Technical Note

Project number	60653132
Project (Client)	Partnership for South Hampshire Strategic Flood Risk Assessment (Portsmouth City Council)
Subject	East Solent Flood Inundation Model Re-Simulations (Hayling Island, Portsea Island, Gosport to Warsash)

Revision	Date	Prepared by	Checked by	Verified by
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Version 2 (Final)	28 Jun 2023	Sarah Littlewood (Principal Consultant)	Veronica Makhesh (Senior Consultant)	Helen Judd (Associate)
Version 3 (Final)	26 Jan 2024	Veronica Makhesh (Senior Consultant)	Sarah Littlewood (Principal Consultant)	Helen Judd (Associate)

1. Introduction

1.1 Overview

1.1.1 AECOM has been commissioned by Portsmouth City Council (PCC) on behalf of ten planning authorities in South Hampshire (the 'Partnership for South Hampshire' (PfSH)) to prepare an updated Strategic Flood Risk Assessment (SFRA). The PfSH SFRA covers the administrative areas of Portsmouth City, Havant Borough, Gosport Borough, Fareham Borough, Eastleigh Borough, Southampton City, Winchester City, Test Valley Borough, New Forest District and New Forest National Park Authority.

1.1.2 The purpose of the SFRA is to assess the risk to an area from flooding from all sources, now and in the future, taking account the impacts of climate change, and to assess the impact that land use changes and development in the area will have on flood risk.

1.1.3 The PfSH SFRA is being prepared in line with the requirements of the National Planning Policy Framework[1] (NPPF) and supporting Planning Practice Guidance[2] (PPG). Reference has also been made to the Environment Agency guidance 'How to prepare a strategic flood risk assessment'[3].

1.1.4 This guidance advises that one of the elements the SFRA should provide is maps showing the risk of flooding from **rivers, the sea, and estuaries**, using the Flood Map for Planning and detailed flood modelling. Detailed flood modelling, where available, may be used to show the impact of climate change on flood risk. New or updated flood modelling may be required if flood models are not available, or the climate change allowances in the flood model are not in line with current climate change guidance.

1.1.5 The Environment Agency supplied the existing 2D hydrodynamic tidal models from the East Solent Study[4] which was completed in 2015 – 2018. This technical note describes the work undertaken to re-simulate the flood models from the East Solent Study, to provide the required outputs to inform the PfSH SFRA.

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[1] MHCLG, July 2021, National Planning Policy Framework https://www.gov.uk/government/publications/national-planning-policy-framework--2
[2] DLUHC, MHCLG, August 2022, Planning Practice Guidance https://www.gov.uk/guidance/flood-risk-and-coastal-change
[3] Defra, Environment Agency, March 2022. https://www.gov.uk/guidance/local-planning-authorities-strategic-flood-risk-assessment
[4] JBA Consulting, July 2018, Model Development Report East Solent Models. JBA Consulting, July 2018, East Solent Flood risk and tidal procedure updates, Final Summary Report.

1.2 Existing East Solent Flood Model

1.2.1 The East Solent Study was undertaken by JBA Consulting between 2015 – 2018. Three separate TUFLOW hydrodynamic tidal models were developed for Hayling Island, Portsea Island and Gosport to Warsash. The model extents are shown in Figure 1-1.

1.2.2 A “With Defences” scenario was simulated for a range of events to understand the present day and future flood risk from tidal sources. A "Without Defences" scenario was also simulated, with all maintained defences removed but defacto defences retaining. This was used to update the Flood Map for Planning Flood Zones and enable the mapping of ‘areas benefitting from defences’ (ABDs) at that time.

1.2.3 For each flood model, the following events were simulated as part of the 2015 study:

- 10%, 4%, 3.33%, 1.33%, 1%, 0.5%, 0.2% and 0.1% Annual Exceedance Probability (AEP) events for the Present Day (2015).
- 0.5% and 0.1% AEP events using UKCP09 climate change guidance medium emissions scenario and projected to the years 2031, 2065 and 2115.

1.2.4 One breach scenario had been considered in the Portsea Island model, at Old Portsmouth.

1.2.5 The following model outputs are available: maximum flood depth, water level, velocity, hazard (ZUK0).

2. Model Updates

2.1 LiDAR DTM

2.1.1 The TUFLOW model builds rely on a Digital Terrain Model (DTM) created from light detecting and ranging (LiDAR) data to represent the ground levels across the model domain.

2.1.2 The latest available LiDAR topographic survey data was downloaded at the start of the project from the Data Services Platform[5] and included the Environment Agency's National LiDAR Programme. This was used to update the TUFLOW models for Portsea, and Gosport to Warsash. The 2020 LIDAR Composite contains surveys undertaken between 6th June 2000 and 1st September 2020. Table 2-1 records the datasets that have been used to update the models.

2.1.3 No changes have been made to the bathymetry in the coastal regions as part of this update. It should be noted that for the Portsea model, the 'portsmouth_harbour' layer which consists of bathymetry representing the estuary / sea bed around Chichester Harbour, was replaced. This caused model instabilities as ground levels associated with this dataset differed significantly when compared with the new LiDAR data. This is likely due to the time in which the LiDAR was flown i.e. high vs low tide.

Table 2-1 Updates to DTM

Model	DTM used in 2015 Study	Updated DTM
Hayling Island	Filename: dtm Command: Read GRID Zpts TUFLOW reads an ASCII grid of points attributed with elevations derived from 2m filtered LIDAR data flown in 2013. Previous 2m DTM is sat underneath, flown in 2013, to provide full coverage.	Filename: Hayling_Island_LiDAR_001 Command: Read GRID Zpts TUFLOW reads in a text file of points attributed with elevations derived from 1m LIDAR flown in 2020. The following tiles were used: National LiDAR Programme DTM 1m SU60NE (2020), SU70NW (2020), SU70NE (2019), SU70SE (2019), SU70SW (2020), SU60SE (2020), SZ69NE (2020), SZ79NE (2019), SZ79NW (2020)
Portsea Island	Filename: dtm Command: Read GRID Zpts TUFLOW reads an ASCII grid of points attributed with elevations derived from 2m filtered LIDAR data flown in 2013. Previous 2m DTM is sat underneath, flown in 2013, to provide full coverage.	Filename: Portsea_Island_LiDAR_001 Command: Read GRID Zpts TUFLOW reads in a text file of points attributed with elevations derived from 1m LIDAR flown in 2020. The following tiles were used: National LiDAR Programme DTM 1m SU50NE (2020), SU50SE (2020), SU50NW (2020), SU60NE (2020), SU60SE (2020), SZ69NE (2020), SZ69NW (2020), SU60SW (2020)
Gosport to Warsash	Filename: dtm Command: Read GRID Zpts TUFLOW reads an ASCII grid of points attributed with elevations derived from 2m filtered LIDAR data flown in 2013. Previous 2m DTM is sat underneath, flown in 2013, to provide full coverage.	Filename: Gosport_LiDAR_001 Command: Read GRID Zpts TUFLOW reads in a text file of points attributed with elevations derived from 1m LIDAR flown in 2020. The following tiles were used: National LiDAR Programme DTM 1m SU40NE (2020), SU40SE (2020), SU50NW (2020), SU50NE (2020), SU60SW (2020) LiDAR Composite DTM 1m SU50SW (2020), SU50SE (2020), SZ69NW (2020), SZ59NE (2020)

[5] Defra Data Services Platform https://environment.data.gov.uk/

2.2 Flood defences

2.2.1 Flood defence improvement works are underway along North Portsea Island and along the Southsea frontage.

2.2.2 No changes to the flood defence levels were required to the Hayling Island model or the Gosport to Warshaw model. There are proposals for flood defence schemes at Alverstoke and Forton (within the Gosport to Warsash model). These proposals have planning approval and funding but at the time of the preparation of the coastal modelling had not started construction. The decision was taken not to include them until construction is complete.

North Portsea Island Scheme

2.2.3 The preferred coastal defence options around North Portsea Island were decided in 2014 and divided into five phases as shown in Figure 2-1 and described below. Phases 1 – 3 have been completed and are included in the TUFLOW model update:

- Phase 1 - Anchorage Park 2015 - 2016: The construction of 1.4km of earth embankment with rock revetment toe. Design height +4.30m AOD. Construction height varies between +4.50m AOD and +4.60m AOD on the northern frontage to allow for settlement. On the Eastern Road stretch, design height of +4.60m AOD. Constructed between +4.80m AOD and +5.10m AOD on the eastern frontage to allow for settlement.
- Phase 2 - Milton Common 2016: The construction of 1.5km of a setback earth embankment and rock revetment structure. Design height: +4.70m AOD (including 150mm settlement).
- Phase 3 - Tipner Lake 2017 - 2019: The construction of 1.9km of a seawall. Design height: +4.50m AOD.
- Phase 4a & 4b - (a)Eastern Road and (b)Kendall's Wharf 2019 - 2023: The construction of a seawall with road raising at the entrance to Kendall's Wharf. Design height: +4.00m AOD design height of the new road. Embankment +4.90m AOD down to +4.60m AOD including settlement allowance. Steel sheet pile wall +4.30m AOD. (Phase 4 has not been included in the TUFLOW model update).
- Phase 5 – Ports Creek 2024 – 2025: Currently going through a detailed design review which once complete will lead to the procurement of the contractor. (Phase 5 has not been included in the TUFLOW model update).

Figure 2-1 North Portsea Island Scheme[6]

2.2.4 As-built drawings provided by Coastal Partners have been used to update the defence crest levels within the Portsea Island TUFLOW model for those schemes that have been constructed (Phase 1-3). In agreement with

[6] Coastal Partners Website: https://coastalpartners.org.uk/project/protecting-the-future-of-north-portsea-island/

project stakeholders it was agreed that the sections of defence that have not yet been constructed should not be included in the model updates until construction is complete (Phase 4 and 5).

Southsea Coastal Scheme

2.2.5 The Southsea Coastal Scheme sets out proposals for building new coastal defences and enable regeneration of the public realm. The design is summarised over the following eight areas:

- Long Curtain Moat: Vertical sea defence with existing high ground and short section of new secondary defence.
- Clarence Pier: grass bund running behind existing buildings. Primary defence could be reintroduced along this line as part of any future development of the area.
- Southsea Common: Existing beach widened combined with a stepped revetment defence and a sloped grass bund. Promenade and road raised.
- Southsea Castle: Rock armour combined with use of existing high ground or new secondary defence. Promenade widened and raised.
- Pyramids Centre: Existing beach widened combined with a stepped revetment defence and buried rock toe.
- South Parade Pier: Stepped revetment defence with a buried rock toe. Steps and rock toe covered in shingle in normal conditions.
- Canoe Lake Park: Existing beach widened combined with a stepped revetment defence and buried rock toe.
- Eastney Esplanade: Long term beach management and monitoring plan put in place to ensure adequate flood risk management. No major flood defence works for approximately next 50 years.

