook.
- 5.4.6 Within the site of interest to the west of the West Brook FSA, flooding occurs at 7.5 hours into the simulation when the flood storage area becomes inundated with flow running west. Flood waters are contained within the FSA due to the embankment.
- 5.4.7 At the south of the site, upstream of the Nore Farm Stream sluice gates on the A27 structure, out of bank flooding occurs 4.25 hours into the simulation. Flow runs in a northerly direction before ponding in low lying ground. This then flows in a north westerly direction before joining with the flow route from the Nore Farm Stream flow route. Overtopping occurs just south of Daffodil Way, when the left bank is overtopped at 5.25 hours into the simulation, before flowing in a south easterly direction.
- 5.4.8 Immediately downstream of the site of interest, flooding occurs 4.25 hours into the simulation downstream of the flood storage area of the West Brook. However, this does not inundate the south east corner of the site. Flooding also occurs downstream of the A27 at the Nore Farm Stream within the residential area. It should be noted that in this location there is culverted reach which could not be modelled and therefore the flood extents in this location are conservative.
- 5.4.9 Flood extents for the design event are presented on **Figure 5.1**. The maximum modelled water levels are shown in **Table 5-3**, with the node locations shown in **Figure 5.2**. Flood extents for the 1 in 100 year and 1 in 1000 year are presented against the Flood Zones 3 and 2 from the Flood Map for Planning on **Figure 5.4**.

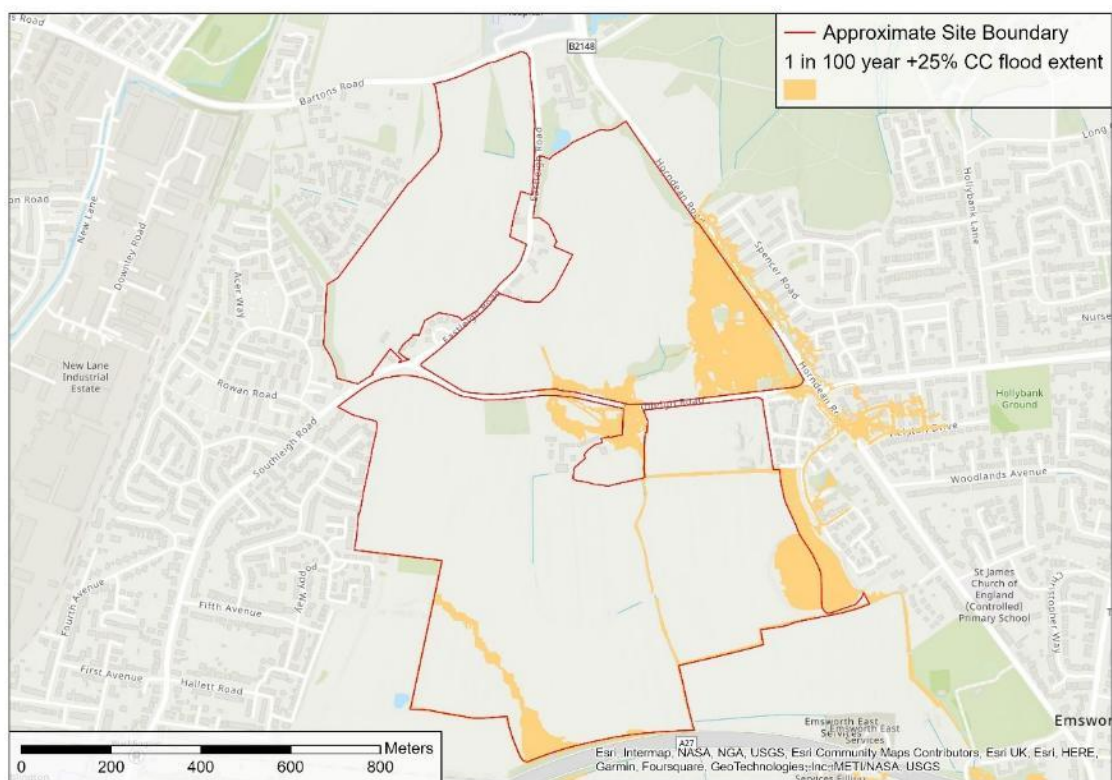
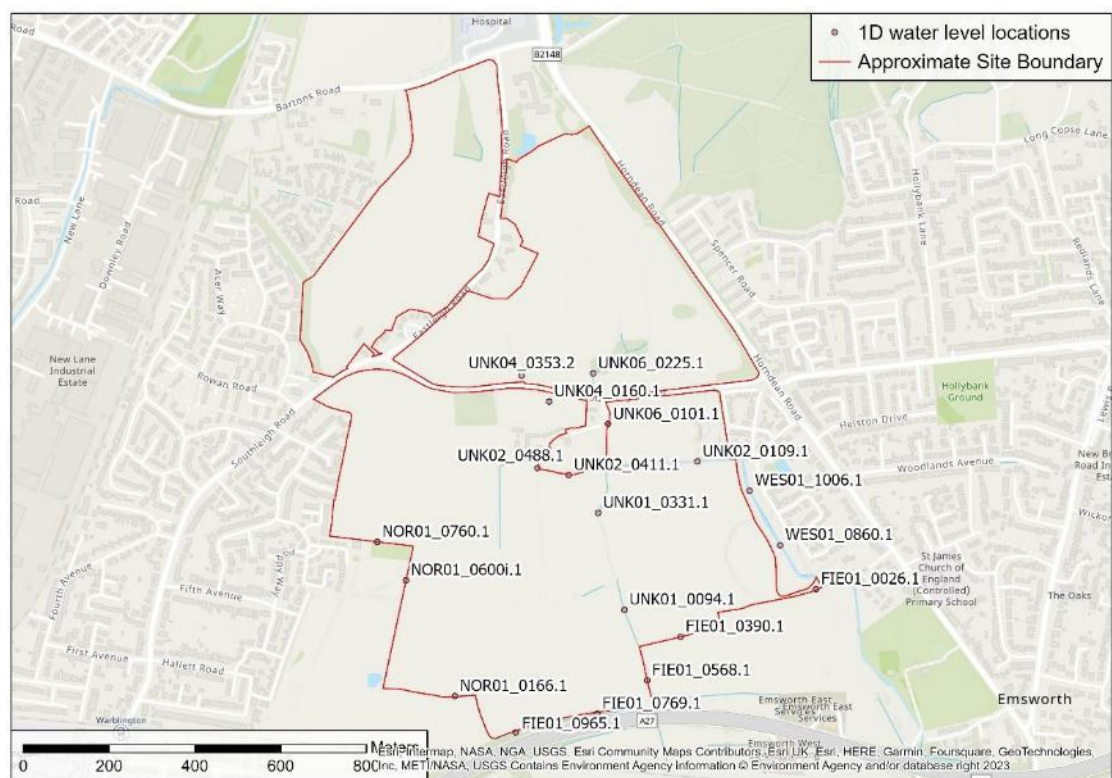


Table 5-3 Maximum modelled water levels (mAOD)

ID	1 in 30 year	1 in 100 year	1 in 100 year +25%CC	1 in 100 year +36%CC	1 in 1000 year
FIE01_0026.1	8.10	8.14	8.19	8.20	8.29
FIE01_0390.1	10.21	10.34	10.37	10.39	10.47
FIE01_0568.1	10.49	10.64	10.69	10.71	10.81
FIE01_0769.1	10.69	11.27	11.29	11.30	11.33
FIE01_0965.1	11.25	11.28	11.29	11.30	11.34
NOR01_0166.1	11.25	11.28	11.31	11.32	11.36
NOR01_0600i.1	12.78	12.82	12.86	12.87	12.88
NOR01_0760.1	13.19	13.24	13.28	13.29	13.26
UNK01_0094.1	10.42	10.56	10.60	10.62	10.72
UNK01_0331.1	10.99	11.02	11.06	11.07	11.11
UNK02_0109.1	9.76	9.82	9.88	9.91	9.98
UNK02_0411.1	11.19	11.19	11.19	11.19	11.19
UNK02_0488.1	11.38	11.38	11.38	11.38	11.38
UNK04_0160.1	12.32	12.35	12.38	12.39	12.44
UNK04_0353.1	14.07	14.08	14.11	14.14	14.22
UNK06_0009.1	11.01	11.04	11.08	11.10	11.14
UNK06_0101.1	11.21	11.27	11.33	11.36	11.43
UNK06_0225.1	13.09	13.09	13.10	13.10	13.11
WES01_0860.1	8.75	8.98	9.20	9.29	9.50
WES01_1006.1	8.75	8.98	9.20	9.29	9.50

5.4.10 The maximum modelled depths are shown in **Figure 5.3**, along with the location where depth and level results have been extracted for the 2D flood extent.

5.4.11 **Table 5-4** shows the maximum depth results for key locations at the site of interest. The results demonstrate that the majority of the major overland flow routes on site are less than 0.15m deep. There are some areas with flood depths greater than 0.15m within the site boundary including upstream of the A27 near the Nore Farm stream, in the central area of the site near Southleigh Road and the flood storage area of the West Brook.

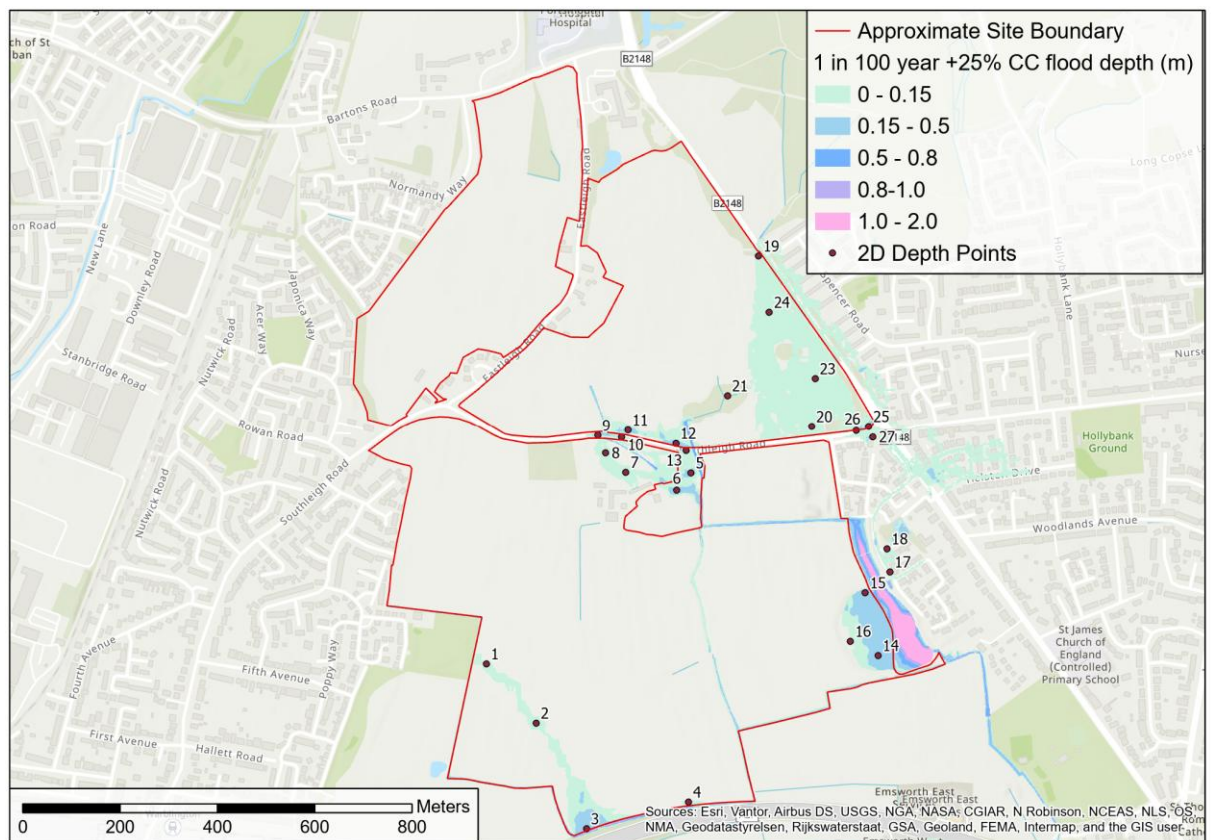


Figure 5.3 - Maximum depth map for 1 in 100 year plus 25% cc event with 2D depth points

Table 5-4 - Maximum depth for 2D flood extent (m)

ID	1 in 30 year	1 in 100 year	1 in 100 year +25% CC	1 in 100 year +36% CC	1 in 1000 year
1	0.00	0.00	0.00	0.01	0.02
2	0.00	0.00	0.00	0.01	0.02
3	0.39	0.42	0.43	0.44	0.48
4	0.00	0.03	0.05	0.05	0.09
5	0.32	0.33	0.33	0.33	0.34
6	0.23	0.26	0.29	0.30	0.33
7	0.00	0.01	0.01	0.01	0.02
8	0.00	0.00	0.00	0.00	0.00
9	0.25	0.26	0.26	0.26	0.27
10	0.11	0.11	0.12	0.12	0.13
11	0.30	0.31	0.32	0.32	0.33
12	0.30	0.30	0.31	0.31	0.32
13	0.03	0.03	0.04	0.04	0.04
14	0.00	0.15	0.38	0.47	0.67
15	0.00	0.13	0.35	0.44	0.65
16	0.00	0.00	0.01	0.10	0.31
17	0.04	0.05	0.06	0.06	0.06
18	0.00	0.00	0.00	0.01	0.01
19	0.01	0.01	0.02	0.02	0.02
20	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.03	0.05
23	0.01	0.01	0.01	0.01	0.02
24	0.00	0.00	0.00	0.00	0.00
25	0.33	0.34	0.34	0.35	0.35
26	0.50	0.50	0.51	0.51	0.52
27	0.25	0.27	0.28	0.29	0.30

5.4.12 The comparison between the modelled extents and the Flood Zones at the site of interest shown in **Figure 5.4** demonstrates that both modelled flood extents at the West Brook and Nore Farm Stream are smaller than the reference EA Flood Zones. This can be explained by the Flood Zone data for the Nore Farm Stream using modelling that predates the FAS scheme and control structures. Therefore, the flow route that runs in a southeasterly direction to the A27 is significantly reduced in flood extent. In the case of the West Brook, the modelled extents are only slightly reduced as the Flood Zones appear to have been delineated according to the Flood Storage area.

