Appendix B - Flood Risk Policy and Development Management Considerations

Introduction

All four planning authorities are undertaking a review of their Local Plans including revisions to strategic policies and proposals for future development, as well as revisions to site allocations and development management policies. As set out in Section 2, at the point of preparation of the SFRA, each of the South Essex Authorities are at slightly different stages in the development of their Local Plans.

The purpose of this Appendix is to present recommendations consistent with the NPPF and PPG for consideration by the South Essex Authorities when developing flood risk management policies. Some of the recommendations are common to all four authorities, and some are specific to particular LPAs. It should be noted that it is ultimately the responsibility of the LPAs to formally formulate these policies and implement them.

Policy Considerations

It is recommended that the following flood risk objectives are taken into account during the policy making process. Guidance on how these objectives can be met throughout the development control process for individual development sites is included within Section 9.

Seeking Flood Risk Reduction through Spatial Planning and Site Design

- Use the Sequential Test to locate new development in areas of lowest risk, giving highest priority to areas within Flood Zone 1.
- Use the Sequential Test within development sites to inform site layout by locating the most vulnerable elements of a development in the lowest risk areas. For example, the use of low-lying ground in waterside areas for recreation, amenity and environmental purposes can provide an effective means of flood risk management as well as providing connected green spaces with consequent social and environmental benefits.
- Avoid development immediately downstream of flood storage reservoirs which will be at high hazard areas in the event of failure.
- Seek opportunities for new development to achieve reductions to wider flood risk issues where possible, e.g. larger developments may be able to make provisions for flow balancing within new attenuation SuDS features.
- Identify long-term opportunities to remove development from the floodplain through land swapping.
- Build resilience into a site’s design (e.g. flood resistant or resilient design, raised floor levels).
- Ensure development is ‘safe’. For residential developments to be classed as ‘safe’, dry pedestrian egress out of the floodplain and emergency vehicular access should be possible. Dry pedestrian access/egress should be possible for the 1% AEP return period event including an allowance for climate change associated with fluvial flooding. In the defended tidal floodplain, safe access should also be provided during the MLWL including an allowance for climate change over the lifetime of the proposed development.

Reducing Surface Water Runoff from New Developments

- All sites require the following:
- Use of SuDS (where possible use of strategic SuDS should be made).
- Discharge rates should be restricted to Greenfield runoff rates.
- 1% AEP attenuation of surface water, taking including an allowance for climate change.
- Space should be specifically set aside for SuDS and used to inform the overall layout of development sites.
- Surface water drainage proposals should have a clear plan for the long term maintenance and adoption of the systems, prior to approval of any planning permission in line with national planning policy.
- Large potential development areas with a number of new allocation sites should look to develop a strategy for providing a joint SuDS scheme. This should be on an integrated and strategic scale and where necessary would require the collaboration of all developers involved in implementing a specific expansion area or site.

Enhancing and Restoring the River Corridor

- An assessment of the condition of existing assets (e.g. bridges, culverts, river walls) should be made. Refurbishment and/or renewal of the asset should ensure that the design life is commensurate with the design life of the development. Developer contributions should be sought for this purpose.
- Those proposing development should look for opportunities to undertake river restoration and enhancement as part of a development to make space for water. Enhancement opportunities should be sought when renewing assets.
- Avoid further culverting and building over culverts. Where practical, all new developments with culverts running through their site should seek to de-culvert rivers for flood risk management and conservation benefit. Any culverting or works affecting the flow of a watercourse requires the prior written consent of either the Environment Agency (for main rivers), or the LLFA (for ordinary watercourses) under the terms of the Land Drainage/Water Resources Act 1991 and Flood and Water Management Act 2010. These regulatory bodies seek to avoid culverting, and their consent for such works will not normally be granted except as a means of access.
- Set development back from rivers, seeking an 8 metre wide undeveloped buffer strip for development by all watercourses including those where the Flood Zone does not exist. Under the terms of the Water Resources Act 1991 and the Land Drainage Byelaws, the prior written consent of the Environment Agency or LLFA is required for any proposed works or structures in, under, over or within 8m of a main river, 16m from a tidal river or within 8m of ordinary watercourse asset or structure. This is to allow easy maintenance of the water course, and includes consent for fencing, planting and temporary structures.