2.2.6 As-built drawings have been provided for Long Curtain Moat and the updated flood defence levels have been incorporated into the TUFLOW model build.

2.2.7 The changes to the flood defence levels for the North Portsea Island Scheme and the Southsea Scheme have been applied using a Z line command in TUFLOW, as described in Table 2-2.

Table 2-2 Flood defence improvements, Portsea Island Model

Layer Name	Command	Purpose
2d_zln_DefenceUpgrades2022_002	Read MI Z Line RIDGE THICK	Data taken from as-built drawings of recent flood defence improvements around North Portsea Island and Southsea.

2.2.8 No changes to the flood defence levels were required to the Gosport to Warshaw model. There are proposals for flood defence schemes at Alverstoke[7] and Forton[8] (within the Gosport to Warsash model). These proposals have planning approval and funding but at the time of the preparation of the coastal modelling had not started construction. It was agreed with the project steering group including LPAs, Coastal Partners and the Environment Agency, that these schemes should not be included within the model build until construction is complete.

2.3 Tidal Boundaries

2.3.1 In order to inform the PfSH SFRA, the models needed to be re-simulated to provide an assessment of the risk of flooding both now and into the future, taking account of the new climate change projections on sea level rise. The epochs of interest for the PfSH SFRA are:

- 2022 (present day scenario).

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[7] Description of Alverstoke Coastal Defence Scheme, Coastal Partners Webpage https://coastalpartners.org.uk/project/alverstoke-coastal-defence-scheme-152
[8] Description of Forton Scheme, Coastal Partners Webpage https://coastalpartners.org.uk/project/forton-scheme

- 2055 (to provide consistency with the epochs in the North Solent Shoreline Management Plan[9]).
- 2122 (to inform local plan preparation and design life of residential developments (100 years)).

2.3.2 All events include a tidal and wave overtopping boundary.

Existing boundary set up

2.3.3 Two types of boundary data were used as inputs into the flood model, these are:

1. a still water boundary, located offshore, which allows propagation of the tide and surge into the model domain, and
2. wave overtopping boundaries along the coastal frontage, which inject wave water into the model at the location of flood defences.

2.3.4 As described in the East Solent Model Development Report, the tidal still water boundary requires the generation of design tidal-graphs. These are time-series data that quantifies how sea levels are expected to change through time during an extreme event. It is these design tidal-graphs that are used to drive the still water component of a flood inundation model at its offshore boundaries. The same approach has been applied to generate the design tidal-curves. This requires three components:

- extreme still water sea level estimates taken from the latest coastal extreme guidance for the UK for the return periods of interest,
- a design surge shape taken from the latest coastal extreme guidance for the UK, and
- a design astronomical tide taken from a gauge local to the site.

Climate change allowances

2.3.5 Current guidance on the climate change allowances that should be applied are set out by the Environment Agency[10]. There are a range of allowances for each river basin district and epoch for sea level rise. The allowances for the south west and south east river basin district are included in Table 2-3. The guidance states that for flood risk assessments and *SFRAs*, LPAs should assess both the *higher central* and the *upper end allowances.*

Table 2-3 Sea level allowances by river basin district for each epoch in mm for each year (based on 1981 to 2000 baseline) – the total sea level rise for each epoch is in brackets

Area of England	Allowance	2000 to 2035 (mm)	2036 to 2065 (mm)	2066 to 2095 (mm)	2096 to 2125 (mm)	Cumulative rise 2000 to 2125 (metres)
South east	Higher central	5.7 (200)	8.7 (261)	11.6 (348)	13.1 (393)	1.20
South east	Upper end	6.9 (242)	11.3 (339)	15.8 (474)	18.2 (546)	1.60
South west	Higher central	5.8 (203)	8.8 (264)	11.7 (351)	13.1 (393)	1.21
South west	Upper end	7 (245)	11.4 (342)	16 (480)	18.4 (552)	1.62

2.3.6 The guidance states, to calculate sea level using Table 2-3, add the allowances for the appropriate one of the 6 geographical areas:

- up to 2035, use the mm for each year rates for the appropriate geographical area, starting from the present day extreme sea levels from Coastal design sea levels – coastal flood boundary extreme sea levels (2018)[11].

[9] North Solent Shoreline Management Plan https://www.northsolentsmp.co.uk/

[10] Environment Agency, May 2022, Flood risk assessments: climate change allowances https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

[11] Coastal Design Sea Levels - Coastal Flood Boundary Extreme Sea Levels (2018) https://data.gov.uk/dataset/73834283-7dc4-488a-9583-a920072d9a9d/coastal-design-sea-levels-coastal-flood-boundary-extreme-sea-levels-2018

- from 2036 to 2065, get the increase in sea level by adding the number of years on from 2035 (to 2065), multiplied by the respective rate for the appropriate geographical area – if the whole time period applies use the cumulative total.
- treat time periods 2066 to 2095 and 2096 to 2125 as you would 2036 to 2065.

2.3.7 Where it is appropriate to apply a credible maximum scenario, use the H++ allowance. There is no H++ value for sea level rise beyond 2100. For the change to relative mean sea level use the H++ scenario of 1.9m for the total sea level rise to 2100.

Updated boundaries

2.3.8 AECOM obtained the latest Coastal Flood Boundary (CFB) dataset (2018) and calculated the revised extreme still water levels using UKCP18 climate change projections for RCP 8.5 at 70th (higher central) and 95th percentiles (upper end) for the 0.5% AEP event for the years 2022, 2055 and 2122. The H++ water level was also generated for the year 2122.

2.3.9 To generate the extreme tidal curve, the same approach was applied as that implemented in the JBA 2015 study. The surge profile at Portsmouth was used for all sites and the astronomical tides were generated using harmonic constants given in Admiralty Tide Tables. The same period tides (13/10/2012 and 19/10/2012) have been used as presented in 2015 JBA report. An example of the resulting tidal graph for chainage point '4616' at Portsmouth Harbour mouth is shown in Figure 2-2. Each of the 2D hydrodynamic models were run for four tidal cycles, to capture the highest peak tidal levels, with the simulation time starting at 52.25 hours and ending at 101.75 hours.

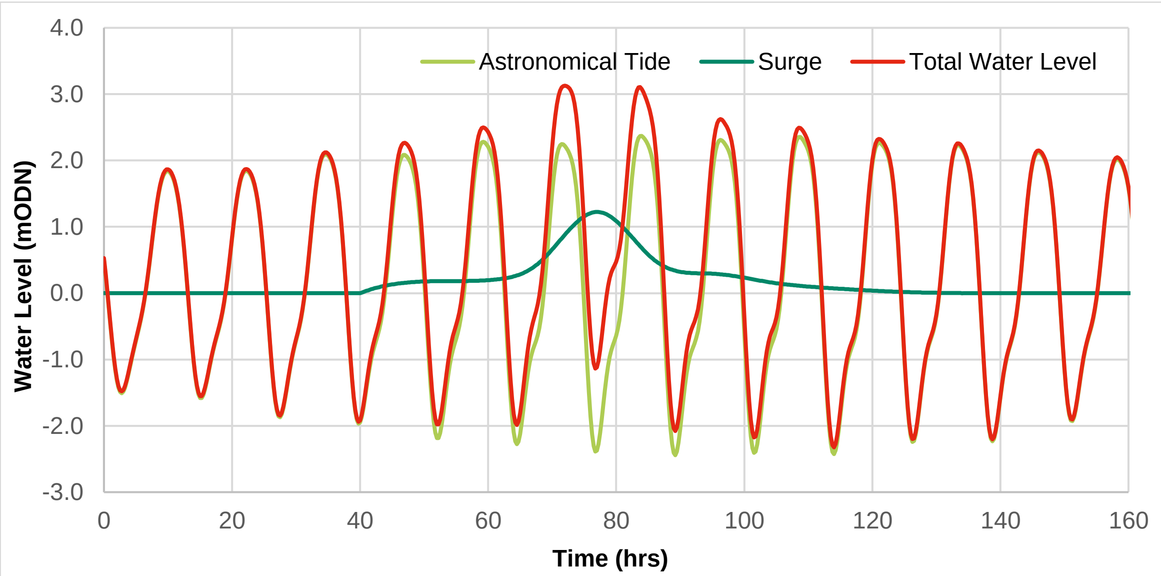

Figure 2-2 Design tidal graph for 0.5% AEP event (2022) based on CFB chainage points 4616 at Portsmouth Harbour mouth

2.3.10 When the East Solent models were simulated in the most recent version of TUFLOW, there was an issue with the mass error which is a sign of poor numerical convergence which could impact the accuracy of the model outputs. This error was associated with the HX line (which links the 1D and 2D elements of the hydraulic model) which interpolates the tidal levels along the tidal boundary.

2.3.11 Following discussions with TUFLOW support, it was agreed that the HX line should be removed from the model and replaced with a HT boundary. This boundary specifies a water level versus a time hydrograph at a particular location. To apply this boundary, several HT boundaries were used to interpolate tidal levels along the boundary of the model. It should be noted that this method is more conservative that the HX approach, as the level of interpolation using this approach is less detailed and it is therefore likely that a slightly higher water level will be applied in some areas.

Wave overtopping

It was agreed with the project steering group that no changes would be made to the wave overtopping boundaries as part of the model re-simulations. Instead, a comparison of the newly calculated maximum water levels for the years 2022, 2055 and 2122 was undertaken with the water levels modelled in the 2015 study, and the wave overtopping inputs for the AEP events that were closest to these events were applied for each event. This is demonstrated in Table 2-4.

It should be noted that for 0.5% AEP (2055) upper end, the wave overtopping inputs corresponding to the water levels modelled in the 2015 study (i.e 0.1% AEP (2031) using UKC09) were not available. So, the next available equivalent - 0.5% AEP 2065 using UKCP09 was substituted. However, a select few of these overtopping inputs (mainly along the Mengham beach front) were lower than the values applied for the higher central estimates (0.5% AEP (2055) higher central). Therefore, the values were compared and the higher of the two were applied to provide a conservative assessment.