5.4.13 The model results show that for both the model developed in this study and the EA Flood Zones for the 1 in 100 year event, there is flooding at the Nore Farm Stream upstream of the A27 and along the West Brook within the FSA. However, the flow path running in a south westerly direction from the Nore Farm Stream to the A27 is not present. The model results from this study are considered more representative of the flood risk than the EA Flood Zones as this model is more detailed including the use of site specific data for both the hydrological assessment and hydraulic model build.

- 5.4.14 The modelled extents are larger than the EA Flood Zones in the centre of the site at Southleigh Road and Horndean Road. This is due to the EA Flood Zones not taking into account the smaller watercourses and ditches on site within the existing modelling studies and therefore the modelled results can be considered more accurate due to the use of site specific data.

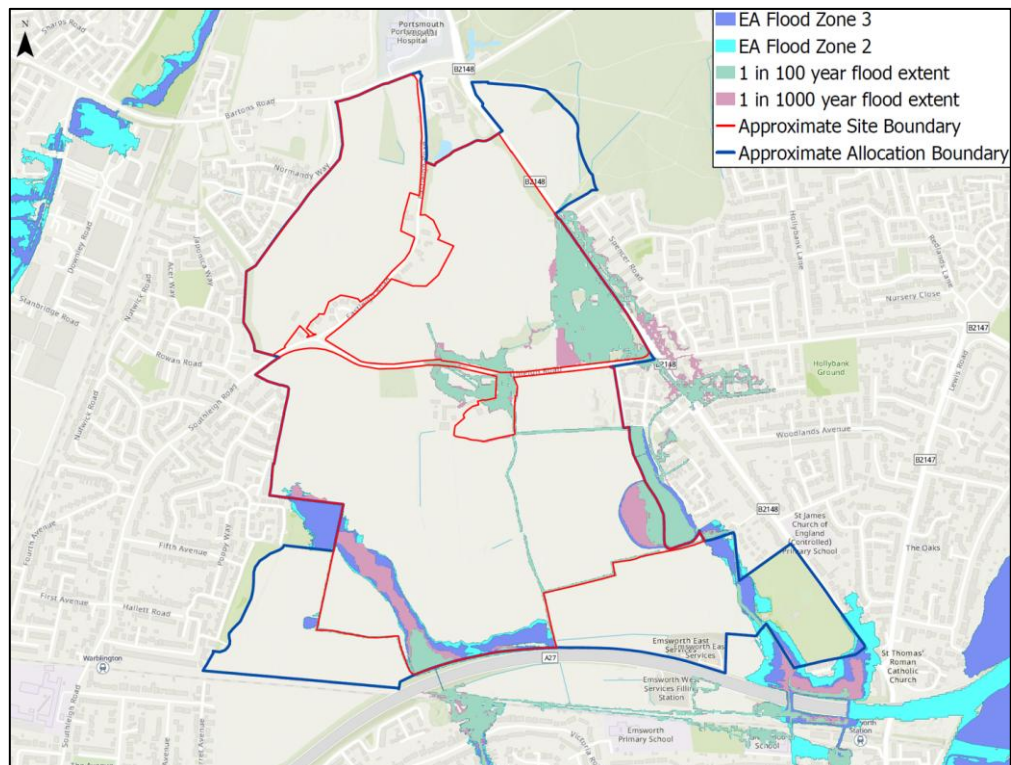


Figure 5.4 - Flood Zone comparison against modelled results

6 Surface Water Hydraulic Modelling Summary

6.1 Model schematisation and approach

6.1.1 The surface water hydraulic model was developed using the fluvial model. This chapter outlines the amendments made to the model in order to convert the fluvial model build to a surface water model. The surface water model was run using TUFLOW version 2023-03-AC-iDP-w64 which is the latest version of software at the time of model build. Double precision was utilised as this is the recommended approach for surface water models.

6.1.2 This model represents the risk of surface water flooding associated with the catchments draining to the site including the Nore Farm Stream and the West Brook. The model has been run for a range of present day and climate change scenarios, based on the allowances set out in **Section 3.2**. The events assessed are:

- 1 in 30 year;
- 1 in 30 year plus 40%;
- 1 in 100 year;
- 1 in 100 year plus 45%;
- 1 in 1000 year

6.2 2D model

Digital Terrain Model

6.2.1 A single 2D domain has been used to represent the surface water model. The area of the 2D domain has been increased at the upstream extent from the fluvial model to appropriately represent the surface water flow routes to the site of interest.

6.2.2 The area of the 2D domain is approximately 3.87km². The 2D domain extends from Hollybank Woods, north of Emsworth Common Road, to the A27 as shown in **Figure 6.1**.

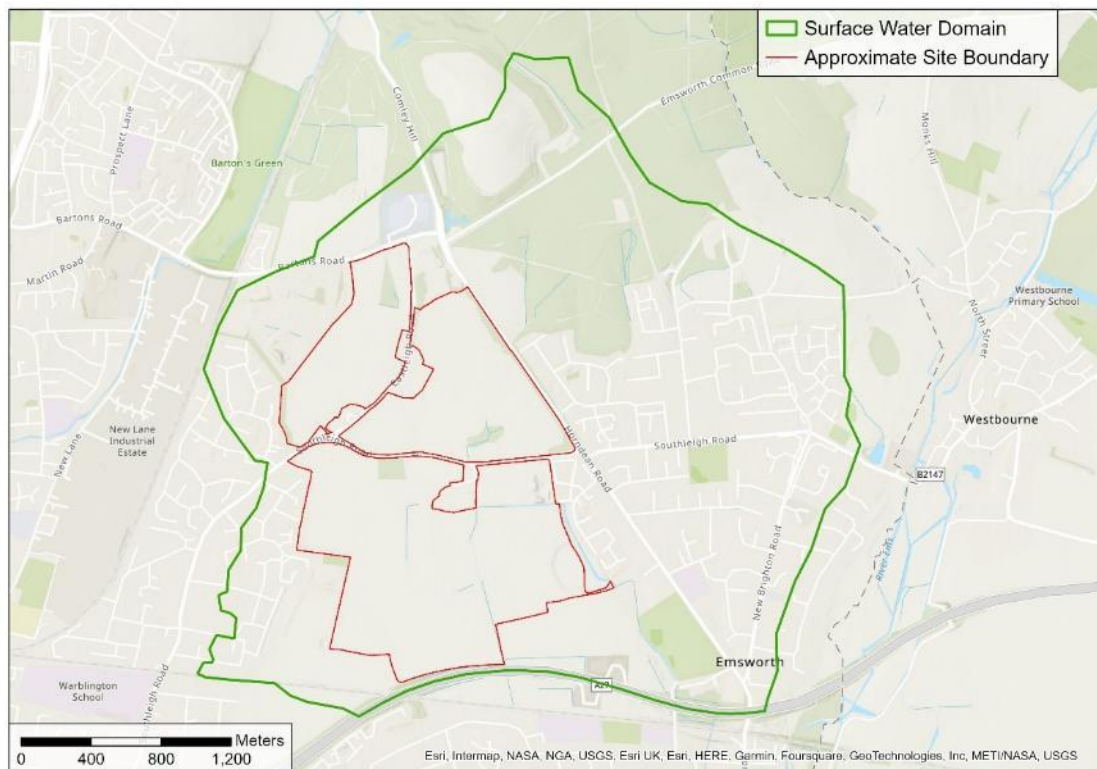


Figure 6.1 - Surface water domain

DTM adjustments

- 6.2.3 Additional changes to the DTM were applied to the surface water model in order to improve the representation of flow routes and ground levels. These changes are summarised below, and shown in **Figure 6.2**.
- 6.2.4 Ditches within the most northern parcel of land have been applied explicitly in 2D using a Z shape with the GULLY command with elevations set from topographic survey (model layer: 2d_zsh_SRHP_v15_ditches_L). The northern parcel of the site was not included in the fluvial model.
- 6.2.5 All buildings within the 2D domain have been raised by 0.3m in accordance with the EA guidance on surface water model builds. This is applied using a grid (model layer: building_raising_trimmed.tif).
- 6.2.6 Roads within the 2D domain have been lowered by 0.15m in accordance with EA guidance, this has been applied using a grid (model layer: Road_lowering.tif).
- 6.2.7 The surface water model has been trimmed so that the downstream of the surface water model is the A27. Therefore, the inactive code layer and banklines and points, and bridge decks have been updated to remove anything downstream of the A27 as this is not relevant to the surface water study.

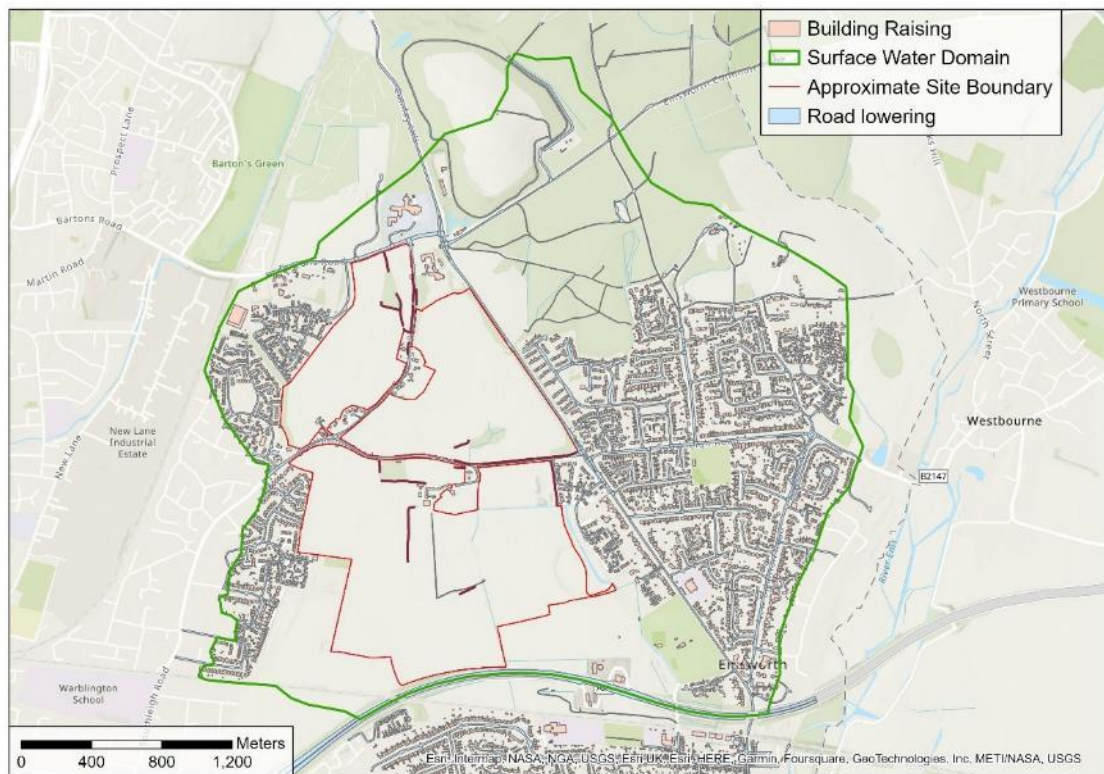


Figure 6.2 - Surface water model DTM adjustments

Roughness

- 6.2.8 The floodplain roughness was updated to include depth varying manning's to apply different roughness values depending on the depth of water. This is defined within the '.tmf' and the initial roughness value applied matches the values applied in the fluvial model presented in

6.2.9 **Table 4-1**, excluding buildings.