Protecting and Promoting Areas for Future Flood Alleviation Schemes

- Protect Greenfield functional floodplain from future development (our greatest flood risk management asset) and reinstate areas of functional floodplain which have been developed (e.g. reduce building footprints or relocate to lower flood risk zones).
- Basildon Borough Council, Rochford District Council and Southend-On-Sea Borough Council should develop appropriate flood risk management policies for the areas within Flood Zone 3b Functional Floodplain that are currently developed, focusing on risk reduction measures, such as:
- Reducing the land use vulnerability wherever possible;
- Not permitting proposals for the change of use or conversion to a use with a higher vulnerability classification;
- Seeking opportunities to ensure there is no increase or achieve a reduction in the number of people at risk (e.g. avoiding conversions and rebuilds of properties that result in an increase in the number of residential dwellings);
- Maintaining or reducing built footprint;
- Raising finished floor levels;
- Increasing floodplain storage capacity and creating space for flooding to occur by restoring functional floodplain;
- Reducing impedance to floodwater flow and restoring flood flow paths;
- Incorporating flood resilient and/or resistance measures;
- Ensuring development remains safe for users in time of flood (this may refer to the timely evacuation of properties prior to the onset of flooding in accordance with an individual Flood Warning and Evacuation Plan for the site).
- Identify sites where developer contributions could be used to fund future flood risk management schemes or can reduce risk for surrounding areas.
- Seek opportunities to make space for water to accommodate climate change.

Improving Flood Awareness and Emergency Planning

- Seek to improve the emergency planning process using the outputs from the SFRA.
- Encourage all those within existing Flood Zone 3a and 3b (residential and commercial occupiers) to sign up to Flood Warning Service operated by the Environment Agency.
- Ensure robust emergency (evacuation) plans are implemented for new developments.

Development Management Considerations

Flood Zone 3b Functional Floodplain

The Functional Floodplain has been defined by each LPA in this SFRA. These areas should be safeguarded from development, with exemptions where development could reduce flood risk overall or improve floodplain storage.

Within this Level 1 SFRA, each LPA has defined Flood Zone 3b Functional Floodplain for their respective administrative areas using the 5% AEP defended flood outline as a starting point for the definition (as described in Section 2.2.4).

Only Water Compatible developments are permitted in Flood Zone 3b, and Essential Infrastructure developments require the Exception Test (see Table 8-4). Where Water Compatible or Essential Infrastructure development cannot be located elsewhere, it must:

- Remain operational and safe for users in times of flood;
- Result in no net loss of flood storage;
- Not impede water flows; and
- Not increase flood risk elsewhere.

Proposals for the change of use or conversion to a use with a higher vulnerability classification should not be permitted. Basements, basements extensions, conversions of basements to a high vulnerability classification or self-contained units should not be permitted.

Where minor development is proposed, schemes should not affect floodplain storage or flow routes through the incorporation of the following mitigation measures in line with CIRIA guidance on SuDS:

- Raised finished floor levels;
- Voids and where possible;
- Direct or indirect floodplain compensation;
- Flood resilience measures;
- The removal of other non-floodable structures;
- Replacement of impermeable surfaces with permeable;
- Improved surface water drainage through the implementation of SuDS features such as water butts/rainwater harvesting;
- Living roofs;
- Infiltration trenches/soakaways; and
- Below ground attenuation tanks.

Development in Flood Zone 3b Washland Areas (Basildon Borough)

Flood Zone 3b comprises land where water has to flow or be stored in times of flood and therefore Basildon Borough Council has identified all the washland areas within the Borough as Flood Zone 3b for the purposes of informing spatial planning across the Borough. Any application to develop within a washland area will receive a holding objection from the Environment Agency and Basildon Borough Council would treat such an application with extra caution.

However, it is recognised that in some cases, it will be necessary to safeguard the future development potential of these areas. When considering the potential for future development within a washland area, the following principles must be considered:

Sequential Test

The status of the washland prior to its designation as Flood Zone 3b within this SFRA will be a consideration. For example if the washland was in Flood Zone 3a prior to its designation as Flood Zone 3b, there should be a presumption against development. Other sites in areas of lower flood risk throughout the Borough should be considered prior to the consideration of a washland site in Flood Zone 3a, in accordance with the principles of the sequential test within PPS25. Only where it can be demonstrated that there are no other sites in areas of lower risk could the site be considered for development.