Table 2-4 Wave Overtopping Inputs

Required Event for PfSH SFRA	Wave overtopping inputs applied from 2015 study
3.3% AEP (2022)	3.3% AEP (2015)
3.3% AEP (2122) higher central	0.1% AEP (2015)
0.5% AEP (2022)	0.5% AEP (2015)
0.5% AEP (2055) higher central	0.1% AEP (2015)
0.5% AEP (2122) higher central	0.1% AEP 2115 using UKCP09
0.5% AEP (2055) upper end	0.1% AEP (2015) and 0.5% AEP 2065 using UKCP09
0.5% AEP (2122) upper end	0.1% AEP 2115 using UKCP09
0.1% AEP (2055) upper end	0.1% AEP 2065 using UKCP09
0.1% AEP (2122) upper end	0.1% AEP 2115 using UKCP09

2.3.12 The overtopping discharge was applied in the 2D hydrodynamic models at the same time as the peak tidal cycle.

Other Model Updates

2.3.13 Other minor updates to the East Solent models include:

- For the Portsea model two stability patches included within the received model were refined. The first (2d_ztin_Portsmouth_stability_004a) was updated to smooth out the bathymetry and the second (2d_zrg_stability_003) was updated to improve the representation at the HM Naval Base Harbour.
- The Initial Water Levels (IWLs) were updated within all models to reflect the changes to the tidal boundary.

2.4 Modelled Scenarios

2.4.1 The scenarios simulated as part of this study alongside the peak extreme still water level are presented in Table 2-5. It should be highlighted that for each model the peak extreme water level has been extracted from the main coastal boundary. Depending on coastal location, the extreme still water level changes. For example, in estuary areas the water level will be different and therefore a factor is applied in the model to account for this. The 0.5% AEP event for 2122 H++ climate change allowance was only simulated for the Gosport to Warsash model as requested by Gosport BC.

Table 2-5 Modelled Scenarios

AEP	Epoch	Climate Change	Gosport Peak Extreme Still Water Level (m AOD)	Hayling Peak Extreme Still Water Level (m AOD)	Portsea Peak Extreme Still Water Level (m AOD)
Defended					
3.3%	2022	Present Day (70th)	2.94	3.23	2.97
3.3%	2122	Higher Central (70th)	3.98	4.27	4.01
0.5%	2022	Present Day (70th)	3.13	3.26	3.20

AEP	Epoch	Climate Change	Gosport Peak Extreme Still Water Level (m AOD)	Hayling Peak Extreme Still Water Level (m AOD)	Portsea Peak Extreme Still Water Level (m AOD)
0.5%	2055	Higher Central (70th)	3.37	3.50	3.44
0.5%	2122	Higher Central (70th)	4.17	4.30	4.24
0.5%	2055	Upper End (95th)	3.44	3.57	3.51
0.5%	2122	Upper End (95th)	4.54	4.67	4.61
0.5%	2122	H++	5.12	n/a	n/a
0.1%	2055	Upper End (95th)	3.59	3.74	3.67
0.1%	2122	Upper End (95th)	4.69	4.84	4.77
Undefended					
0.5%	2055	Higher Central (70th)	3.37	3.50	3.44
0.5%	2122	Higher Central (70th)	4.17	4.30	4.24
0.1%	2055	Higher Central (70th)	3.52	3.67	3.60
0.1%	2122	Higher Central (70th)	4.32	4.47	4.40
0.5%	2055	Upper End (95th)	3.44	3.57	3.51
0.5%	2122	Upper End (95th)	4.54	4.67	4.61
0.1%	2055	Upper End (95th)	3.59	3.74	3.67
0.1%	2122	Upper End (95th)	4.69	4.84	4.77

2.5 Outputs

2.5.1 The following outputs have been supplied to the client group for each modelled scenario.

- Maximum depth grid (ASCII format).
- Maximum hazard (ZUK0) grid (ASCII format).
- Maximum water level grid (ASCII format).
- Maximum flood extent grid (GIS shapefile).

2.6 Future Flood Zones

2.6.1 In order to provide an indication of how the Flood Zones may change in the future as a result of climate change, a future Flood Zone 2 and future Flood Zone 3 have been generated. The same approach has been applied as was used for generating the Flood Zones in the 2015 East Solent Study:

- Future Flood Zone 2 was generated by combining the maximum flood extents for the 0.1% AEP (Upper End) 2122 defended and undefended scenarios.
- Future Flood Zone 3 was generated by combining the maximum flood extents for the 0.5% AEP (Upper End) 2122 defended and undefended scenarios.

2.6.2 Flood Zones 2 and 3, as shown on the Flood Map for Planning (Rivers and Sea), are generally described as presenting the risk of flooding from the sea assuming *defences are not in place*. However, it is noted that, somewhat counterintuitively, in some locations the maximum flood extent is greater during the defended model simulation compared to the undefended simulation. The removal of raised flood defences from the model enables water to flow back out to sea as the tide recedes, whereas during the defended scenarios it remains in the model domain and accumulates with the next tidal cycle.

2.6.3 Furthermore, in some locations the ground levels are above the *still water* flood risk and the flood risk comes only from wave overtopping. In these situations, the modelling approach can lead to the defended flood risk areas being larger than the undefended flood risk extents. This is due to the wave overtopping ponding behind the defences in the defended scenarios but flowing back to sea in the undefended scenarios.

2.6.4 As a result, the future Flood Zones presented in this SFRA are derived from the maximum flood extent from both the undefended and defended scenarios, rather that solely the undefended scenario. As noted above, this is consistent with the method applied in the 2015 East Solent Study.

3. Breach modelling

3.1 Residual risk

3.1.1 The Planning Practice Guidance[2] (PPG), defines residual risks as those remaining after applying the sequential approach to the location of development and taking mitigating actions. Examples of residual flood risk include:

- the failure of flood management infrastructure such as a breach of a raised flood defence, blockage of a surface water conveyance system, overtopping of an upstream storage area, or failure of a pumped drainage system
- failure of a reservoir, or
- a severe flood event that exceeds a flood management design standard, such as a flood that overtops a raised flood defence, or an intense rainfall event which the drainage system cannot cope with.

3.1.2 Areas behind flood defences are at particular risk from rapid onset of fast-flowing and deep water flooding, with little or no warning if defences are overtopped or breached.

3.1.3 The SFRA should consider the residual risk of flooding in the study area.

3.1.4 The coastal modelling described in Section 2 includes 'undefended' scenarios, which enable an assessment of the risks if defences were not in place. However, as described in the Environment Agency Breach of Defences Guidance[12], the development of 'with defences' and 'without defences' modelling and mapping is not a surrogate for residual risk assessment and can both overestimate and in some cases underestimate the 'true' flood risk and hazard. In addition, the hazard from a sudden release of water from a failure is often not properly appreciated in assessments of flood defences.

3.1.5 There is scope within the SFRA to carry out breach assessments at specific locations around the study area, where appropriate. The justification for these specific breach assessments as part of the SFRA will depend on where development is proposed, and the local characteristics of the defences that could make them susceptible to a breach, for example:

- Whether it is a 'breachable' location, i.e. the ground levels behind the defence are lower than the crest level of the defence
- Whether there are any vulnerable points in the existing defence, for example structures in the defence or a known defect.

3.2 Breach locations and parameters

3.2.1 Breach locations have been identified based on a review of the defence types, the extent of Flood Zone 2 and a review of the ground levels behind the defence using LiDAR topographic data. The breach locations were discussed and agreed with the Environment Agency and steering group in Summer 2021.

3.2.2 The Environment Agency Breach of Defences Guidance[12] sets out the parameters that should be applied for different types of defence. Table 3-1 reproduced from the guidance summarises the breach widths and time to close.

3.2.3 The invert level of the breach has been determined by interrogation of the LiDAR on the landward side of the breach location, applying the rule of thumb that the breach invert level should be the lowest ground level within a radius the same as the breach width.

3.2.4 The breaches are modelled to occur 1 hour prior to the peak water level and lower the defence to the specific invert level over a set period of time, dependent on the type of defence. The length of defence defined to breach is lowered using a variable zshape feature in TUFLOW.

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[12] Environment Agency, 29th June 2021, LIT56413 Breach of Defences Guidance.

Table 3-1 Breach parameters (width and time to close)

Source	Defence Type	Breach Width (m)	Time to close – urban (hrs)	Time to close – rural (hrs)
Estuary/Tidal River	Earth Bank	50	30	30
	Reinforced Concrete	20	18	18
Open Coast	Earth Bank	200	44	56
	Earth Bank with facing	100	44	56
	Dunes	100	44	56
	Shingle Bank	100	30	30
	Reinforced Concrete	50	18	30
River	Earth Bank	40	30	56
	Reinforced Concrete	20	18	18
Tidal/Coastal	Tidal Gates	Gate width	Gates fail on low tide preceding the peak level with emergency closure effected during the following low tide	

3.2.5 The following section demonstrates the location of each breach and provides a table presenting the key information such as defence type, source of flood risk, width of the breach, invert levels both seaward and landward and also the length of time the defence is breached. The specific breach reference is also provided which relates directly to the model simulations.

3.2.6 Given the model simulation time (approximately 3 days), breach locations were grouped together based on location and length of time the defences are breached. It was ensured that breach locations that were modelled within the same simulation were located suitably far apart to ensure that the flood extents did not converge. Where required, flood defences within the rest of the model were raised to 100m AOD to ensure that floodwater entering the model domain was from the breach only and not from overtopping of other defences. This is based on the information within the SMP[9]. Where defences are to be maintained or improved, these were raised within the model. The overtopping boundaries were also removed from the model.

3.2.7 For Hayling Island, a total of 3 breach models were simulated. One included breach locations STO1, EAS2 and MAR1, another included NOR1, EAS1 and EAS3 and the final model included MEN1.