6.2.10 The initial manning's 'n' value applied to buildings has been updated to 0.1, in the fluvial model build the value was 1.0, this is considered to be more realistic given the buildings are represented as 0.3m high setting the roughness to a lower value allows water to be conveyed within the buildings. This is a 'stubby' building approach which is an option recommended by the EA for representation of buildings.

Boundaries

6.2.11 No initial water levels have been applied to the model.

6.2.12 The rainfall is applied to the model using 2d_rf boundaries (model layer: 2d_rf_SRHP_v18_reduced_R), these apply the rural and urban rainfall to the model as discussed in **Section 3.2** and shown in **Figure 6.3** below.

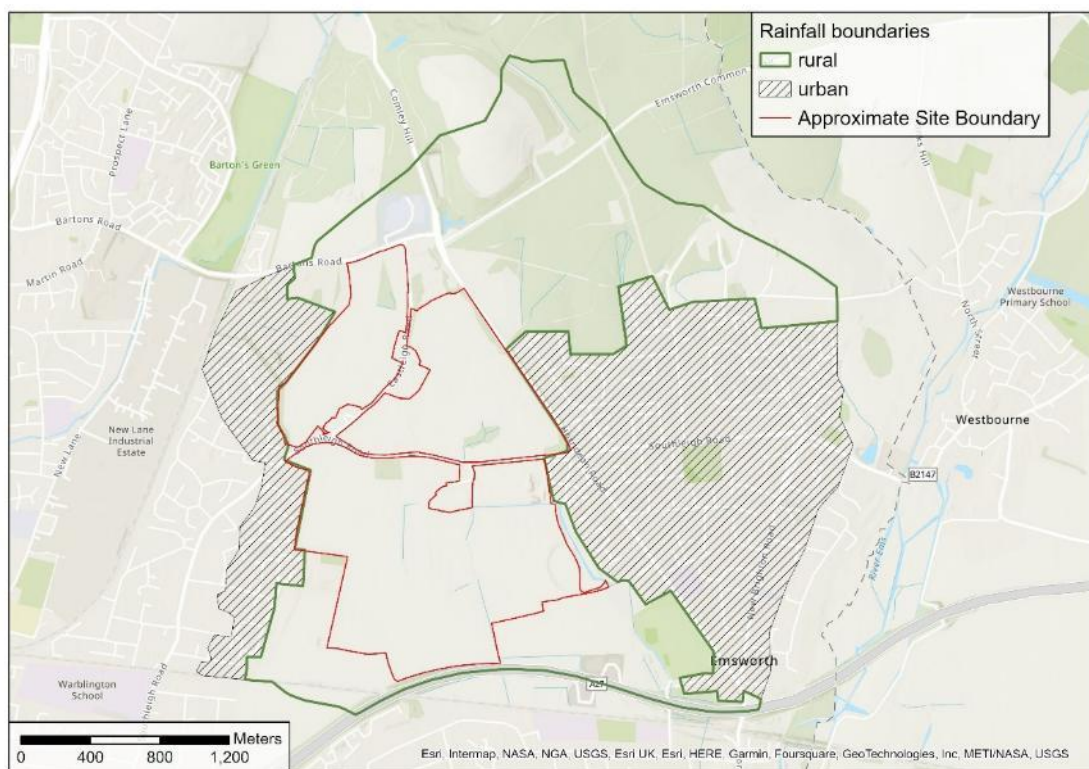


Figure 6.3- Rainfall application

6.2.13 The 2D domain boundaries are defined by HT (Head/Time) boundaries at the perimeter of the model domain to allow water to drain out of the model (model layer: 2d_bc_SRHP_v19_reduced_L). These have been set to just below the LiDAR level, this prevents ponding at boundaries and the resulting increase in run times due to deep water. A sensitivity test will be undertaken on the HT value applied at a later date to ensure that the boundaries applied are appropriate.

6.2.14 The model has been trimmed so that the downstream of the surface water model is the A27. Therefore, HX and CN lines have been removed downstream of the A27 as this is not relevant to the surface water study.

6.2.15 An inflow for the Nore Farm stream intervening area has not been applied in 2D downstream of the A27 as this is not within the surface water model domain.

6.3 1D model

- 6.3.1 The conveyance of the watercourse channels are represented in 1D using ESTRY software, as discussed above the extent of watercourses represented has been trimmed to upstream of the A27. The 1D model extent is shown in **Figure 6.4**, this removes the following structures from the West Brook reach; WES_501, WES_362 and WES_122.

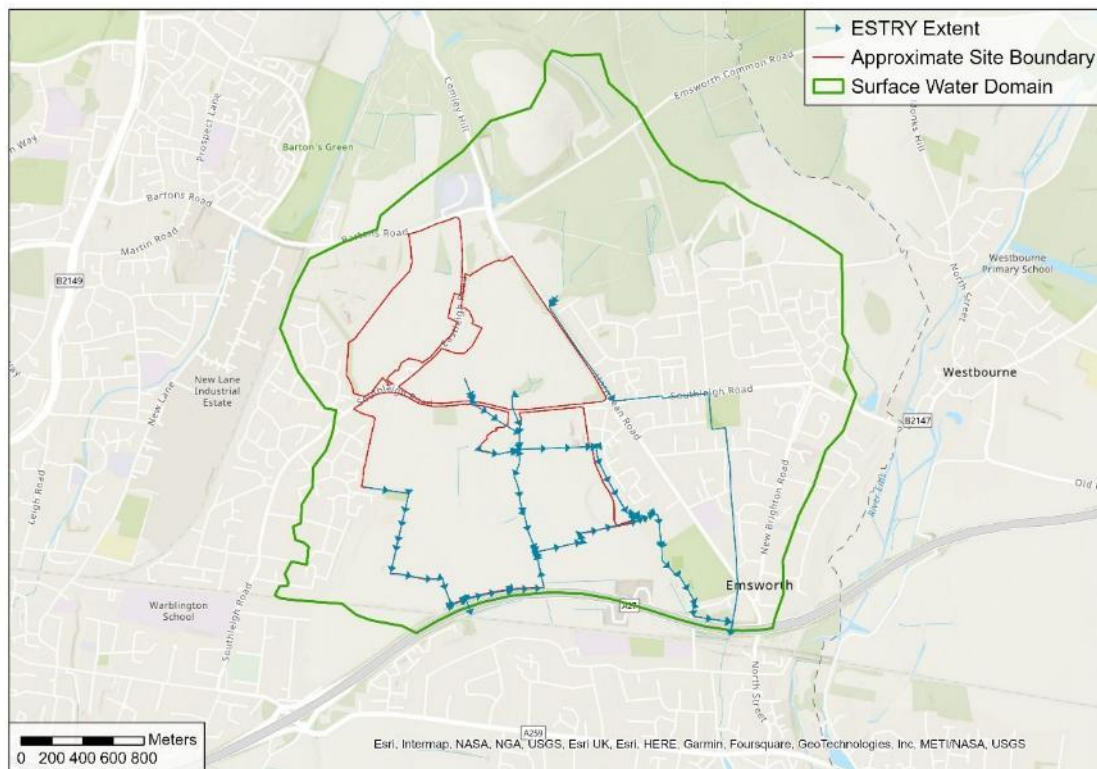


Figure 6.4 - Surface water 1D extent

- 6.3.2 The fluvial model required additional storage, which is a known fix recommended by TUFLOW, to improve stability. This has been removed for the surface water model and checks have been undertaken to ensure that these are not needed.

Structures

- 6.3.3 There are three structures that have been added to ditches within the northern parcel of the site for the surface water model. These culverts connect the ditch that runs north to south along Eastleigh Road. The location of these are shown within **Figure 6.5**, and the details of the structure representation are provided in **Table 6-1**.

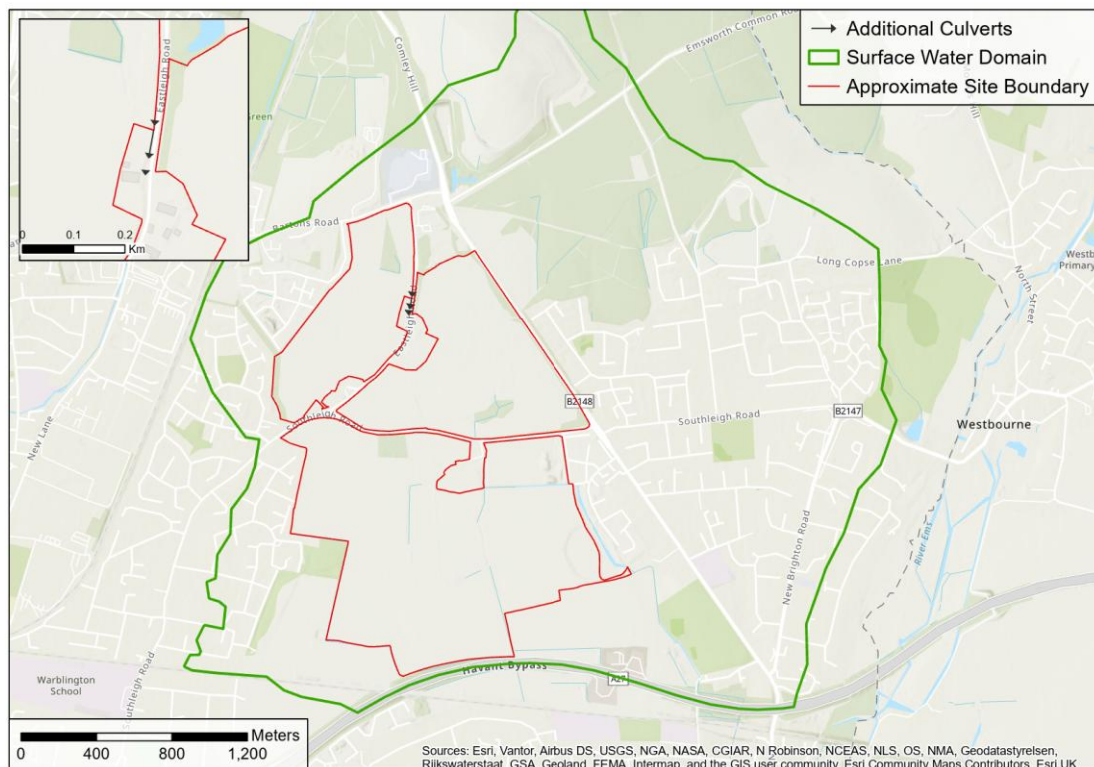


Figure 6.5 - Additional structures

Table 6-1 Surface water model structures

Structure ID	Description and Data Source	Model Representation
Cul1	Circular culvert, informed by topographic survey. No photograph available.	Represented as a circular culvert with upstream invert of 26.07mAOD and downstream invert of 25.79mAOD. Diameter 0.225m Spill represented in 2D
Cul2	Circular culvert, informed by topographic survey. No photograph available.	Represented as a circular culvert with an upstream invert of 25.07mAOD and a downstream invert of 23.5mAOD. Diameter 0.3m. Spill represented in 2D
Cul3	Circular culvert, informed by topographic survey. No photograph available.	Represented as a circular culvert with an upstream invert of 22.4mAOD and a downstream invert of 22.32mAOD. Diameter 0.3m. Spill represented in 2D

Boundaries

- 6.3.4 The upstream boundaries applied to the watercourses are QT (Flow/Time) boundaries which apply the baseflow to the model according to the splits outlined in **Section 3.2**. The 1D inflow locations match the fluvial inflow locations described in **Section 4.3**.
- 6.3.5 The culverts applied to the ditches along Eastleigh Road have been connected via SX lines (model layer: 2d_bc_SRHP_v16_reduced_links_L), in order to allow water to pass from the 1D pipe into the 2D ditch and vice versa.
- 6.3.6 1D HT (Head/Time) boundaries have been applied to the downstream of the culverts that run under the A27 (model layer: 1d_bc_SRHP_v18_reduced_inflows_P). A value of 1mm above the soffits have been applied as a conservative approach.
- 6.3.7 A sensitivity test will be performed at a later date to ensure that the boundary selected does not unduly influence results at the site of interest.

7 Surface Water Hydraulic Model Results

7.1 Model run scenarios and parameters

- 7.1.1 The surface water hydraulic model was run for three storm durations for the largest event, 1 in 1000 year, to determine the critical storm duration. This was determined to be the 6 hour storm, which was therefore run for all return periods with the 1 hour and 3 hour storm durations only run for the 1 in 1000 year event.
- 7.1.2 The hydraulic model was run for the 1 in 30 year, 1 in 100 year and 1 in 1000 year present day events and the 1 in 30 year with 40% climate change allowance and 1 in 100 year with 45% climate change allowance. These events have been selected to understand the impacts of climate change over the lifetime of the development.
- 7.1.3 The simulation time of 30 hours was adopted to allow sufficient time after the peak water levels for the model to drain on site. Based on the 2m grid size for the 2D domain a 2D timestep of 1 second and a 1D timestep of 0.5 seconds were used.