For washlands that are located within areas of Flood Zone 1 and it is only the washland that has been designated Flood Zone 3b within this SFRA, this in itself would be material to determining whether a redevelopment scheme could be deemed acceptable.

Betterment

Where development of a washland site is appropriate in accordance with the Sequential Test, it will be necessary to prove that full or partial development of the site would not increase the flood risk to the site or the surrounding area. Where this is the case, the requirements of NPPF would be satisfied and the Environment Agency and Basildon Borough Council would uphold this.

Wherever possible, additional capacity on site or off site should be created to ensure that additional benefit can be brought to the area, for example in the form of added gain of flood protection or biodiversity.

Flood Zone 3a High Probability

Flood Zone 3a High Probability comprises land having a 1% (1 in 100 year) annual probability or greater. Water Compatible and Less Vulnerable developments are permitted in Flood Zone 3a; Essential Infrastructure and More Vulnerable developments require the Exception Test and Highly Vulnerable development is not permitted in this flood zone (see Table 8-4). Where development is proposed opportunities should be sought to:

- Relocate existing development to land in zones with a lower probability of flooding;
- Reduce the overall level of flood risk in the area through the layout and form of the development, and the appropriate application of sustainable drainage techniques;
- Ensure it remains safe for users in times of flood; and
- Create space for flooding to occur by restoring natural floodplain and flood flow paths and by identifying, allocating and safeguarding open space for flood storage.

Flood Zone 2 Medium Probability

Flood Zone 2 Medium Probability comprises land having between a 1% (1 in 100 year) and 0.1% (1 in 1000 year) annual probability of flooding from fluvial watercourses. Water Compatible, Essential Infrastructure, Less Vulnerable and More Vulnerable developments are permitted in the Flood Zone 2, and Highly Vulnerable development requires the Exception Test (see Table 8-4). Where development is proposed in areas of Flood Zone 2, the planning policy approach is similar to Flood Zone 3a. Opportunities should be sought to:

- Relocate existing development to land in zones with a lower probability of flooding;
- Reduce the overall level of flood risk in the area through the layout and form of the development, and the appropriate application of sustainable drainage techniques;
- Ensure it remains safe for users in times of flood; and
- Create space for flooding to occur by restoring natural floodplain and flood flow paths and by identifying, allocating and safeguarding open space for flood storage.

Flood Zone 1 Low Probability

Flood Zone 1 Low Probability comprises land having a less than 0.1% (1 in 1000 year) annual probability of flooding from fluvial watercourses. All development vulnerability classifications are permitted in Flood Zone 1 (see Table 8-4). Where development over 1ha is proposed or there is evidence of flooding from another localised source in areas of Flood Zone 1, opportunities should be sought to:

- Ensure that the management of surface water runoff from the site is considered early in the site planning and design process;
- Ensure that proposals achieve an overall reduction in the level of flood risk to the surrounding area, through the appropriate application of sustainable drainage techniques.

Cumulative Impact of Minor and Permitted Development

The PPG advises that minor developments (as defined in Section 8.3) are unlikely to result in significant flood risk issues unless:

- they would have an adverse effect on a watercourse, floodplain or its flood defences;
- they would impede access to flood defence and management facilities; or

- where the cumulative impact of such developments would have a significant impact on local flood storage capacity or flood flows.

In parts of the study area there is potential for both minor development as well as permitted development to be considered to be having a cumulative impact on flood risk in the local area as a result of impacts on local flood storage capacity and flood flows. Given the small scale of the development in the context of the wider fluvial catchments it is not possible to undertake modelling to confirm the impact of such development.

There is opportunity for LPAs to consider making an Article 4 direction[58] to remove national permitted development rights for developed areas of land within Flood Zone 3b where cumulative impact is considered to be a problem. The removal of permitted development rights will ensure that a planning application and site specific FRA will be required for any development in these areas.