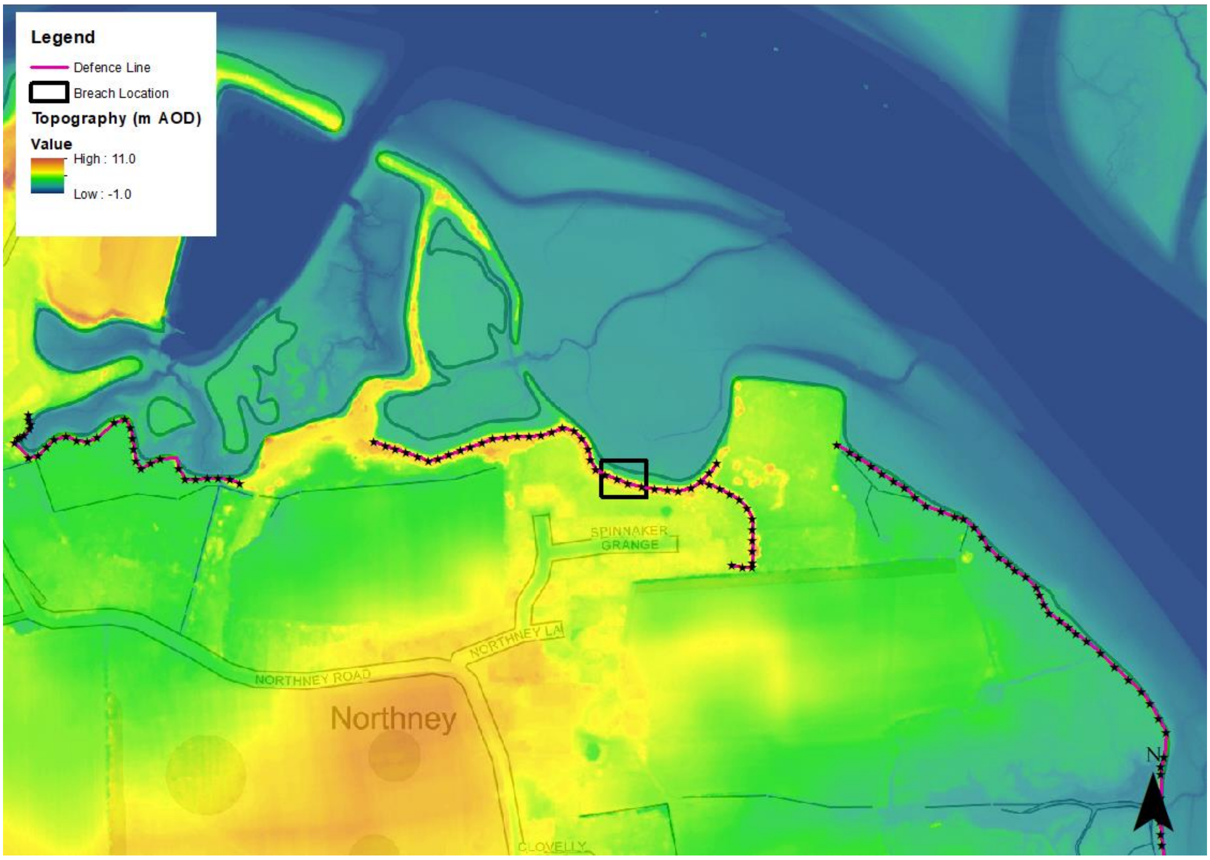
3.2.8 For Portsea Island, a total of 3 breach models (A, B and C) were simulated. Breach A included breach locations POR1, HOR1, ESN_OPTION_2 and HIL1, Breach B included breach location ESN_OPTION_1 and Breach C included breach location Old_Portsmouth_AEC.

3.2.9 For the Gosport to Warsash model, a total of 2 breach model was simulated. One included breach locations HAS1 and BLO2 while the other included breach locations BLO1 and WAR2.

3.2.10 Each breach model was simulated for the 0.5% AEP event for 2122 using the upper end (95th percentile) climate change allowance on sea level rise.

3.3 Hayling Island Model – Breaches

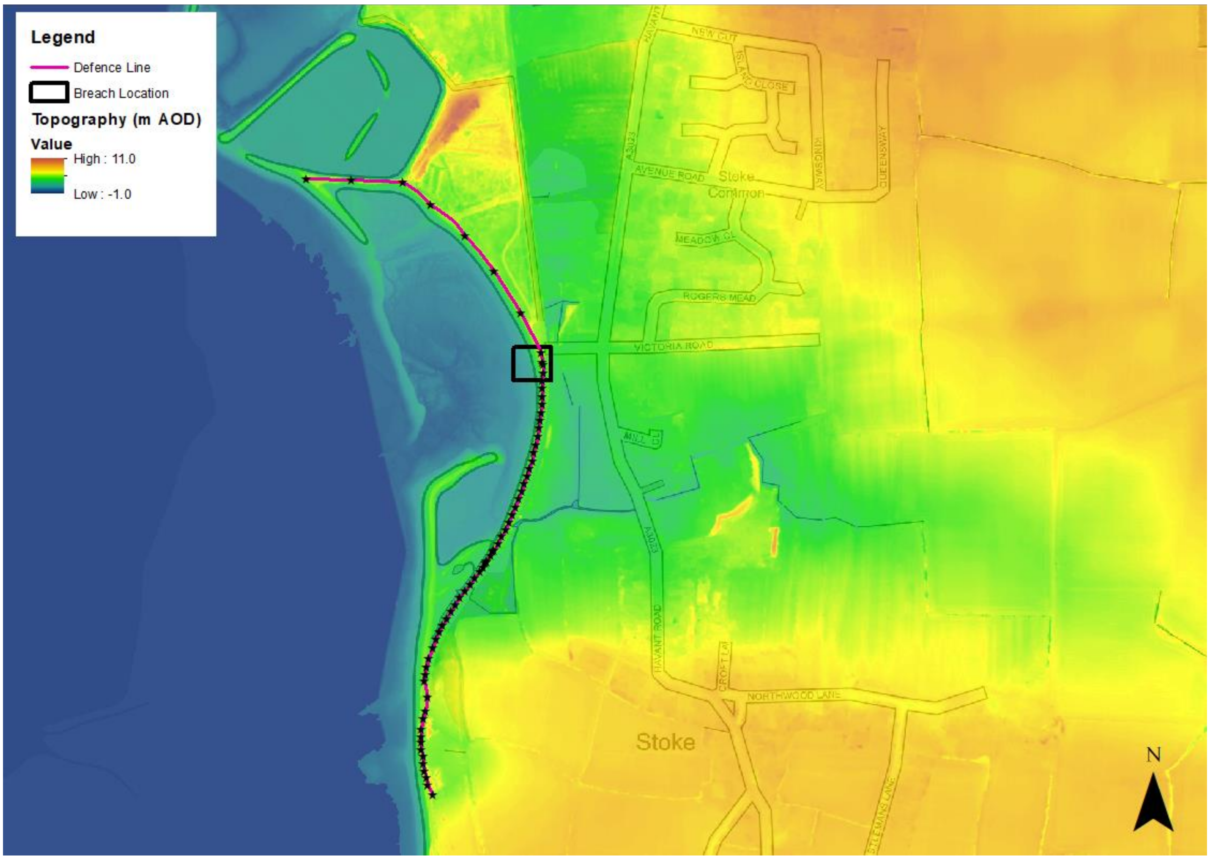
Breach Location NOR1



Location of breach NOR1

Breach Reference	NOR1
Grid Reference	SU7327503956
Description of location	Shoreline north of Northney village (North Hayling).
Description of defence	Earth Bank
Source	Estuary/tidal river
Width of breach (m)	50
Seaward invert level (m AOD)	1.1
Inland invert level (m AOD)	3.7
Length of time breached (hrs)	30

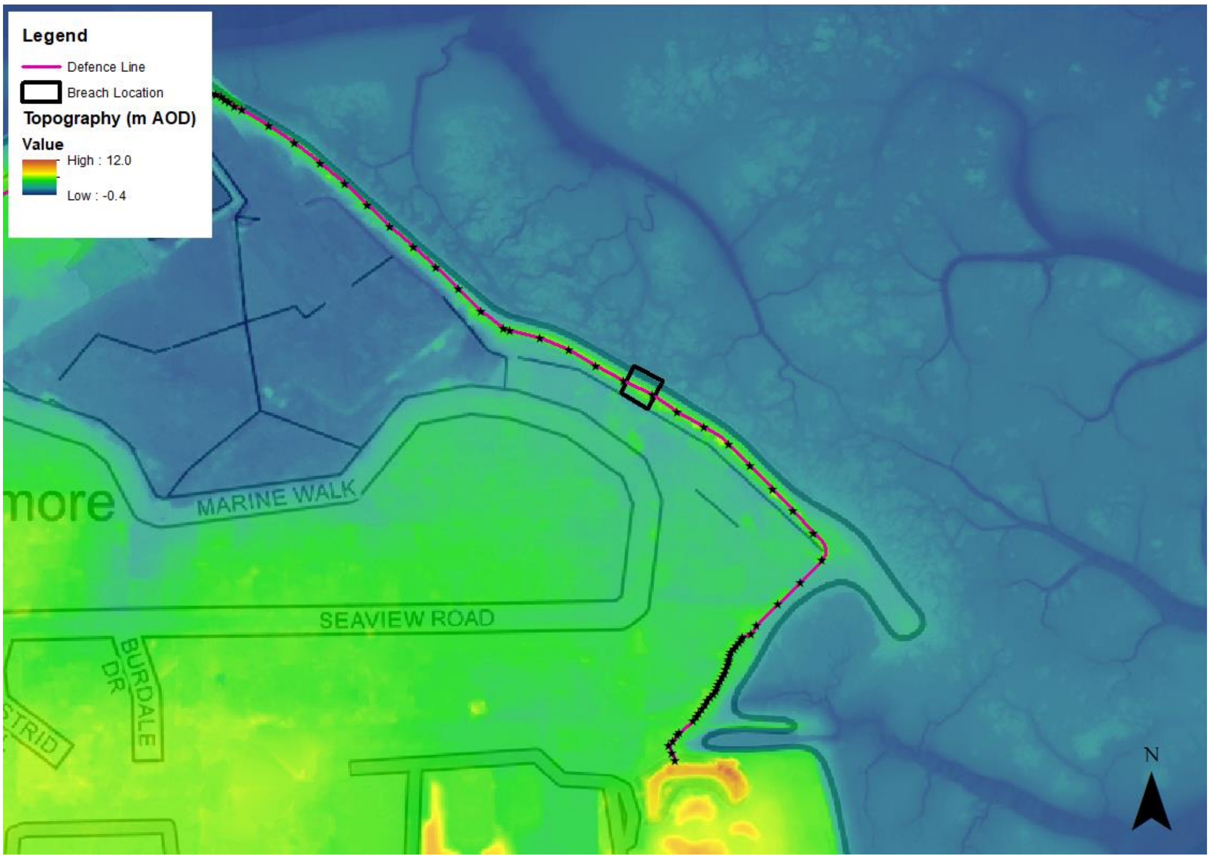
Breach Location STO1



Location of breach STO1

Breach Reference	STO1
Grid Reference	SU7171402944
Description of location	Stoke (eastern shore of Langstone Harbour).
Description of defence	Shingle bank
Source	Estuary/tidal river
Width of breach (m)	50
Seaward invert level (m AOD)	0.6
Inland invert level (m AOD)	2.2
Length of time breached (hrs)	30