7.2 Model Simulations

- 7.2.1 The model simulations and the model version used are summarised in **Table 7-1**.

Table 7-1 Surface water model simulations

Event	Model File
1 in 30 year	SRH~s1~_v19~e1~.tcf
1 in 30 year plus 40% climate change	SRH~s1~_v19~e1~.tcf
1 in 100 year	SRH~s1~_v19~e1~.tcf
1 in 100 year plus 45% climate change	SRH~s1~_v19~e1~.tcf
1 in 1000 year	SRH~s1~_v19~e1~.tcf

- 7.2.2 The ESTRY commands are contained within the 1D section of the TUFLOW control file (.tcf) and the TUFLOW geometry and boundary files are named 'SRHF_v19.tgc' and 'SRHF_v19.tbc' respectively.

7.3 Model performance overview

- 7.3.1 The model performance was based on all simulated events. The 1D and 2D mass balance error for all return periods are presented in **Table 7-2**.

Table 7-2 Surface water mass balance summary

Event	1D Mass Balance	2D Mass Balance	Negative depths
1 in 30 year	1.52	1.36	0
1 in 30 year plus 40% climate change	0.52	0.04	0
1 in 100 year	0.46	0.16	0
1 in 100 year plus 45% climate change	0.40	0.02	0
1 in 1000 year	0.35	0.02	0

- 7.3.2 The mass balance error is within acceptable limits for both the 1D and 2D domains for all events greater than the 1 in 30 year. TUFLOW recommends that the mass balance error should be within +/-1%; therefore the 1 in 30 year is slightly over this recommended limit.
- 7.3.3 An investigation of the 1 in 30 year results has been undertaken with the conclusion that the higher mass balance is in relation to instabilities in water level during the falling limb within two ESTRY reaches. The first is located within unknown ditch 4 just upstream of Southleigh Road. It should be noted that this is after the peak and is likely associated with low flows (0.04m³/s). The second is related to instabilities in flow only just upstream of the structure on the Nore Farm Stream which runs under the A27, again this is believed to be associated with low flows within the channel of 0.034m³/s and therefore the culvert has very low flows.
- 7.3.4 For all model scenarios there are no negative depths during the simulations. Warnings prior to the simulation starting are mainly associated with null, SX lowering and ignored objects. The files that the warnings are associated with have been reviewed with the conclusion that they do not impact the model results.
- 7.3.5 Warning's during the simulation are mostly associated with repeated timesteps, TUFLOW recommends that the time and location of these repeating HPC timesteps should be investigated. It was found that these errors were located throughout the model but all within the first hour of the simulation and therefore are likely to be associated with initial wetting and drying and should have no impact on model results at the peak at the site of interest.
- 7.3.6 Based on the above the Southleigh surface water model produces stable and representative results.

7.4 Baseline results

- 7.4.1 Both the fluvial and surface water (pluvial) hydraulic model results will be presented for the site of interest. As out of bank fluvial flooding does not cover the entire site, the pluvial results have been used to inform peak flood levels where fluvial flood extents do not reach e.g., in the northern parcel of land.
- 7.4.2 Where both fluvial and pluvial results are present in the 2d floodplain, the higher of the two flood levels will be used to inform the development and any subsequent mitigation measures as this would be considered as a more conservative and therefore acceptable approach.

- 7.4.3 Mapped results from the model presenting flood extents and flood depths for all modelled events are included in **Appendix G**.
- 7.4.4 In a direct rainfall model, rainfall is applied to every cell in the model, and therefore all modelled cells are shown as wet. For the purpose of presenting the mapped results, a cut-off depth of 0.02m has been applied. This allows the results to be interrogated and major flow routes and flood mechanisms can be easily identified.
- 7.4.5 Flood extents for the design event, 1 in 100 year plus 45% climate change allowance scenario, are presented on **Figure 7.1** along with major flow routes, with maximum modelled flood depths shown in **Figure 7.2**. Modelled flood extents for the 1 in 100 year are presented on **Figure 7.4** against the EA RoFSW extents.

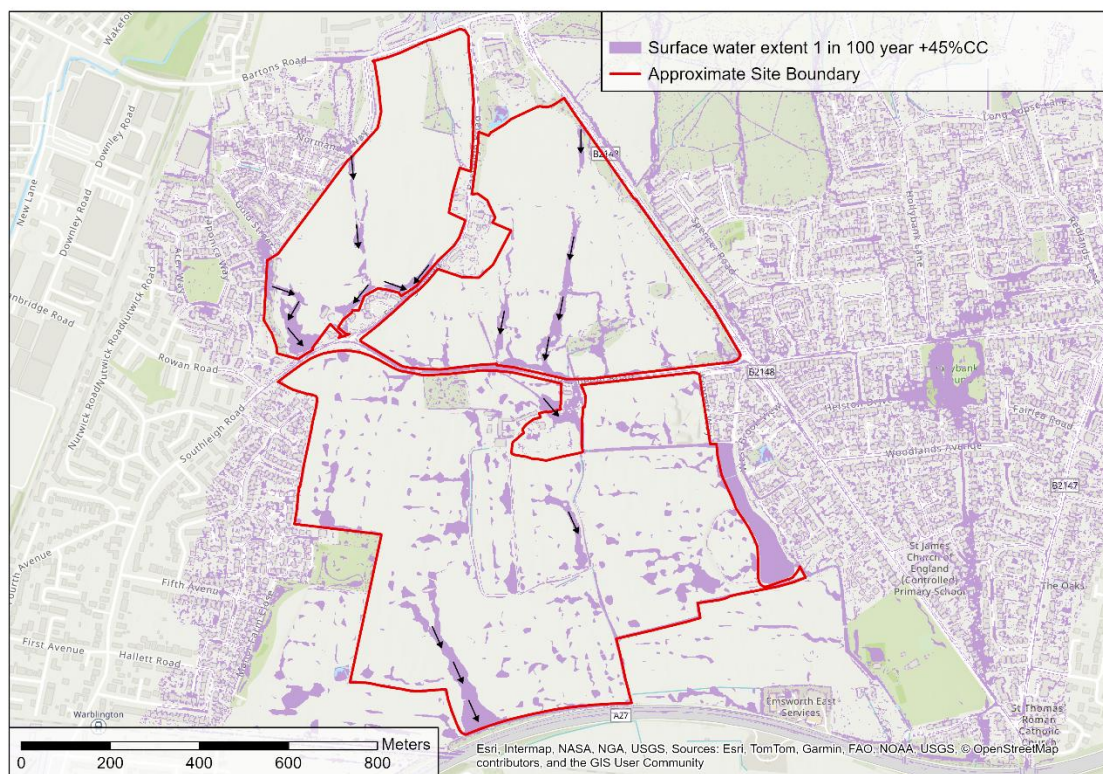


Figure 7.1- Surface water flood extent, 1 in 100 year plus 45% cc allowance with 2cm cut off

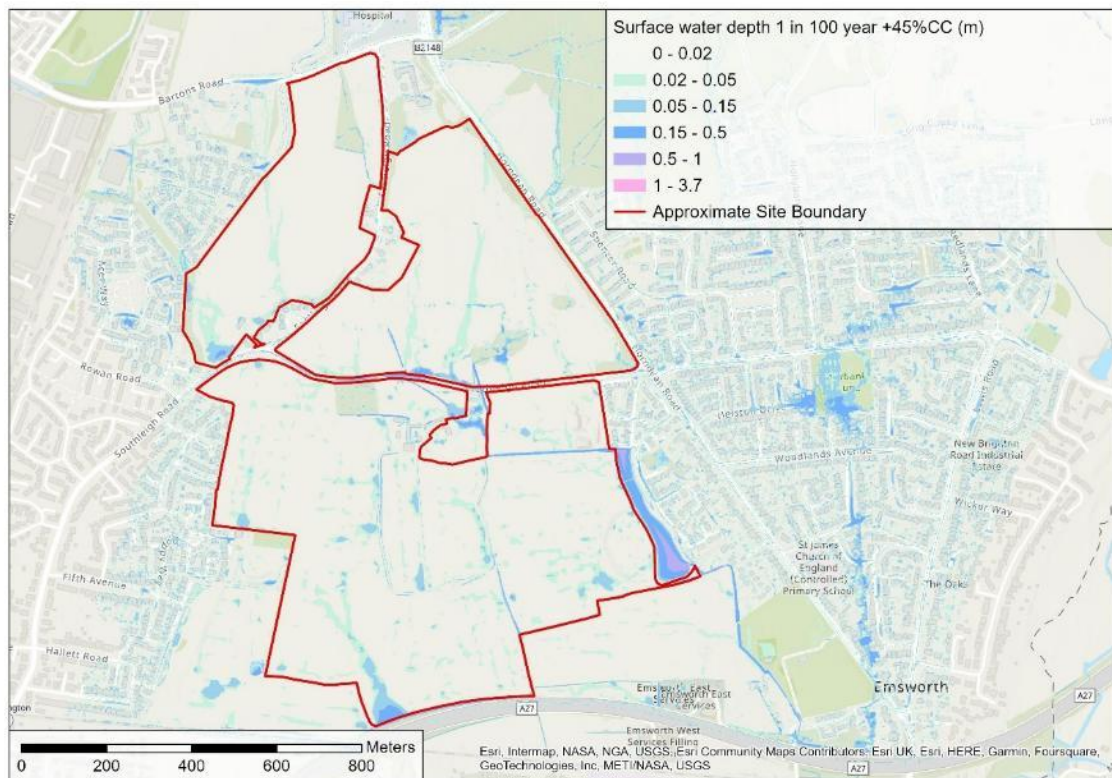


Figure 7.2 - Surface water depth, 1 in 100 year plus 45% climate change allowance with 2cm cut off

- 7.4.6 The maximum modelled depths are shown in **Table 7-3**, the locations where depth results have been extracted for the 2D flood extent are shown in **Figure 7.5**. The results demonstrate that the majority of the major flow routes on site are less than 0.15m deep.
- 7.4.7 There are some areas with flood depths greater than 0.15m within the site boundary including upstream of the A27 near the Nore Farm stream, in the central area of the site near Southleigh Road, in the north east of the site where Southleigh Road joins Horndean Road and the northern parcel in the south west corner.

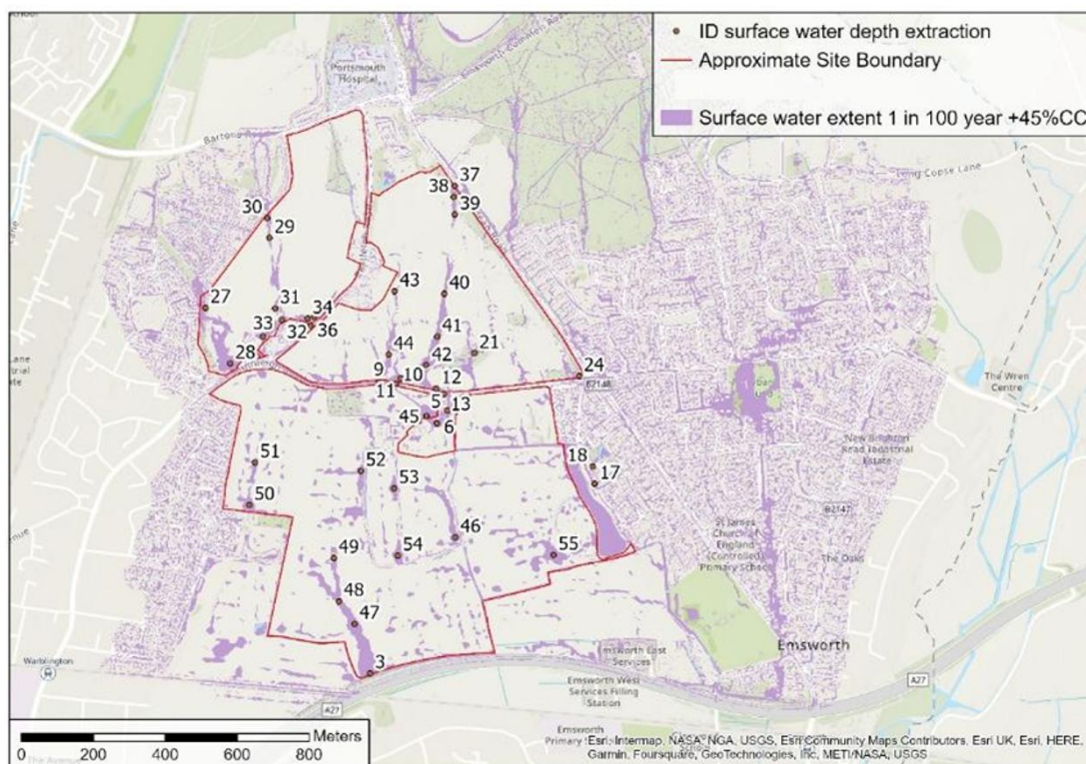


Figure 7.3 - Maximum depth extraction locations

Table 7-3 Surface water maximum modelled depth (m)