FRAs for all minor development within Flood Zone 3 should demonstrate that the proposal is safe and will not increase flood risk elsewhere by not impeding the flow of flood water, reducing storage capacity of the floodplain. Details of flood mitigation measures to reduce the impact of flooding on the proposed development and ensure that the proposed development does not result in an increase in maximum flood levels within adjoining properties should be provided. This may be achieved by ensuring (for example) that the existing building footprint is not increased, that overland flow routes are not truncated by buildings and/or infrastructure, hydraulically linked compensatory flood storage is provided within the site (or upstream), and/or the incorporation of floodable voids (more information will be provided in the Level 2 SFRA). It is acknowledged that full compensation may not be possible on all minor developments, however, an applicant must be able to demonstrate that every effort has been made to achieve this and provide full justification where this is not the case.

Changes of Use

Where a development undergoes a change of use and the vulnerability classification of the development changes, there may be an increase in flood risk. For example, changing from industrial use to residential use will increase the vulnerability classification from Less to More Vulnerable (Table 8-3).

For change of use applications in Flood Zone 2 and 3, applicants must submit a FRA with their application. This should demonstrate how the flood risks to the development will be managed so that it remains safe through its lifetime including provision of safe access and egress and preparation of Flood Warning and Evacuation Plans where necessary. Further guidance will be provided within the Level 2 SFRA Report.

As changes of use are not subject to the Sequential or Exception Tests, the South Essex Authorities should consider when formulating policy what changes of use will be acceptable, having regard to paragraph 157 (6th bullet) of the NPPF: "identify areas where it may be necessary to limit freedom to change the uses of buildings, and support such restrictions with a clear explanation" and taking into account the findings of this SFRA. This is likely to depend on whether developments can be designed to be safe and that there is safe access and egress.

Basement Development

Basement development may involve either the extension of an existing habitable basement under a house, or the construction of a completely new basement. It is becoming increasingly popular to construct basements which extend beyond the footprint of the host property and under the amenity area.

In accordance with the PPG, self-contained dwellings or bedrooms at basement level in Flood Zone 3 should not be permitted due to the vulnerability of users. Basements, basement extensions, conversions of basements to a higher vulnerability classification or self-contained units are not acceptable in Flood Zone 3b. Basements for other uses in Flood Zone 3a and 2 may be granted provided there is a safe means to escape via internal access to higher floors 300mm above the 1% annual probability (1 in 100 year) flood level including an allowance for climate change.

The Environment Agency Areas Susceptible to Groundwater Flooding maps provided in Appendix A Figures 4.4 (Basildon Borough), 5.4 (Castle Point Borough), 6.4 (Rochford District) and 7.4 (Southend-on-Sea Borough) should be used to help assess the suitability of potential basement developments. However, it should be made clear that the Areas Susceptible to Groundwater Flooding maps are high level strategic maps and even though there are areas of no risk is mapped it does not mean that there is no risk present. Therefore, it is recommended that ground investigations and groundwater monitoring should be undertaken at each potential basement development site.

[58] An article 4 direction is a direction under article 4 of the General Permitted Development Order which enables the Secretary of State or the local planning authority to withdraw specified permitted development rights across a defined area.

Basement development may affect groundwater flows, and even though the displaced water will find a new course around the area of obstruction this may have other consequences for nearby receptors e.g. buildings, trees. If basement development is located within an aquifer corridor, it may lead to localised elevations in groundwater and increase flood levels. An FRA must provide details of an appropriate sustainable urban drainage system for the site and investigation to determine whether a perimeter drainage system or other suitable measure is necessary to ensure any existing sub-surface water flow regimes are not interrupted.

The FRA must also address the impact of the proposed extension on the ability of the floodplain to store floodwater during the 1% annual probability (1 in 100 year) event including allowance for climate change and where necessary provide compensatory floodplain storage on a level for level, volume for volume basis.