Breach Location MEN1



Location of breach MEN1

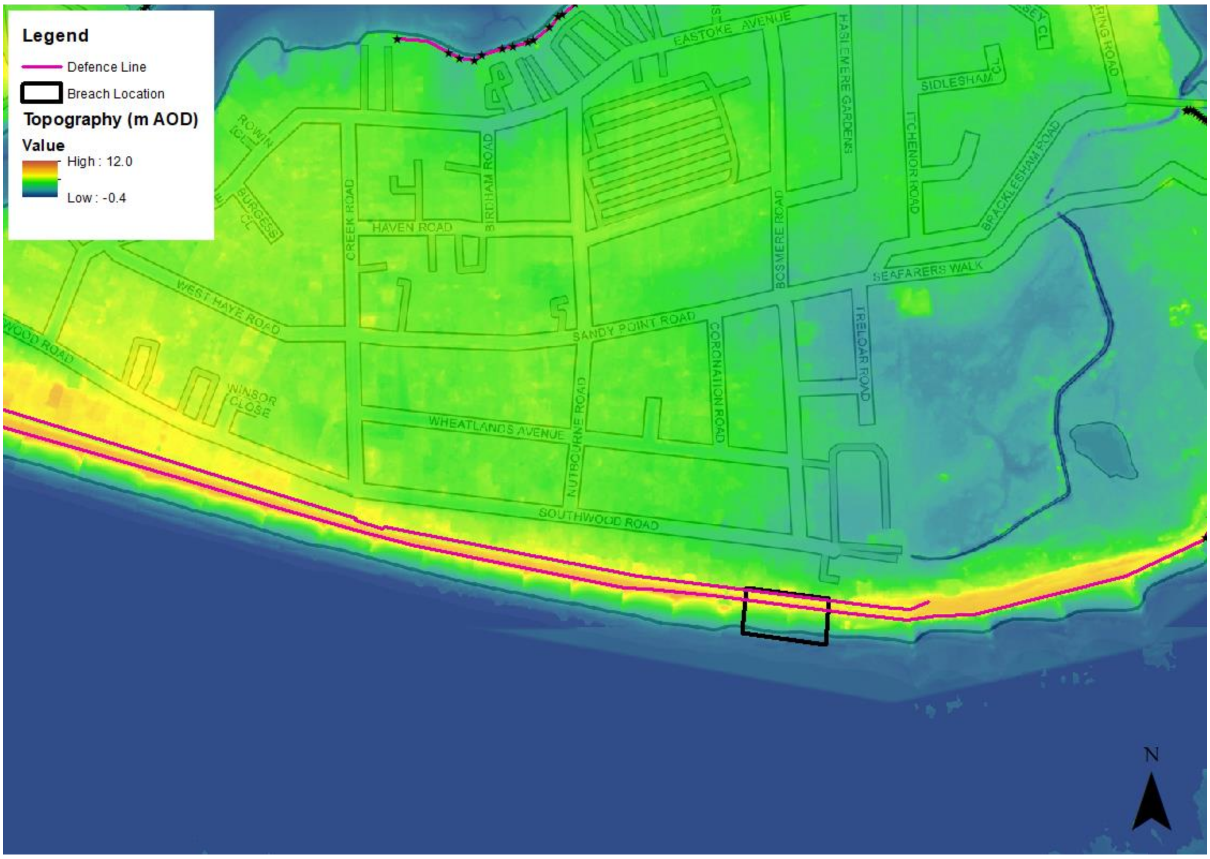
Breach Reference	MEN1
Grid Reference	SZ7383199257
Description of location	Mengham Salterns (western side of Chichester Harbour).
Description of defence	Reinforced concrete wall
Source	Estuary/tidal river
Width of breach (m)	20
Seaward invert level (m AOD)	1.2
Inland invert level (m AOD)	2.0
Length of time breached (hrs)	18

Breach Location MAR1

Location of breach MAR1

Breach Reference	MAR1
Grid Reference	SZ7453898857
Description of location	Marina, Hayling Island
Description of defence	Reinforced concrete wall
Source	Estuary/tidal river
Width of breach (m)	20
Seaward invert level (m AOD)	0.9
Inland invert level (m AOD)	2.7
Length of time breached (hrs)	18

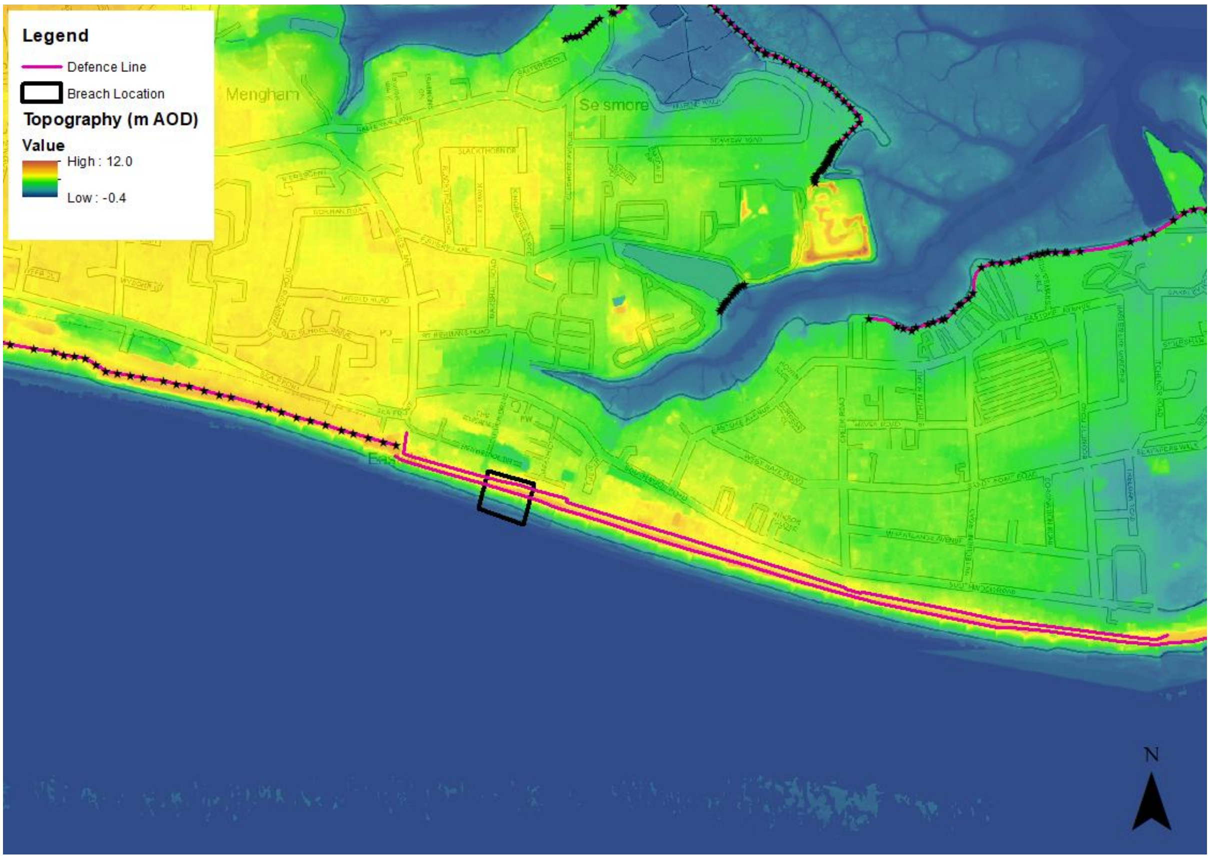
Breach Location EAS3



Location of breach EAS3

Breach Reference	EAS3
Grid Reference	SZ7453898857
Description of location	Eastern end of Eastoke beach near Southwood Road (Hayling Island).
Description of defence	Shingle Bank
Source	Open Coast
Width of breach (m)	100
Seaward invert level (m AOD)	0.5
Inland invert level (m AOD)	4.0
Length of time breached (hrs)	30

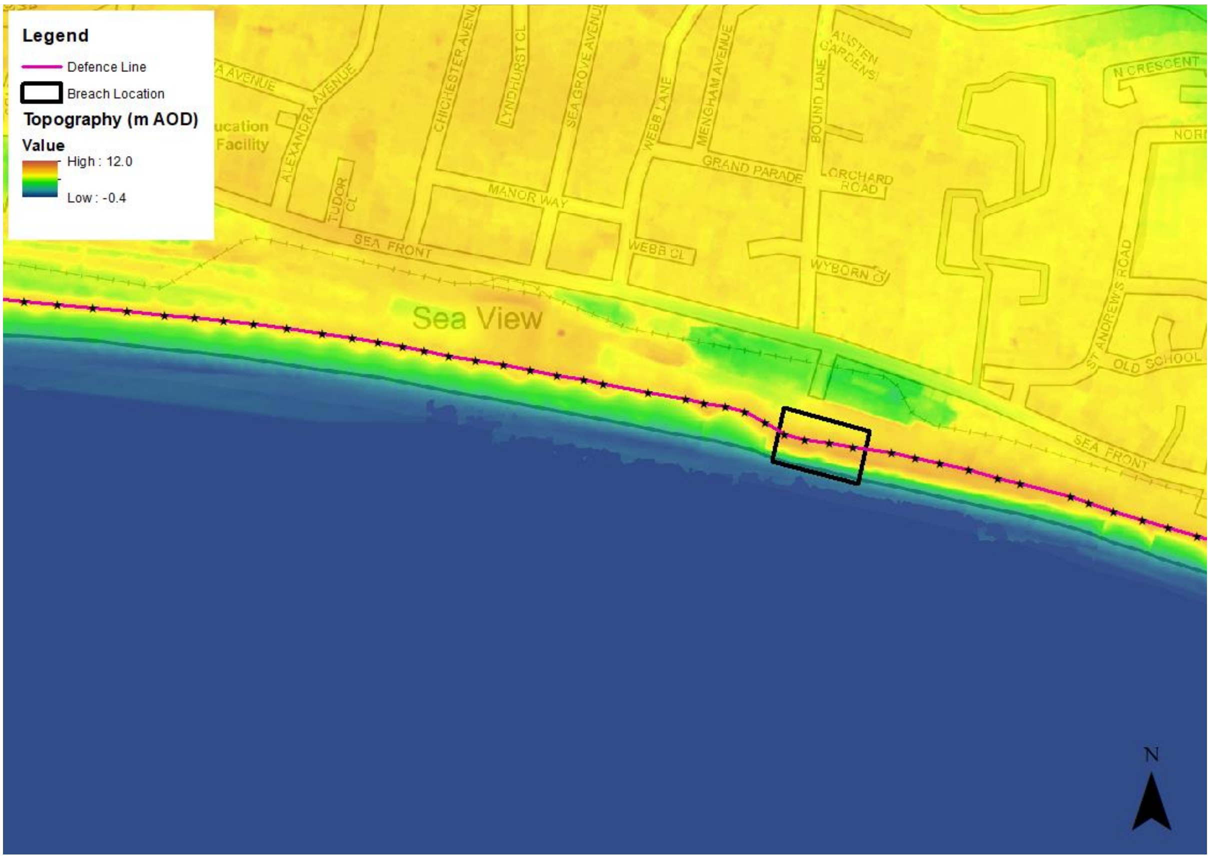
Breach Location EAS2



Location of breach EAS2

Breach Reference	EAS2
Grid Reference	SZ7314798368
Description of location	Eastoke beach near Bembridge Drive.
Description of defence	Shingle Bank
Source	Open Coast
Width of breach (m)	100
Seaward invert level (m AOD)	0.2
Inland invert level (m AOD)	4.5
Length of time breached (hrs)	30