ID	1 in 30 year	1 in 30 year +40% CC	1 in 100 year	1 in 100 year +45%CC	1 in 1000 year
3	0.03	0.25	0.17	0.40	0.43
5	0.26	0.27	0.26	0.28	0.28
6	0.19	0.22	0.21	0.24	0.25
9	0.37	0.38	0.38	0.40	0.41
10	0.16	0.18	0.17	0.19	0.20
11	0.29	0.30	0.30	0.32	0.33
12	0.15	0.16	0.16	0.17	0.18
13	0.06	0.06	0.06	0.07	0.08
17	0.01	0.01	0.01	0.06	0.09
18	0.00	0.00	0.00	0.00	0.00
21	0.10	0.12	0.11	0.14	0.15
24	0.20	0.21	0.21	0.21	0.22
27	0.03	0.07	0.05	0.10	0.11
28	0.12	0.15	0.14	0.18	0.19
29	0.00	0.01	0.01	0.02	0.03
30	0.02	0.04	0.03	0.06	0.06
31	0.03	0.04	0.03	0.05	0.05
32	0.05	0.06	0.06	0.07	0.08

ID	1 in 30 year	1 in 30 year +40% CC	1 in 100 year	1 in 100 year +45%CC	1 in 1000 year
33	0.09	0.10	0.10	0.12	0.13
34	0.07	0.08	0.07	0.09	0.09
35	0.03	0.04	0.03	0.04	0.04
36	0.03	0.04	0.04	0.05	0.06
37	0.31	0.33	0.32	0.36	0.36
38	0.02	0.04	0.03	0.05	0.05
39	0.01	0.02	0.02	0.03	0.03
40	0.03	0.04	0.03	0.05	0.06
41	0.02	0.03	0.03	0.04	0.04
42	0.04	0.05	0.04	0.06	0.06
43	0.02	0.03	0.02	0.03	0.03
44	0.03	0.04	0.03	0.05	0.05
45	0.17	0.20	0.19	0.21	0.22
46	0.06	0.07	0.06	0.07	0.08
47	0.06	0.07	0.07	0.09	0.10
48	0.03	0.04	0.04	0.06	0.06
49	0.08	0.09	0.09	0.10	0.10
50	0.12	0.13	0.13	0.15	0.15
51	0.04	0.05	0.05	0.06	0.06
52	0.05	0.06	0.06	0.07	0.07
53	0.03	0.05	0.04	0.07	0.08
54	0.05	0.07	0.06	0.09	0.09
55	0.09	0.10	0.09	0.11	0.11

- 7.4.8 The comparison between the modelled extents and the reference RoFSW 1 in 100 year event at the site of interest shown in **Figure 7.4** demonstrates that the modelled extents show a smaller flood extent in the central area of the site with no flow route running north west to south east from the Unknown drain 6.
- 7.4.9 There is an increase in flood extent for the Nore Farm Stream flow route and the West Brook flood extent is not aligned with the RoFSW extent.
- 7.4.10 In the northern parcel there is a larger extent in the south west with no ponding in the centre of the northern parcel.
- 7.4.11 Throughout the site there are areas of ponding not found in the reference RoFSW mapping. This can be explained by the RoFSW mapping using a broadscale modelling grid, where the channel capacity will not be well represented and does not directly represent culvert and bridge structures. In the case of the West Brook, the modelled extents do not match the RoFSW as this extent predates the construction of the Flood Storage area.
- 7.4.12 The model results from this study are considered more representative of the flood risk than the EA Flood Zones as this model is more detailed including the use of site specific data for both the hydrological assessment and hydraulic model build.

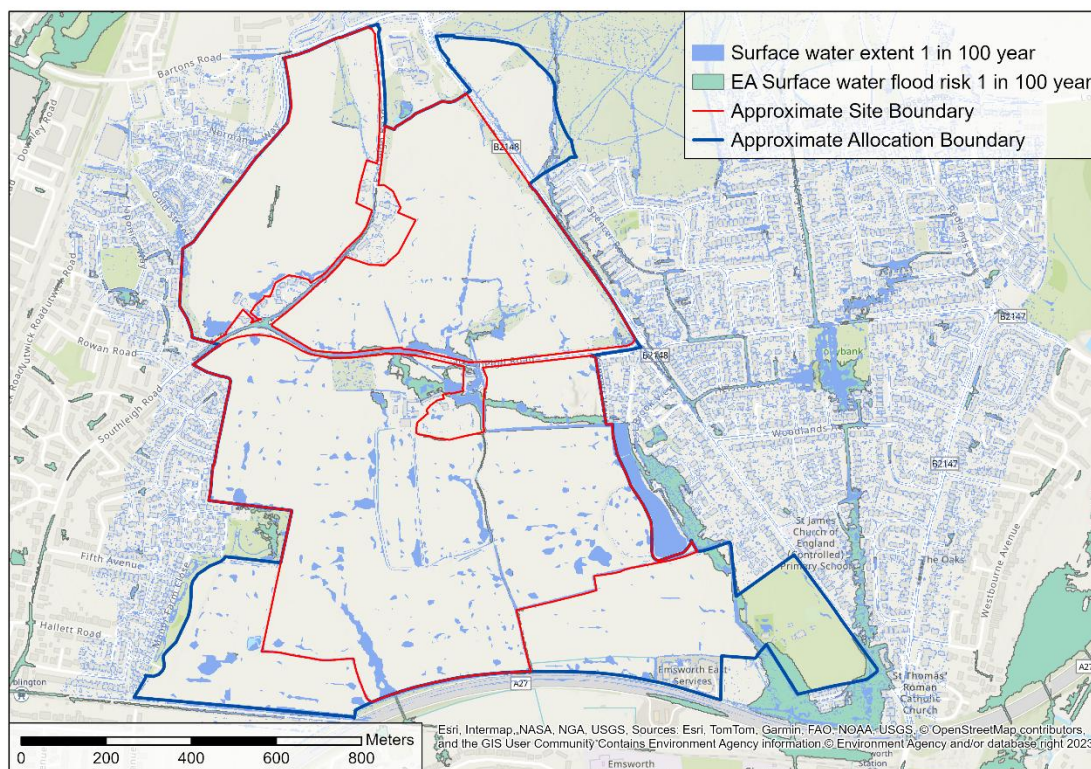


Figure 7.4 - Comparison between RoFSW and modelled surface water extents 1 in 100 year

8 Sensitivity Testing

The following sensitivity tests have been carried out on the 1 in 100 year baseline fluvial model:

- **+/- 20% Manning's 'n' in both the 1D and 2D models.**
- **Downstream boundaries**
- **90% blockage applied to 4 culverts across the model**
- **Additional Node Area (ANA)**

8.1 Manning's 'n'

8.1.1 Roughness sensitivity has been tested by adjusting the roughness values by +/- 20% .

8.1.2 **Figure 8.1** provides the flood extents for the +/-20% Manning's 'n' sensitivity tests. It indicates that there are generally small differences to the flood extents, when compared to the baseline. The largest differences are encountered in the vicinity of the Southleigh Road / Horndean Road junction.

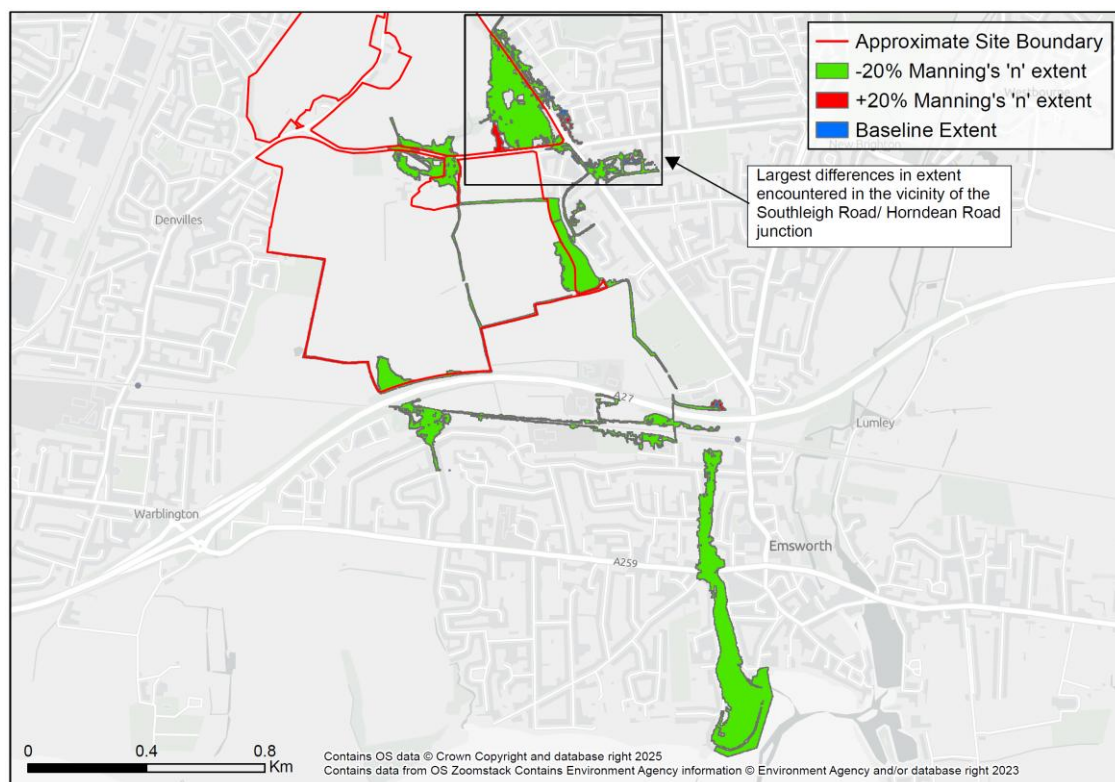


Figure 8.1 - Manning's 'n' sensitivity test

8.1.3 For a 20% decrease in Manning's 'n', there was a general reduction in water level throughout the majority of the site, within +/-0.05m. The maximum decrease of -0.16m was noted to the south east of the site, adjacent to the A27.

8.1.4 For a 20% increase in Manning's 'n', there was a general increase in water level throughout the majority of the site, within $\pm 0.05\text{m}$. A maximum increase of 0.22m was noted to the south east of the site, north of the A27.

8.1.5 Based on these sensitivity tests, it is considered that the model is not particularly sensitive to variations in the Manning's 'n' values, with relatively small changes to the flood extent and flood levels within the site.

8.2 Downstream Boundary

8.2.1 Sensitivity was tested on the downstream boundary by increasing the tidal downstream boundary from the mean water spring tide value of 1.97m AOD to the highest astronomical tide level of 2.42m AOD . Sensitivity to the HQ boundaries was also included by decreasing the slope values 20%, making them less efficient.

8.2.2 **Figure 8.2** shows the comparison of the baseline results at the tidal downstream boundary. The results show that the downstream boundary extent is slightly larger than the baseline extent at a small number of locations. Comparison of the flood levels shows that the sensitivity testing has a localised impact, limited to the edge of the flood extent, with the same flood levels recorded approximately 30m upstream.