Appendix C Prittle Brook Climate Change Modelling

Introduction

As part of the update to the South Essex Strategic Flood Risk Assessment (SFRA), the councils are required to map the predicted outlines of Flood Zone 3 including allowances for climate change (CC). In February 2016, the Environment Agency amended the projected impacts of climate change on river flow[59]. Previous climate change allowances considered only a 20% increase in river flows across all river basins. This was amended to include a range of projected increases in river flows for each river basin, for a range of epochs, and for different development vulnerability classifications. As such, previous modelled outlines for the 1% Annual Exceedance Probability (AEP) event (equivalent to the 1 in 100 year event or the maximum extent of Flood Zone 3) are not in line with the amended climate change allowances.

For the Prittle Brook, the Environment Agency holds an existing model that has been acquired and revised to reflect the amended climate change allowances. This technical note summarises the methodology that has been undertaken to revise the climate change allowances and presents the results of the analysis.

Methodology

Existing Model

The existing model for the Prittle Brook was obtained from the Environment Agency. The model is from July 2008 and is a one dimensional (1D) model that was originally built and run using the hydraulic modelling package ISIS. At the time of the SFRA this model is in the process of being revised; however, for the purposes of the SFRA it has been assumed that the existing model is suitable for use in this assessment. The model includes the channel of the Prittle Brook from Westwood Gardens (Hadleigh) to Sutton Road close to the confluence with the River Roach. AECOM has not reviewed in detail the representation of the watercourse, the model parameters or model assumptions as part of this project.

Inflow Boundaries

The model includes six inflow boundaries that have been represented as Flood Estimation Handbook (FEH) inflows. These are either representing point inflows at specific locations or lateral inflows to account for the cumulative input from the contributing urban area. The FEH inflow boundaries are referenced PB1-PB6. Table C-1 presents the peak flows associated with the existing 1% AEP, 1% AEP plus 20% climate change and 0.1% AEP flood events. Peak flows for updated climate change allowances associated with a 25%, 35% and 65% increase in river flow are also provided in Table C-1 for each of the FEH inflow boundaries.

The resulting peak flows for the revised climate change allowances demonstrate that, even for the 1% AEP plus 65%CC event, peak flows are individually between 46% and 56% of the peak inflows for the 0.1% AEP event in this model.

Table C-1 - Prittle Brook Climate Change Peak Flows

	Existing Model Inflows (m^3/s)			Updated CC Inflows (m^3/s)		
Inflow Reference	1% AEP	1% AEP +20% CC	0.1% AEP	1% AEP +25% CC	1% AEP +35% CC	1% AEP +65% CC
PB1	2.83	3.40	9.21	3.54	3.82	4.67
PB2	3.77	4.52	11.64	4.71	5.09	6.22
PB3	0.37	0.44	1.12	0.46	0.50	0.61
PB4	7.39	8.86	25.79	9.24	9.98	12.19
PB5	1.20	1.44	4.27	1.50	1.62	1.98
PB6	1.37	1.64	4.07	1.71	1.85	2.26

[59] Environment Agency, February 2016. URL: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances. Last accessed October 2017.