Breach Location EAS1



Location of breach EAS1

Breach Reference	EAS1
Grid Reference	SZ7244998588
Description of location	Eastoke beach near Bound Lane (Hayling Island).
Description of defence	Shingle Bank
Source	Open Coast
Width of breach (m)	100
Seaward invert level (m AOD)	1.3
Inland invert level (m AOD)	4.6
Length of time breached (hrs)	30

3.4 Portsea Island Model – Breaches

Breach Location HIL1

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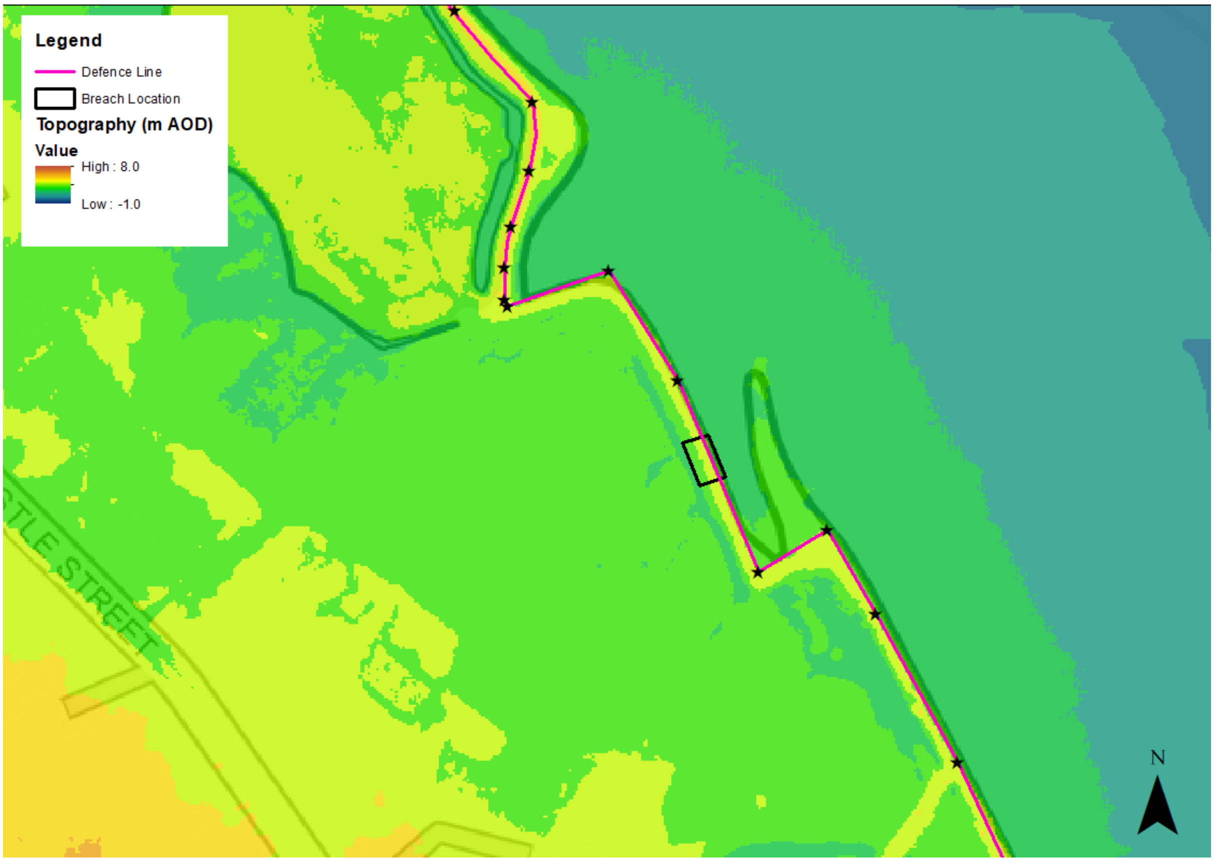
Location of breach HIL1

Breach Reference	HIL1
Grid Reference	SU6497504157
Description of location	East side of Hilsea Bastion Gardens (immediately opposite M275).
Description of defence	Reinforced concrete wall
Source	Estuary/tidal river
Width of breach (m)	20
Seaward invert level (m AOD)	0.8
Inland invert level (m AOD)	1.9
Length of time breached (hrs)	18

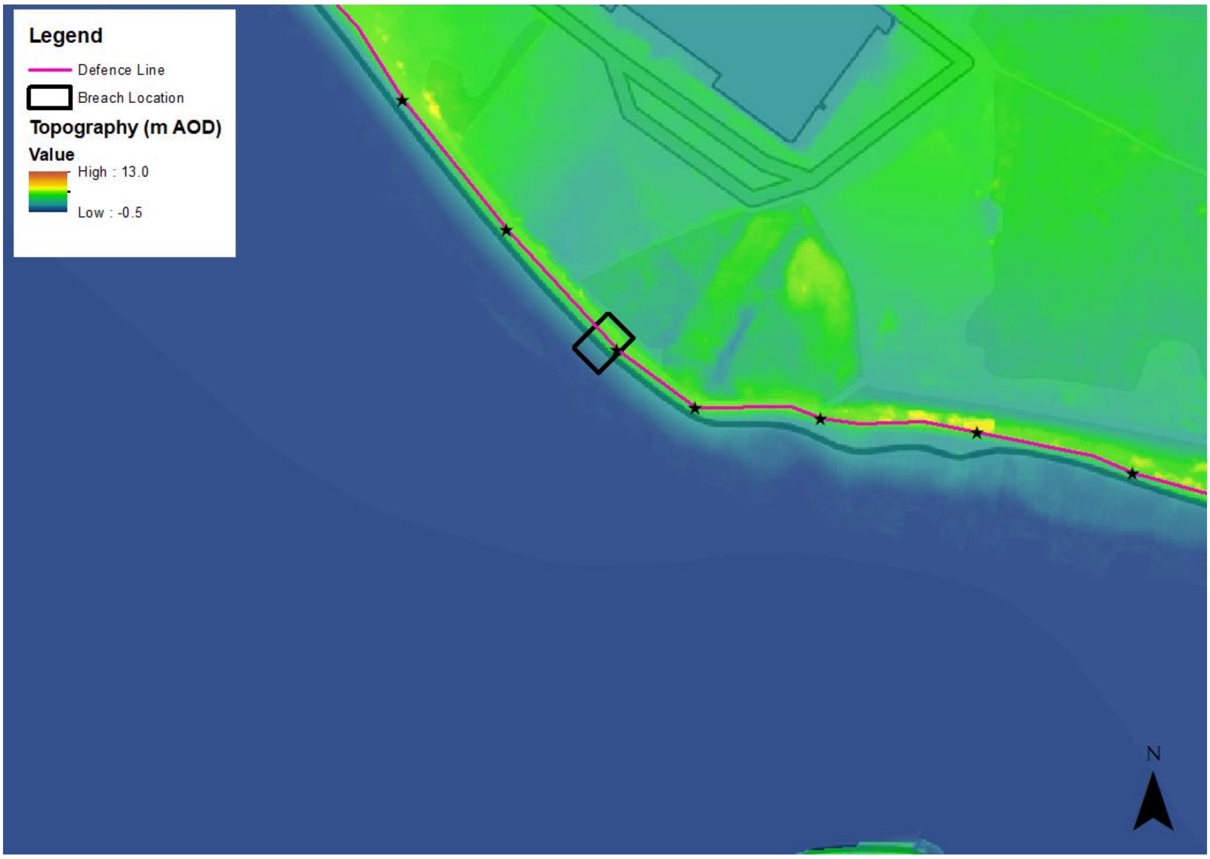
Breach Location POR1



Location of breach POR1

Breach Reference	POR1
Grid Reference	SU6241504942
Description of location	West side of Paulsgrove Lake (Portchester).
Description of defence	Reinforced concrete wall
Source	Estuary/tidal river
Width of breach (m)	20
Seaward invert level (m AOD)	1.3
Inland invert level (m AOD)	1.4
Length of time breached (hrs)	18