8.2.3 Sensitivity testing of the tidal downstream boundary does not impact the site.

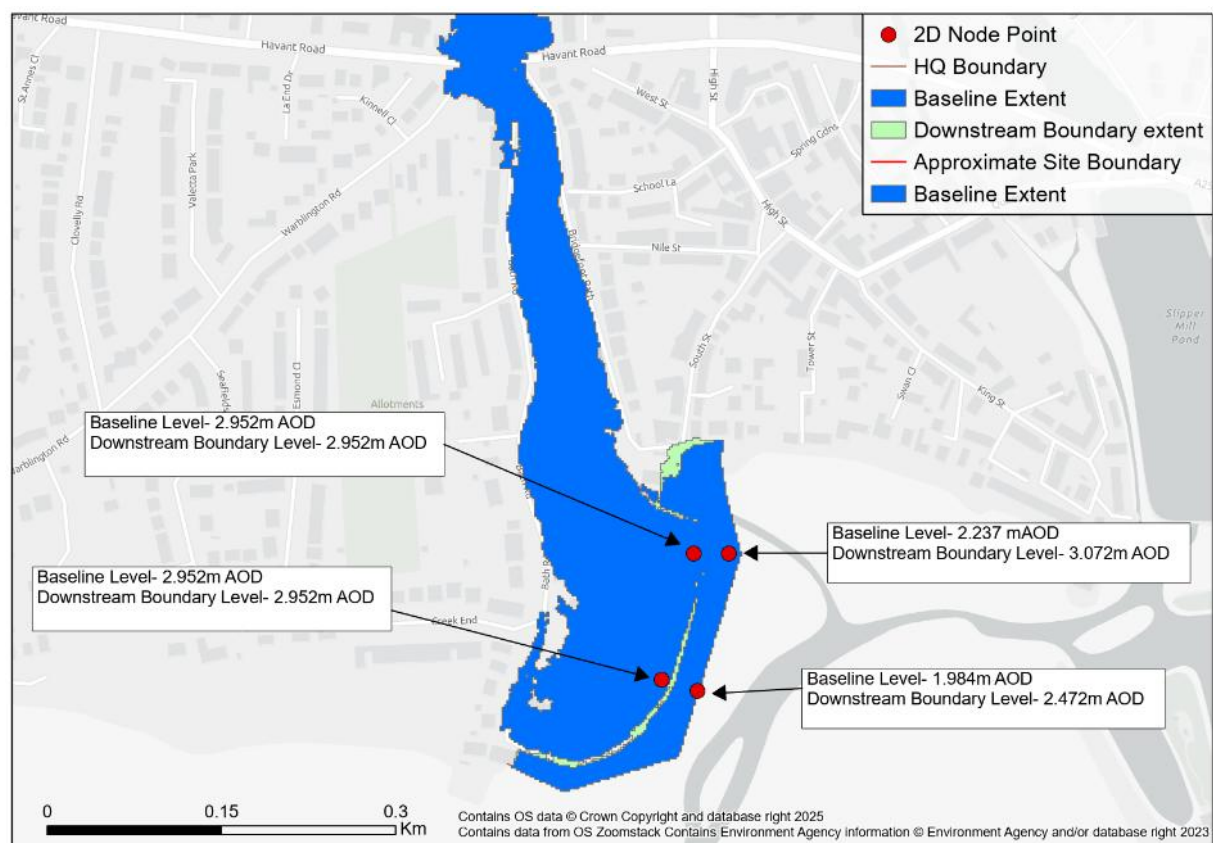


Figure 8.2 - Downstream boundary sensitivity test (tidal)

8.2.4 **Figure 8.3** shows the comparison of the baseline extent with the downstream boundary along the western HQ boundary. The figure shows no change between the flood extents; however, there are localised changes in the flood levels. Immediately adjacent to the HQ boundary, water

levels change by a minimal 3mm, reducing to no impact approximately 20m upstream. In this location the downstream boundary sensitivity testing had no influence at the site.

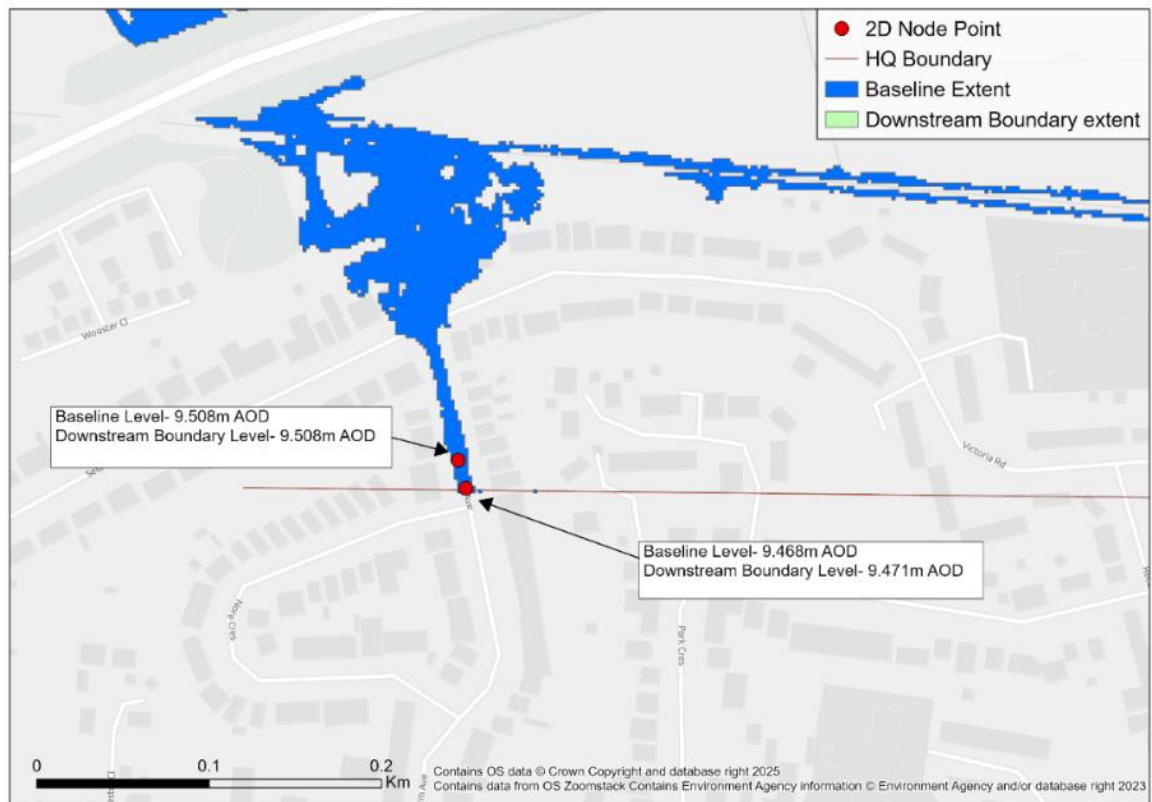


Figure 8.3 - Downstream boundary sensitivity test (HQ west)

- 8.2.5 **Figure 8.4** shows the comparison of the baseline extent with the downstream boundary along the eastern HQ boundary. The figure shows very little change between the flood extents, with a very small additional area of downstream boundary extent along the HQ boundary. There are no changes to the rest of the extent in this location.
- 8.2.6 There are localised changes in the flood levels immediately adjacent to the HQ boundary, where water levels change by a minimal 3mm reducing to no impact 4m upstream. In this location the downstream boundary sensitivity testing also had no influence at the site.

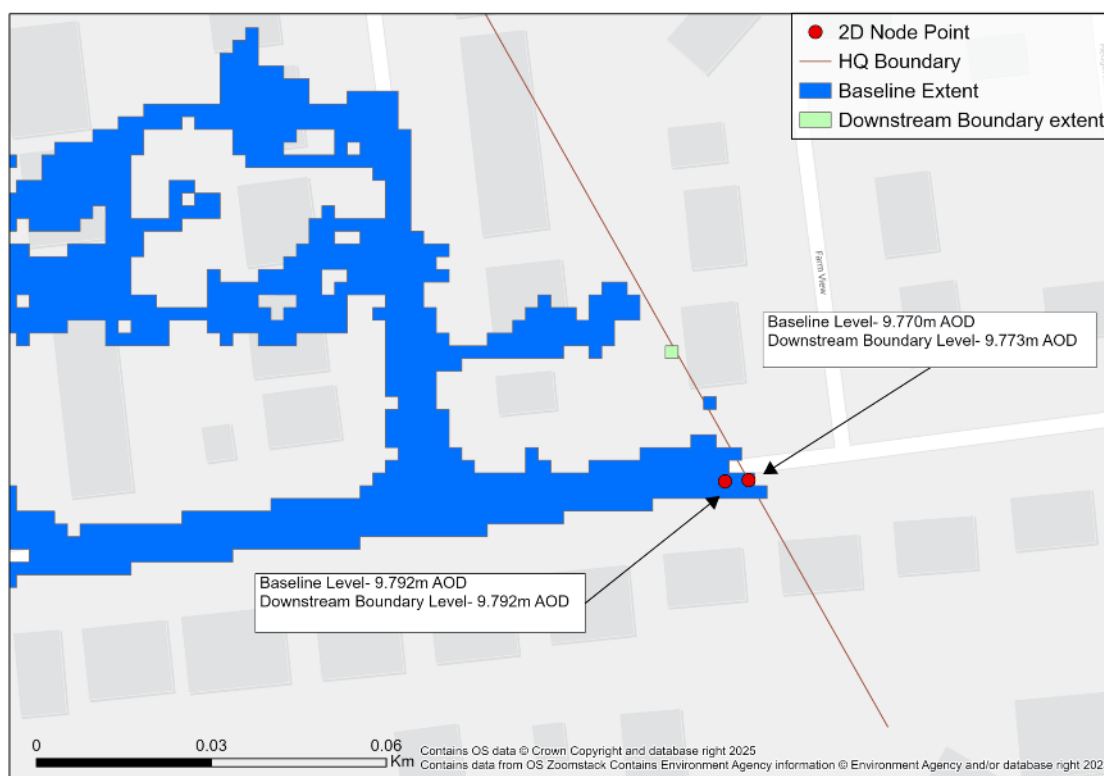


Figure 8.4 - Downstream boundary sensitivity test (HQ east)

8.2.7 Based on these sensitivity tests, it is considered that the model is not particularly sensitive to variations in the downstream boundary, with little to no change in the extent and only localised changes to the water levels.

8.2.8 The site is not impacted by any changes to the downstream boundary conditions.

8.3 Blockage

8.3.1 Sensitivity on blockage has been undertaken on structures of interest. This involved applying a 90% blockage to four key culverts; the culvert on Horndean Lane, Southleigh Road, under the A27 in the west of the site and the A27 in the east of the site.

8.3.2 The British Standards 8533 2017 document - Assessing and managing flood risk in development — Code of practice has been used to determine the extent of blockage to consider. It states that the following instances should be taken into account:

1. For bridge openings and culverts that are less than 1 m², the increase in depth and frequency of flooding within the site as a results of a 90% blockage of the cross-sectional area; and

2. for bridge openings and culverts that are greater than, or equal to, 1 m², the increase in the depth and frequency of flooding within the site as a result of a 50% blockage of the cross-sectional area.

8.3.3 Below shows the culvert information from the baseline model that was used to determine a percentage blockage:

- **Horndean Lane** - circular culvert with a diameter of 0.3m and a calculated area of 0.071m². Therefore, as this is less than 1m² a 90% blockage was applied.

- **A27E** - circular culvert with a diameter of 1.06m² and a calculated area of 0.882m². Therefore, as this is less than 1m² a 90% blockage was applied.
- **A27W** - irregular culvert of which the dimensions are contained within a height width table with an area less than 1m². Therefore a 90% blockage was applied. It is not possible to apply a blockage value to irregular culverts, and therefore the original height was retained (0.14m) but a new width of 0.014m was applied.
- **Southleigh Road** - irregular culvert of which the dimensions are contained within a height and width table with an area less than 1m². Therefore a 90% blockage was applied. It is not possible to apply a blockage value to irregular culverts, and therefore the original height was retained (0.41m) but a new width of 0.012m was applied.

8.3.4 **Figure 8.5** shows the location of the blocked culverts.

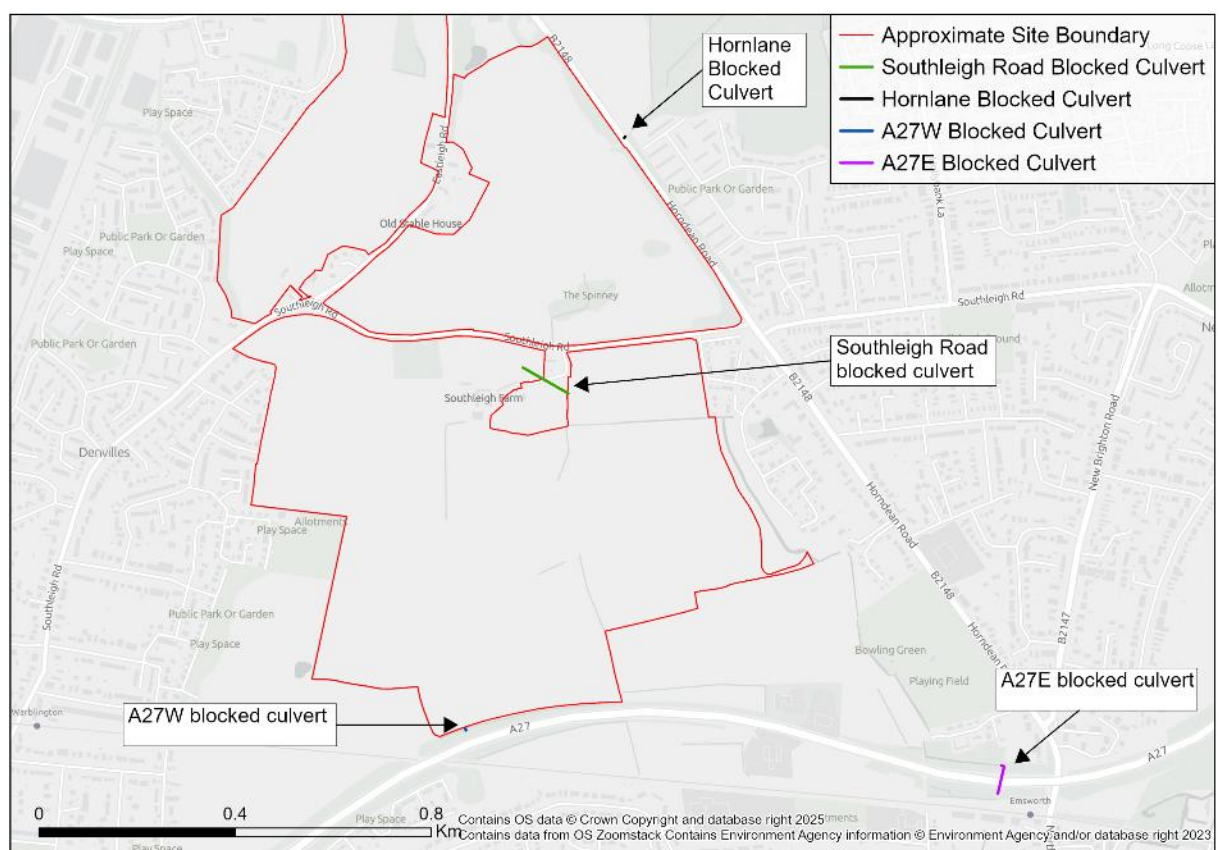


Figure 8.5 - Location of blocked culverts

8.3.5 **Figure 8.6** displays the comparison of the baseline extent with the Southleigh Road blockage extent. It shows that the Southleigh Road blockage extent is very marginally larger than the baseline extent in some areas, but largely matches the baseline extent.