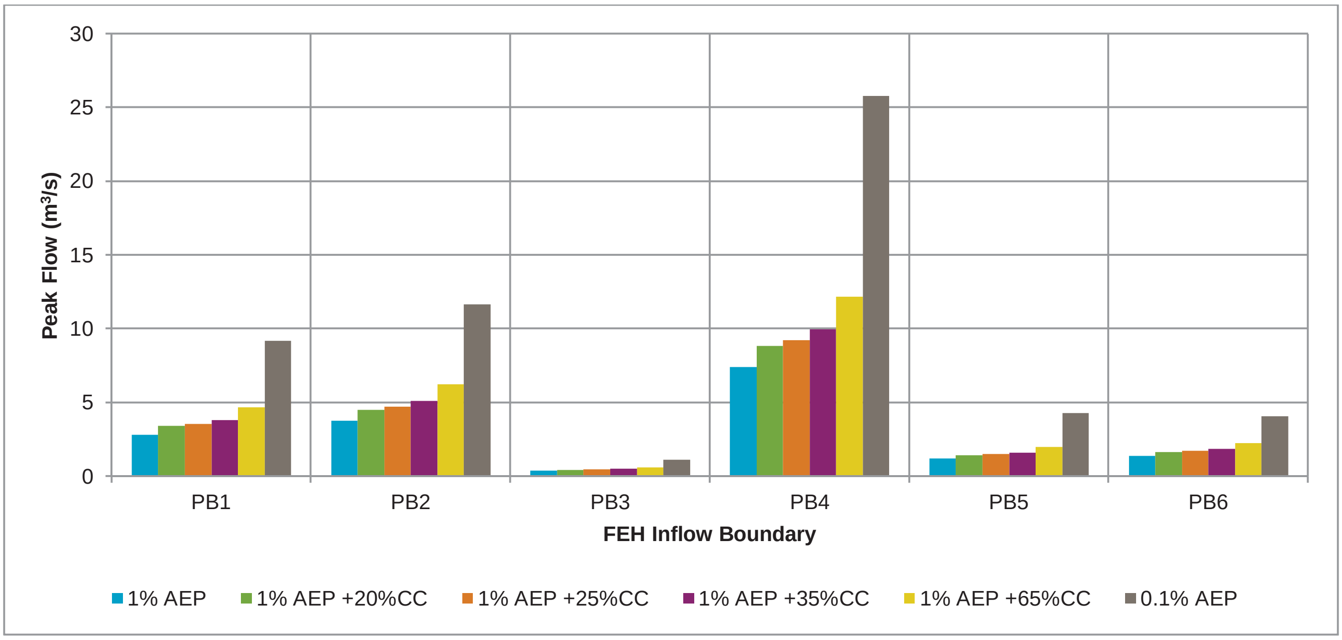

Figure C1 - Prittle Brook Climate Change Peak Flows

Revised Model

Copies were made of the existing ISIS model for the 1% AEP event and the FEH inflow boundaries within each of the models were scaled to the peak flows as shown in Table C-1 for each of the three climate change allowances. The model was subsequently re-run to produce results for the 25%, 35% and 65% climate change scenarios.

Results

The model results have been exported and reviewed in detail. It was not possible to produce flood outlines for each of the climate change allowances due to the lack of a Triangular Irregular Network (TIN) that was used to produce the original flood outlines. The results show, however, that for all nodes the peak flood water level in the 0.1% AEP event is greater than the flood water level for the 1% AEP +65% CC event. This is shown at a high level in Figure C2, which shown a long section through the entire model. In addition, for a significant proportion of the urban area through which the Prittle Brook flows, the flow remains in the channel and does not extend onto a floodplain. As such, it is recommended that the 0.1% AEP flood outline be retained as the 1% AEP +CC outline. This additional hydraulic modelling has confirmed that this is an appropriate and conservative assumption throughout the modelled reach of the Prittle Brook.