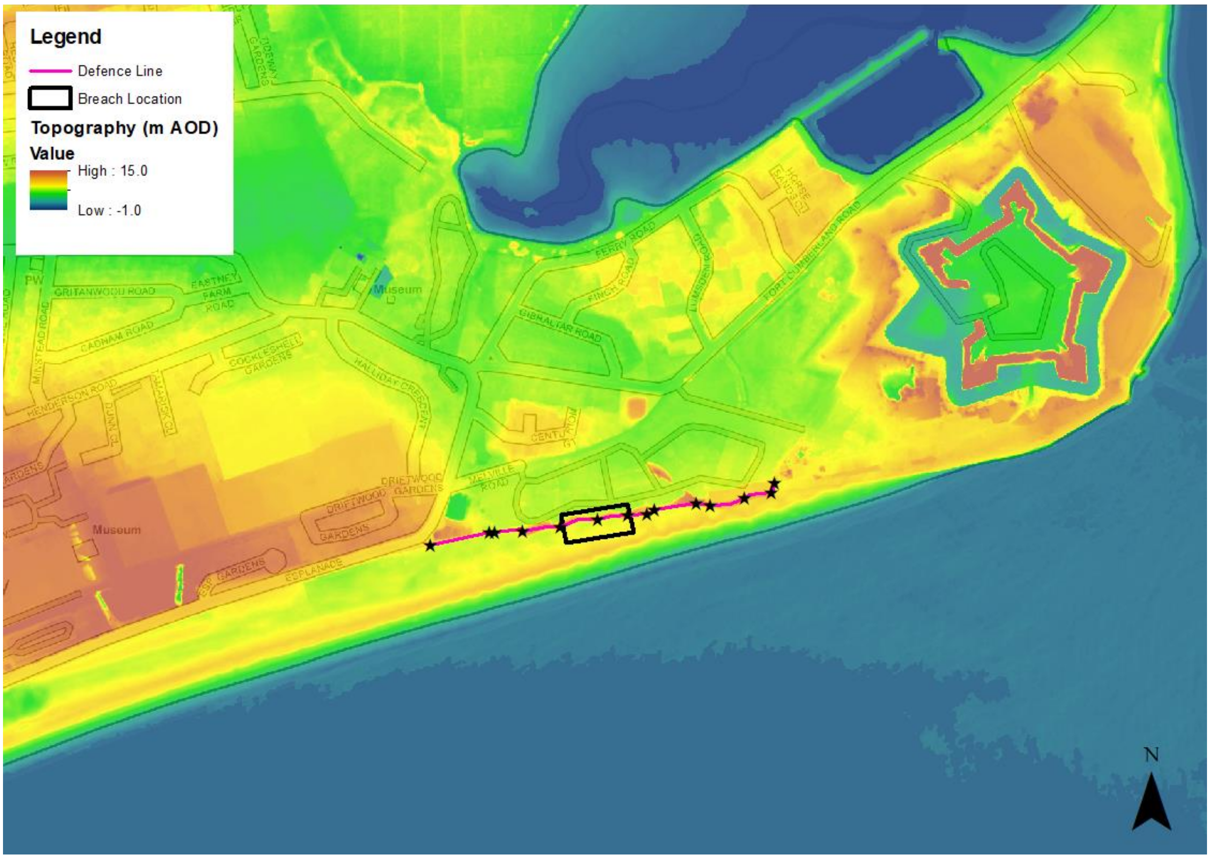
Breach Location HOR1



Location of breach HOR1

Breach Reference	HOR1
Grid Reference	SU6378603975
Description of location	Southern side of Horsea Island.
Description of defence	Reinforced concrete wall
Source	Estuary/tidal river
Width of breach (m)	20
Seaward invert level (m AOD)	0.2
Inland invert level (m AOD)	2.6
Length of time breached (hrs)	18

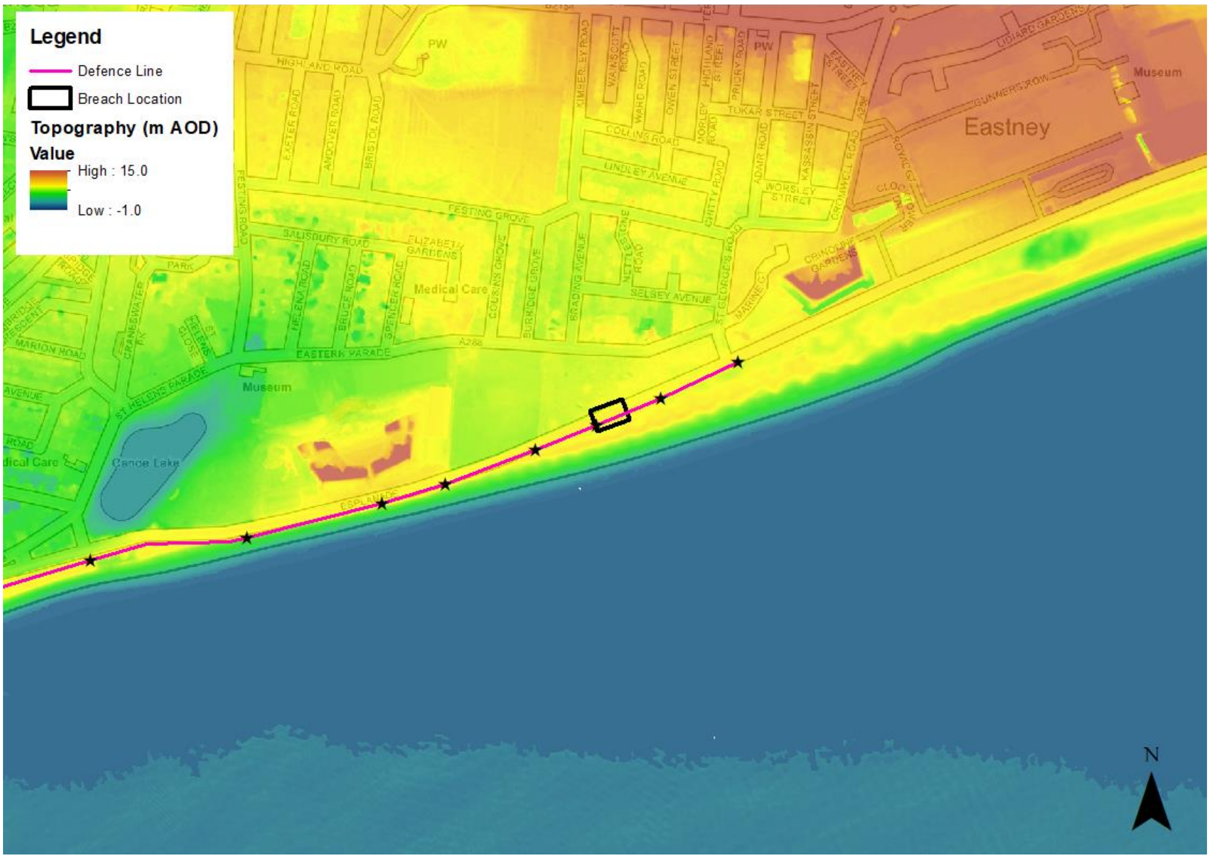
Breach Location ESN OPTION 1



Location of breach ESN OPTION 1

Breach Reference	ESN OPTION 1
Grid Reference	SZ6763498913
Description of location	Eastern end of Eastney Beach.
Description of defence	Shingle Bank
Source	Open coast
Width of breach (m)	100
Seaward invert level (m AOD)	4.4
Inland invert level (m AOD)	3.9
Length of time breached (hrs)	30

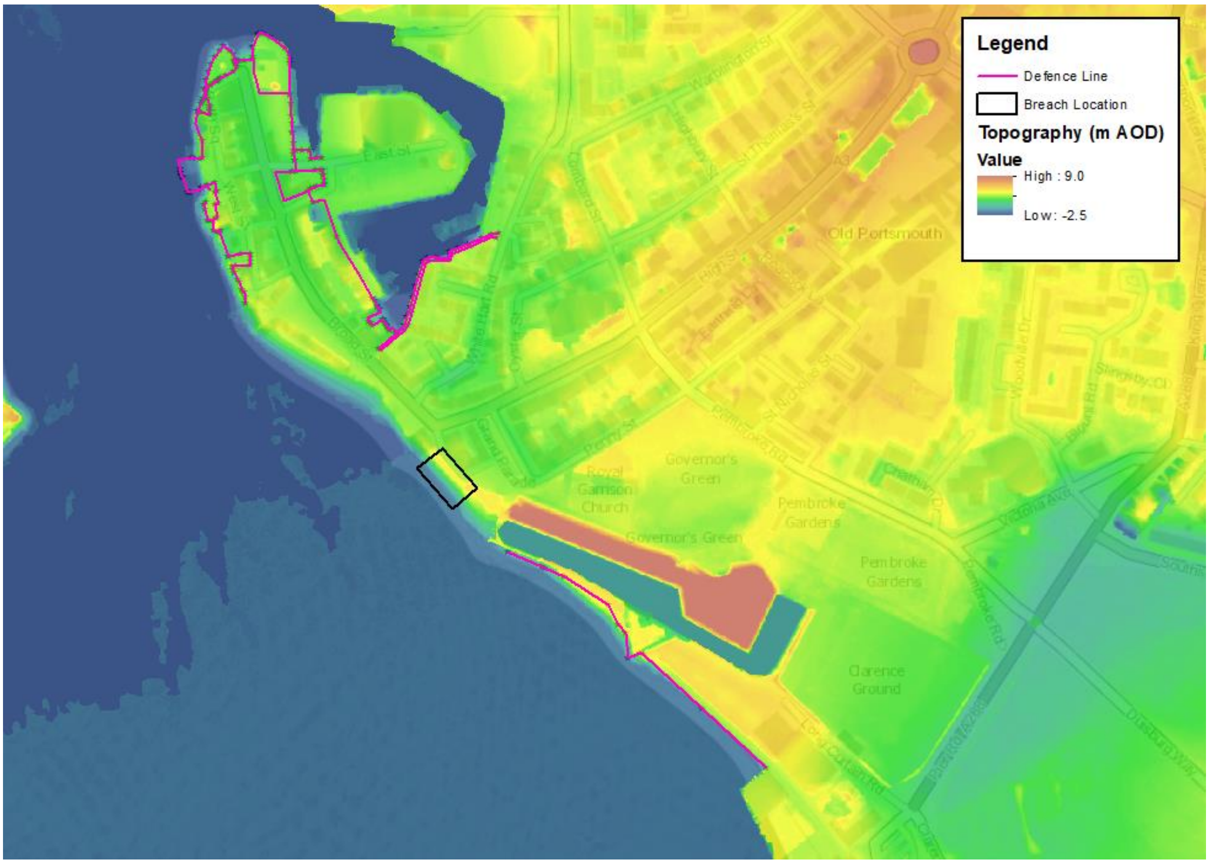
Breach Location ESN OPTION 2



Location of breach ESN OPTION 2

Breach Reference	ESN OPTION 2
Grid Reference	SZ6614098387
Description of location	Western end of Eastney Beach.
Description of defence	Reinforced concrete wall
Source	Open coast
Width of breach (m)	50
Seaward invert level (m AOD)	4.4
Inland invert level (m AOD)	4.3
Length of time breached (hrs)	18