8.3.6 There is a very small increase in water level, of 3mm between the Southleigh Road blockage and the baseline. This culvert is originally a circular culvert; however, due to significant siltation build up, the culvert has been modelled as an irregular culvert to account for the existing blockage (see 4.3.14). This may account for the small change noted in the blockage scenario as the culvert opening was already modelled as being blocked.

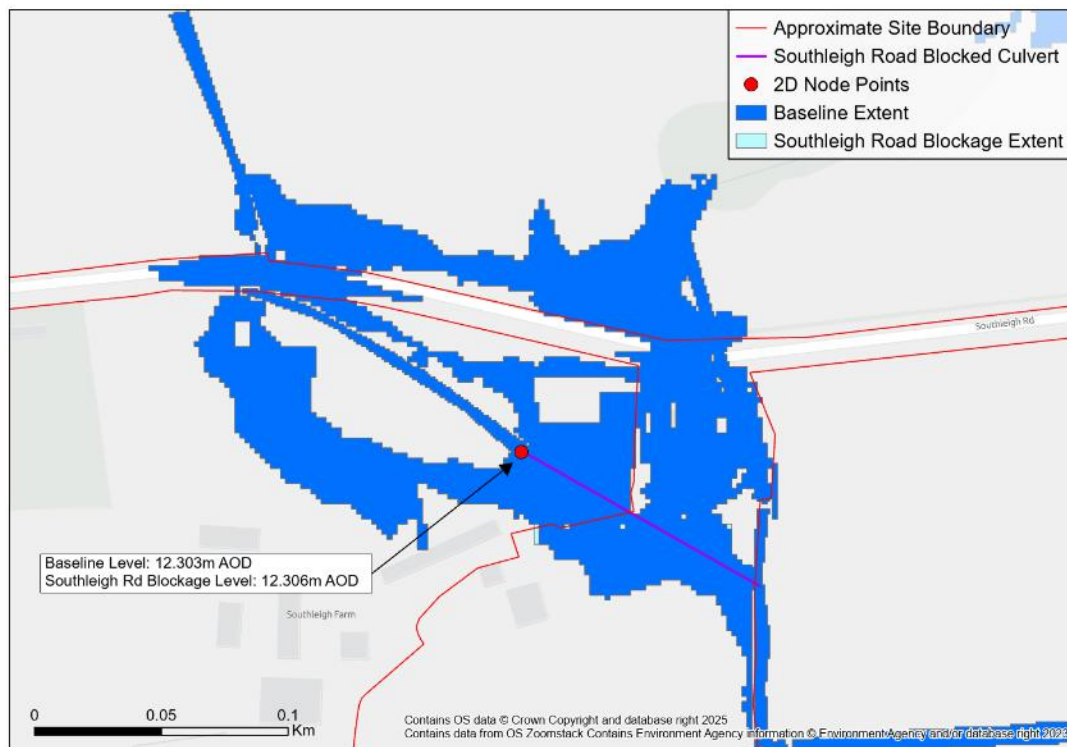


Figure 8.6 - Southleigh Road blockage

- 8.3.7 **Figure 8.7** shows the comparison of the A27W culvert blockage and baseline extents. It can be seen that a localised increase in the A27W culvert blockage flood extent is encountered when compared to the baseline, adjacent to the A27W culvert. The A27W water levels show an increase of 0.01m AOD at the 2D node point shown in the Figure.
- 8.3.8 The modelled opening at this location is already restricted (a small hole removed from the sluice gate – see **4.3.14**) which is the likely cause of the limited impact on flood levels and extent at this location.

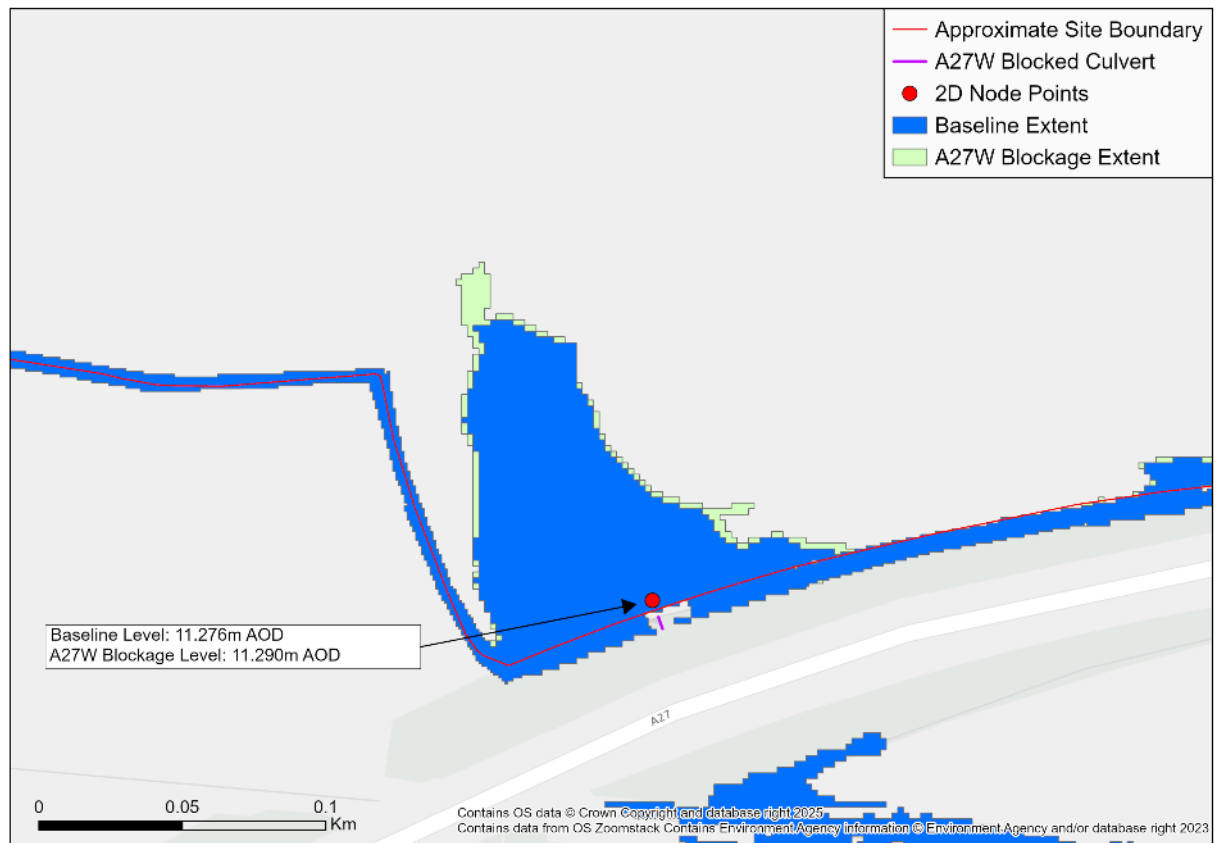


Figure 8.7 - A27W blockage

- 8.3.9 **Figure 8.8** shows a comparison of the A27E culvert blockage extent with the baseline extent. It shows that the A27E culvert blockage extent is significantly larger than the baseline extent, backing up to the north and north west of the culvert, as well as causing an increase in extent to the south of the A27.
- 8.3.10 Additionally, immediately adjacent to the opening of the blocked culvert, there is a significant change in water level of 1.18m.
- 8.3.11 While a blockage at this location is significant in the local area, the impacts do not reach the site, see **Figure 8.8**, which shows no change in flood levels at the south east corner of the site.

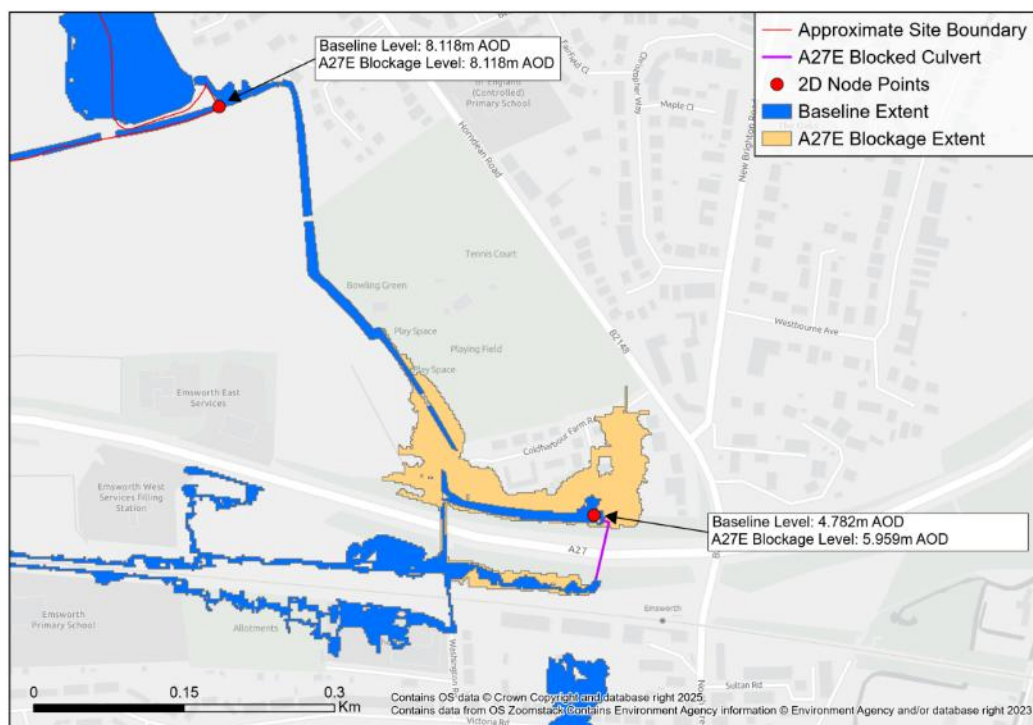


Figure 8.8 - A27E blockage

8.3.12 **Figure 8.9** shows the comparison of the Hornlane culvert blockage extent with the baseline extent. It shows that the Hornlane culvert blockage extent is significantly larger than the baseline extent, particularly downstream of the blocked culvert. Impacts within the site are limited to between the Hornlane and Southleigh Roads.

8.3.13 There is a small change in water level of 20mm, adjacent to the opening of the blocked culvert.



8.4 Additional Node Area (ANA)

8.4.2 It is important to undertake sensitivity testing on the nodal storage to ensure that results are not unduly affected. Sensitivity of the nodal storage area has been tested by running a scenario in which the ANA values were removed.

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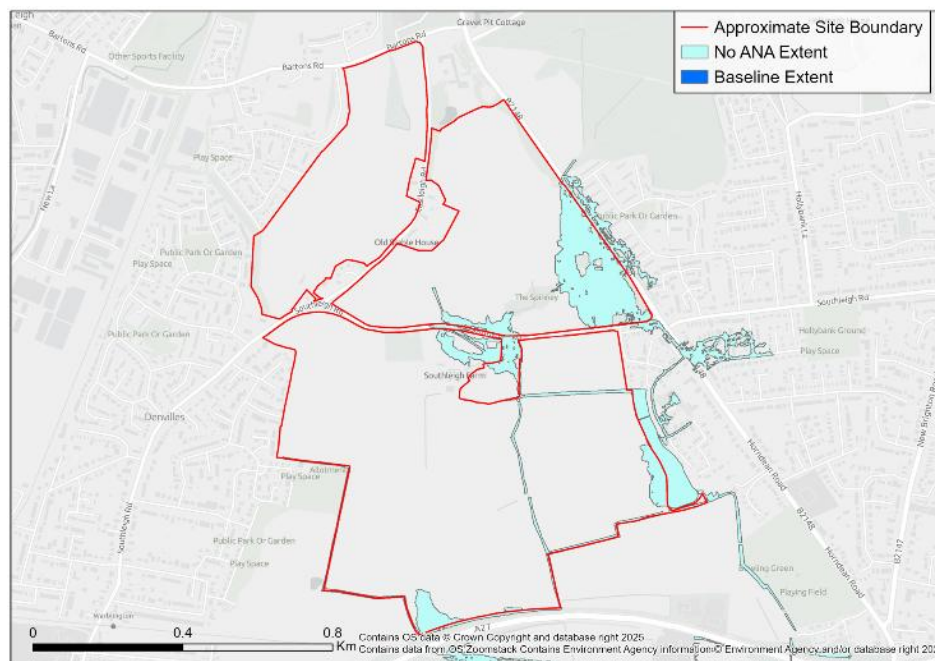


Figure 8.10 - ANA extent sensitivity test

- 8.4.4 Based on this sensitivity test, it is considered that the extent and levels are not sensitive to the use of ANA storage at a small number of locations, with little to no changes to the extent and very small changes to the water level.