Breach Location OLD PORTSMOUTH AEC 001

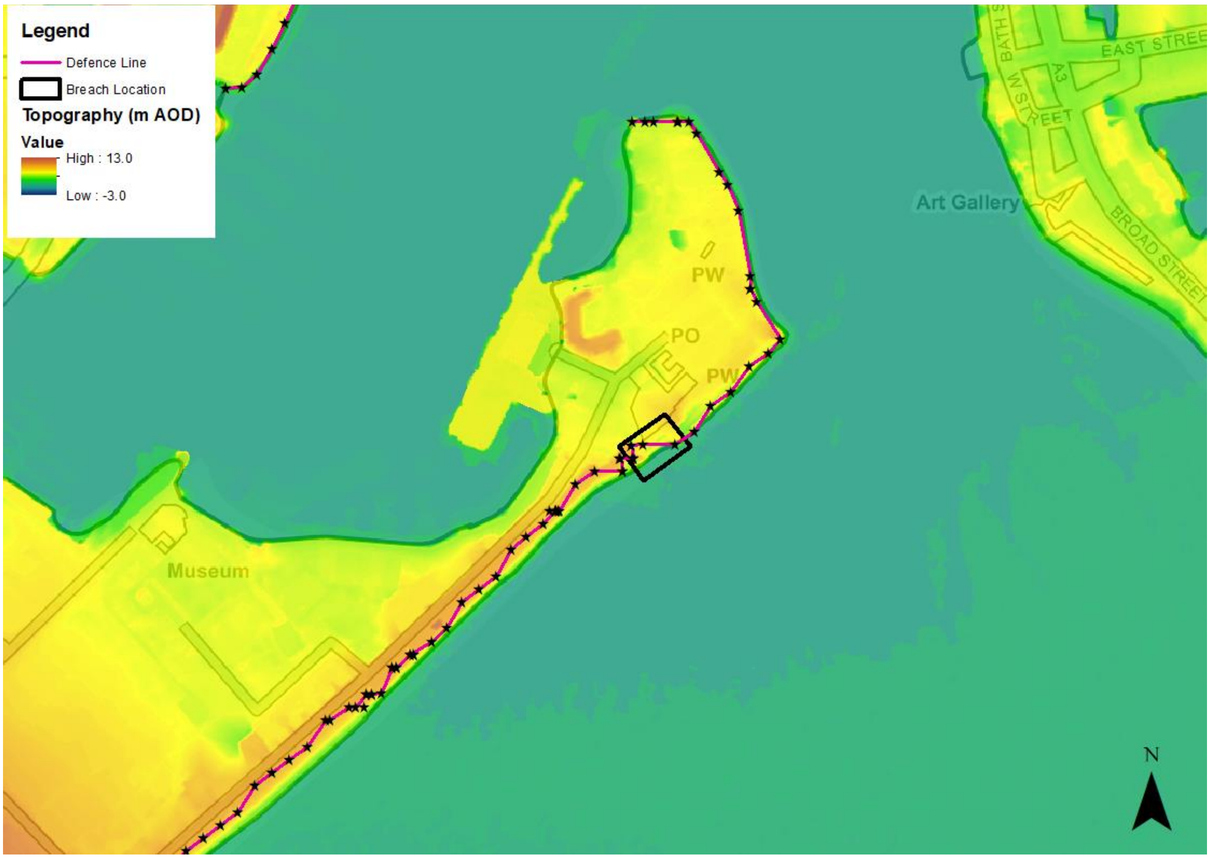


Location of breach OLD PORTSMOUTH AEC 001

Breach Reference	OLD PORTSMOUTH AEC 001
Grid Reference	SZ6310199219
Description of location	Western side of Old Portsmouth
Description of defence	Reinforced Concrete Wall
Source	Open coast
Width of breach (m)	50
Seaward invert level (m AOD)	0.3
Inland invert level (m AOD)	3.0
Length of time breached (hrs)	18

3.5 Gosport to Warsash Inundation Model

Breach Location BLO2



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Location of breach BLO2

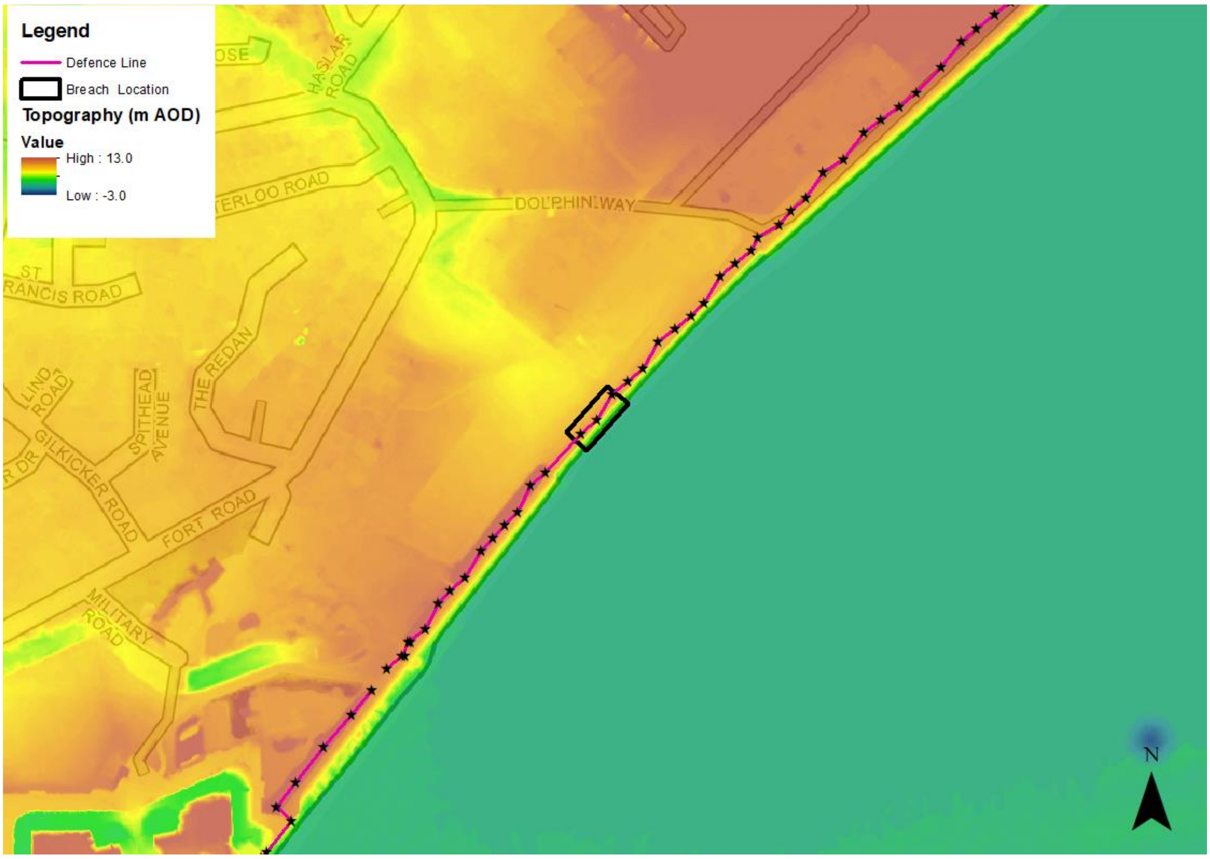
Breach Reference	BLO2
Grid Reference	SZ6257699165
Description of location	Fort Blockhouse, Gosport
Description of defence	Reinforced concrete wall
Source	Open coast
Width of breach (m)	50
Seaward invert level (m AOD)	0.4
Inland invert level (m AOD)	4.5
Length of time breached (hrs)	18

Breach Location BLO1

Location of breach BLO1

Breach Reference	BLO1
Grid Reference	SZ6224298874
Description of location	South of Fort Blockhouse, Gosport.
Description of defence	Reinforced concrete wall
Source	Open Coast
Width of breach (m)	50
Seaward invert level (m AOD)	0.4
Inland invert level (m AOD)	5.4
Length of time breached (hrs)	18

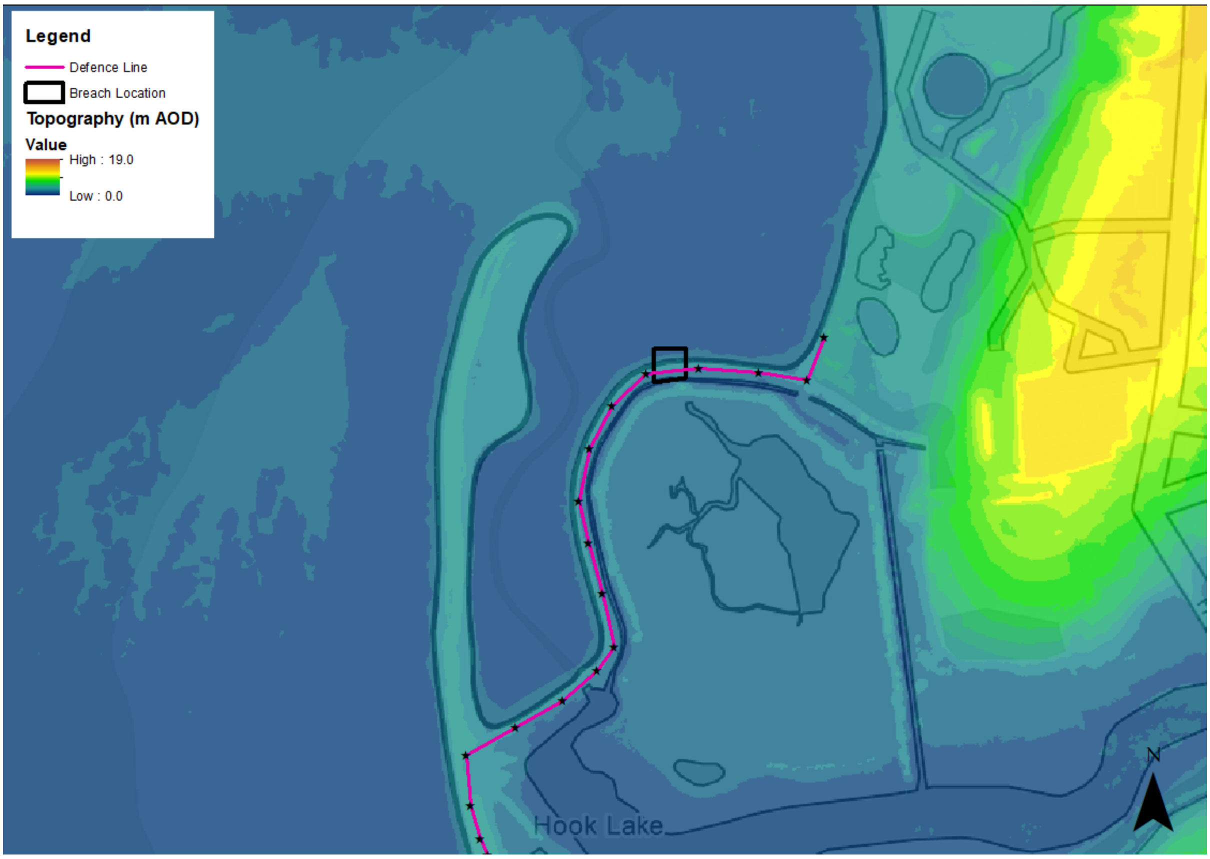
Breach Location HAS1



Location of breach HAS1

Breach Reference	HAS1
Grid Reference	SZ6159898264
Description of location	Haslar sea wall (south of Dolphin Way).
Description of defence	Reinforced concrete wall
Source	Open Coast
Width of breach (m)	50
Seaward invert level (m AOD)	0.4
Inland invert level (m AOD)	5.1
Length of time breached (hrs)	18

Breach Location WAR2



Location of breach WAR2

Breach Reference	WAR2
Grid Reference	SU4896205328
Description of location	Warsash maritime academy
Description of defence	Reinforced concrete wall
Source	Estuary/tidal river
Width of breach (m)	20
Seaward invert level (m AOD)	0.2
Inland invert level (m AOD)	0.8
Length of time breached (hrs)	18