8.5 Nore Farm Stream Overland Flow Route

- 8.5.1 A sensitivity test was carried out to understand the impact of mitigating the small overland flow overtopping the left bank of the Nore Farm Stream, in the 1 in 100 AP +25% climate change event. The floodwater is shown to spill out on the left (east) bank of the channel at a local low point, and it flows broadly in a south-east direction, joining flooding upstream of the A27.
- 8.5.2 This flow route only occurs in events exceeding the modelled present day baseline 1 in 100 fluvial event.
- 8.5.3 The baseline modelling confirmed that the overland flow was very shallow, at 0.01m depth in the 1 in 100 AP plus climate change event and 0.02m depth in the 1 in 1,000 AP event. Interrogation of the results further confirmed the overland flow was a negligible - in the order of 2l/s.
- 8.5.4 To mitigate this, the left bank ground levels were fixed in the model to a minimum level of 13.1mAOD. In addition, the channel for this section of watercourse has been widened from the bed level to bank level by 0.5m on the site side (otherwise retaining the bank slope), to ensure there is significant surplus channel capacity to allow for the small increase in in-channel flow.
- 8.5.5 This channel modification revision was run for the fluvial design event. The change in flood extent is demonstrated in **Figure 8.11** below and the results demonstrate that mitigating this flow route has a local reduction (up to 70mm) in flood levels in the Nore Farm Stream, with no increase in flooding.
- 8.5.6 No change in flood level is encountered in the area of flooding upstream of the A27 (where the overland flow route rejoins) or beyond the site.

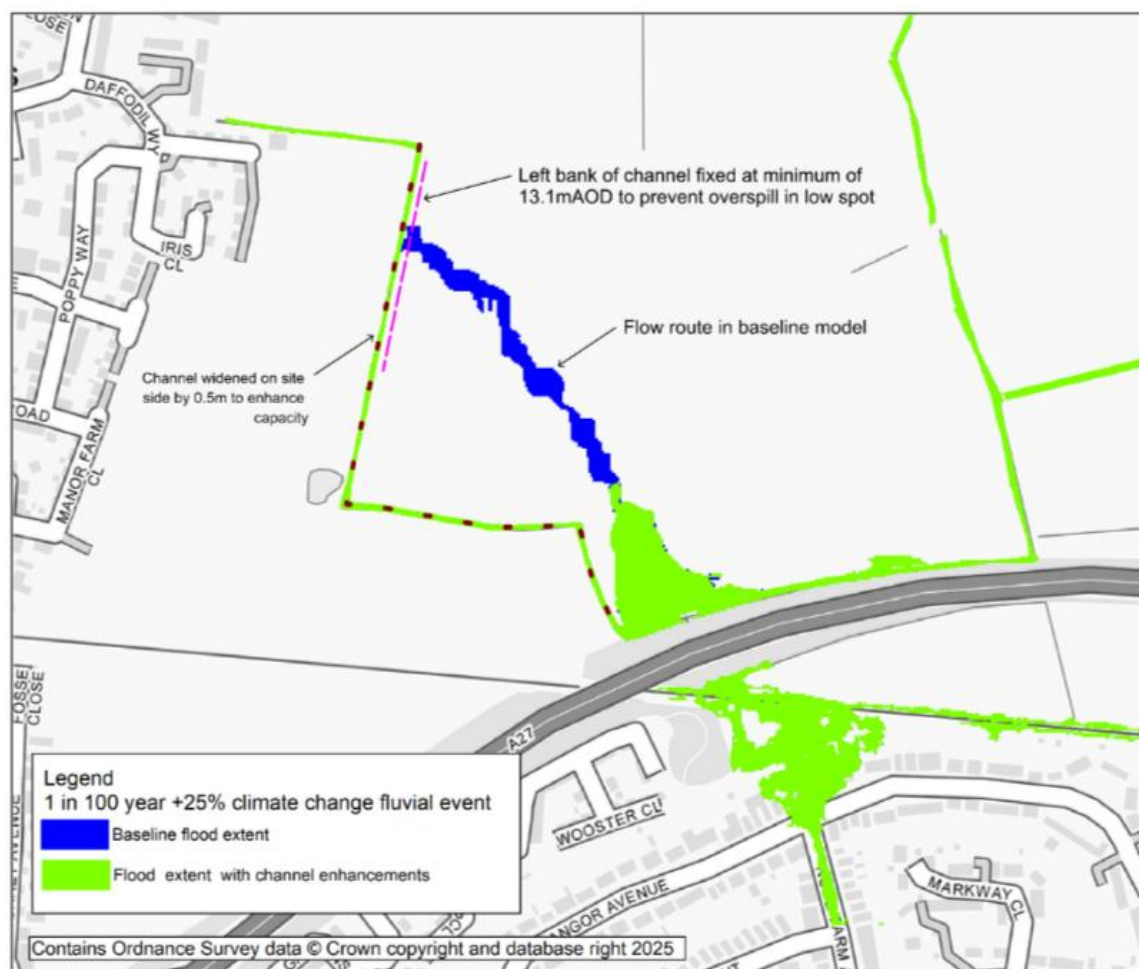


Figure 8.11 - Nore Farm Stream overland flow route sensitivity test

9 Limitations and Assumptions

9.1 General

- 9.1.1 The results of the hydraulic models are largely dependent on the accuracy of the hydrological and topographic/geometry data included in the model. While the most appropriate available information has been used to construct the model there are uncertainties and limitations associated with it. Effort has been made to limit the level of uncertainty to meet the objectives of this study.
- 9.1.2 Hydraulic roughness estimates are based on land-use according to aerial imagery, site specific survey photographs, site visit observations and modeller experience and is a simplification of the real-world situation. It is not possible to achieve the level of detail to capture the full range of complex hydraulics that would be likely to occur on the ground and as such, this approach is considered appropriate and applicable. The roughness values are based on available guidance (Chow, 1959). The roughness value may vary over the year and as such sensitivity analysis was undertaken to quantify the impact.
- 9.1.3 To calibrate any model data from suitable flow and level gauges is required with quality historical flows and spatial information showing the extents of major flood events. No gauge data is available within the model domain to calibrate the models.
- 9.1.4 During the watercourse survey process there were some structures that were inaccessible and unsafe to survey due to dense vegetation and some structures could not be located. Due to this lack of data assumptions were made in order to apply these structures to the model. For example, the outlet of the Horndean Road structure could not be located during the channel survey. However, additional data was requested and informed the structure representation as this structure was deemed important to the study.
- 9.1.5 Hydraulic coefficients for structures have been applied using available guidance within the TUFLOW software. The dimensions of structures are based on detailed survey collected specifically for this project.
- 9.1.6 The downstream boundary for both 1D and 2D model domains are located a sufficient distance from the site of interest and there are no features downstream of the Emsworth Mill Pond (for the fluvial model) or the A27 (for the surface water model) that are anticipated to control the flood levels or have a significant back water effect at the site of interest.
- 9.1.7 Sensitivity testing has been carried out on the 1 in 100 year fluvial model to understand the impact on key model parameters. This includes +/-20% on the roughness values, downstream boundary conditions and use of Additional Nodal Area (ANA), along with blockages at 4 structures.
- 9.1.8 ESTRY-TUFLOW predictions are largely dependent on the modelled volume of overtopping between the channel and the floodplain. Banktop levels have been set using the channel survey sections collected at appropriate spacing. Furthermore additional elevation points are included in various locations to account for localised changes in bank elevation evident in the topographic survey or LiDAR data.

9.2 Fluvial model

- 9.2.1 An assumption has been made for the location of one of the inflows to the fluvial model, the upstream inlet of the WES01_1112 culvert could not be located, therefore it has been assumed that all flow entering the culvert outfalls into the West Brook near West Brook View Road. This is a conservative approach as the flow for the full catchment may not reach the site.

9.3 Surface water model

- 9.3.1 The ground levels at property locations have been modified (uplifted) to account for threshold levels, a threshold level of 0.3m has been applied according to recommended guidance.
- 9.3.2 The ground levels at roads have been modified (lowered) by 0.15m to better represent these flow paths, this is in keeping with modelling guidance for surface water models.
- 9.3.3 Surface water drainage networks have not been represented in the model, instead a reduction of 5mm/hr has been applied within the hydrological analysis for urban areas to represent the impacts of the drainage system. This is considered a conservative approach as the recommended value is 12mm/hr.
- 9.3.4 Infiltration has not been represented in the surface water model, with rainfall losses handled within the hydrological analysis.

10 Conclusion

- 10.1.1 An assessment of fluvial and surface water flood risk has been undertaken for a proposed development at Southleigh, Havant. This is to better understand the risk of flooding to the proposed development in the present day and to consider the impacts of climate change. The reference flood mapping data for the site is based on strategic modelling provided by the Environment Agency (EA).
- Stantec has built a new **fluvial hydraulic model** of the Nore Farm Stream, West Brook and unnamed ditches that run through the development site.
 - A site specific **pluvial model** has also been developed to assess the risk of surface water at the site.
- 10.1.2 To support the development of the hydraulic models, Stantec commissioned channel survey of the watercourses and hydraulic structures. The channel survey was used to develop a 1D model of the watercourses in the study area and structures in the fluvial and surface water models. The 1D was linked to the 2D domain in both models to provide detailed flood extents across the floodplain. This hydraulic modelling report details the 1D and 2D model build for both the fluvial and surface water models to create a site specific baseline model to assess flood risk at the site.
- 10.1.3 The fluvial model was run for the following return periods and the depths and extents provided as part of the results; 1 in 30 year, 1 in 100 year and 1 in 1000 year. Climate change was modelled for the latest climate change allowances; +25% and +36% (for the 1 in 100 year event), representing the 'central' and 'higher central' allowances for the 2080s.
- 10.1.4 The surface water model was run for the following return periods and the depths and extents provided as part of the results; 1 in 30 year, 1 in 100 year and 1 in 1000 year. Climate change was modelled for the latest climate change allowances; 40% for the 1 in 30 year event and 45% for the 1 in 100 year event.
- 10.1.5 The model results from this study were compared to the EA national scale mapping at time of model construction, for both fluvial and surface water mapping. Stantec are aware that the EA Flood Zones were updated in March 2025 and the EA Surface Water extents were updated in January 2025 as part of the NaFRA update. These were reviewed and notably the EA Flood Zones are less extensive over the site, so the modelling and associated comparison remains a conservative approach, and the EA Surface Water extents are broadly comparable over the site. The results for the fluvial modelling indicate that the reference EA Flood Zones were comparable at the site of interest, with reduced extents found for the Nore Farm Stream and West Brook. The results from the surface water modelling overall showed a greater extent than the EA surface water model extents, excluding the central flow route, this can be explained by the EA mapping using broadscale modelling and the modelled extents using detailed topographic data.
- 10.1.6 The results for the fluvial model show that there are flow routes on site in the 1 in 100 year plus 25% climate change allowance scenario and therefore there is a requirement to mitigate flood risk where there is proposed development over such areas.
- 10.1.7 The results of the surface water model demonstrate that there are flow paths on site, which for the most part are below a building threshold level of 0.15m, and areas of ponding. However, where these flow paths are shallow these can be mitigated by the drainage strategy for the site and in areas of deeper water it is recommended that these areas are not developed unless appropriate mitigation is undertaken, for example by raising building platforms.

- 10.1.8 Sensitivity testing has been carried out on the 1 in 100 year fluvial model for +/-20% on roughness values, downstream boundary conditions, Additional Node Area (ANA) and blockages.
- 10.1.9 A sensitivity test has also been carried out to understand the impact of mitigating the small overland flow route overtopping the left bank of the Nore Farm Stream, and demonstrated that increasing local channel capacity, and fixing local bank levels, eliminate the overland flow route and contain flow within the channel, while providing a nominal reduction in local flood levels.
- 10.1.10 Based on the assessment undertaken, it is considered that the Southleigh models represent a reliable baseline condition for the purpose of informing flood risk to the proposed development site on Southleigh, Havant.

Appendix A Watercourse Survey

Appendix B Topographic Survey

Appendix C Data Supplied by EA

Appendix D CCTV and Sewer Plans

Appendix E Hydrological Assessment

Appendix F Fluvial Hydraulic Model Results

Appendix G Surface Water Hydraulic Modelling Results