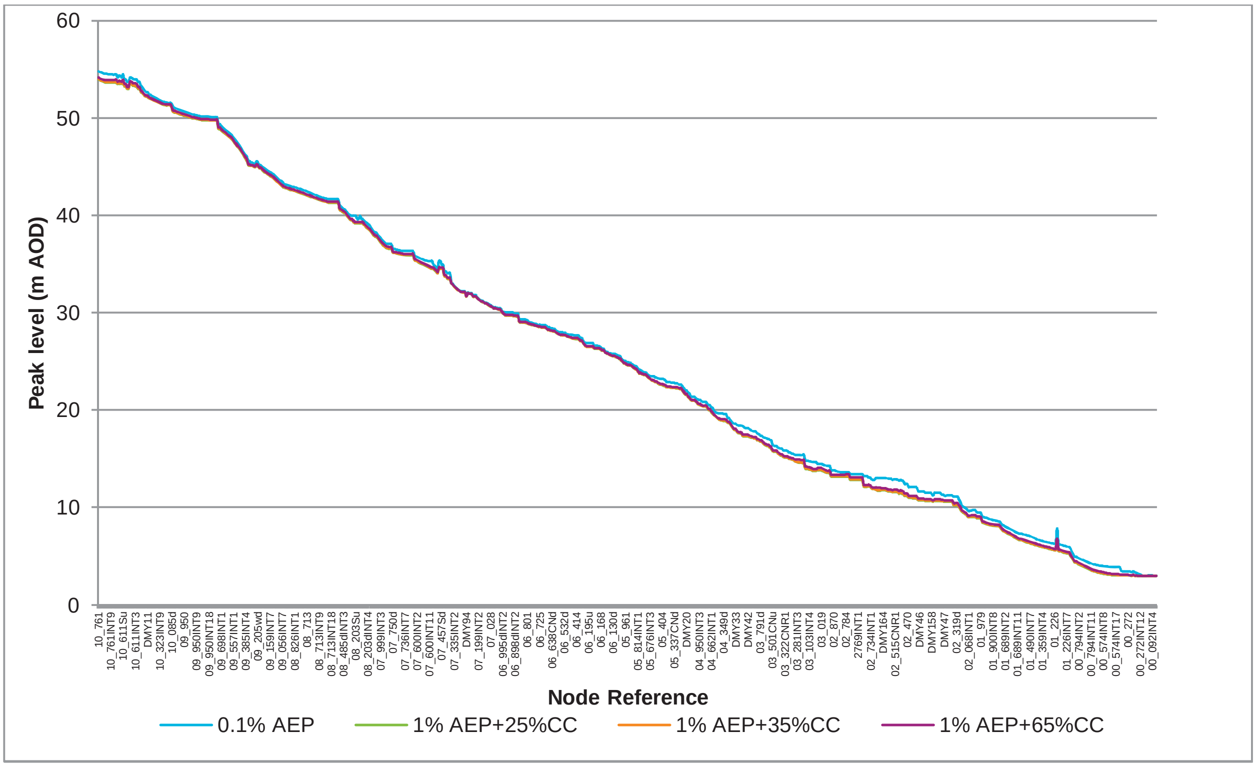

Figure C2 - Prittle Brook Peak Flood Level Long Section

Assumptions and Limitations

The following assumptions and limitations are noted as part of this modelling study:

- It is noted that the hydraulic modelling of the Prittle Brook is currently being updated. The climate change outlines in the SFRA should be reviewed once this has been completed to ensure that the mapping is accurate and representative.
- A detailed model review, including a review of the assumptions and parameters in the existing model used as part of this study has not been undertaken. It is noted that the model is a 1D only model that does not represent two dimensional (2D) overland floodplain flow or the risk of surface water flooding.
- Transposition of the peak flood water levels onto the ground surface has not been undertaken as part of this study due to the lack of an underlying TIN upon which the previous flood outlines were created.

Appendix D South Essex Breach Modelling Methodology

This modelling methodology was prepared by AECOM and agreed with the South Essex Authorities and the Environment Agency in January 2017 to inform the preparation of the Level 1 SFRA update for Basildon Borough, Castle Point Borough, Rochford District, Southend-on-Sea Borough and Essex County Councils.

Introduction

The area around South Essex (Figure D1) including the North Thames Bank and Crouch Estuaries are exposed to the tidal influence of the North Sea and as such, are at risk of tidal flooding. The existing tidal defences protect these areas from tidal inundation and therefore the risk of flooding to South Essex is only if the defences fail (breach).

As part of the Level 1 SFRA, AECOM are required to update tidal breach modelling carried out as part of the previous SFRA (2010) to inform the assessment of residual flood risk at a strategic scale.

The previous SFRA was prepared by URS Scott Wilson in 2010 and included simulating a breach within the existing defences at some 27 locations. These breach models are required to be updated to utilise current terrain data and recommended allowances for climate change on extreme water levels within the outer Thames region.

The purpose of this technical note is to document the agreed breach assessment methodology (January 2017) by the Environment Agency and Local Council representatives.

The methodology described below is based on the previous SFRA methodology and guidance contained within the Environment Agency breach methodology document[60] and discussion from the meeting with the Environment Agency Asset Performance Team (February 2017). It should be noted that although many of these breach locations were previously identified, all of the breach modelling conducted within this study is original and does not use or incorporate any previous modelling; each breach cell has been reconstructed exclusively for this study. In addition, every breach location has been assessed for suitability to this study.

The South Essex SFRA is split into four discrete areas these are:

1. Basildon Borough Study Area;
2. Castle Point Borough Study Area;
3. Rochford District Study Area; and
4. Southend-on-Sea.

[60] Environment Agency (2005) *'Requirements for Hazard Mapping v5_EA Breach modelling methodology'*,

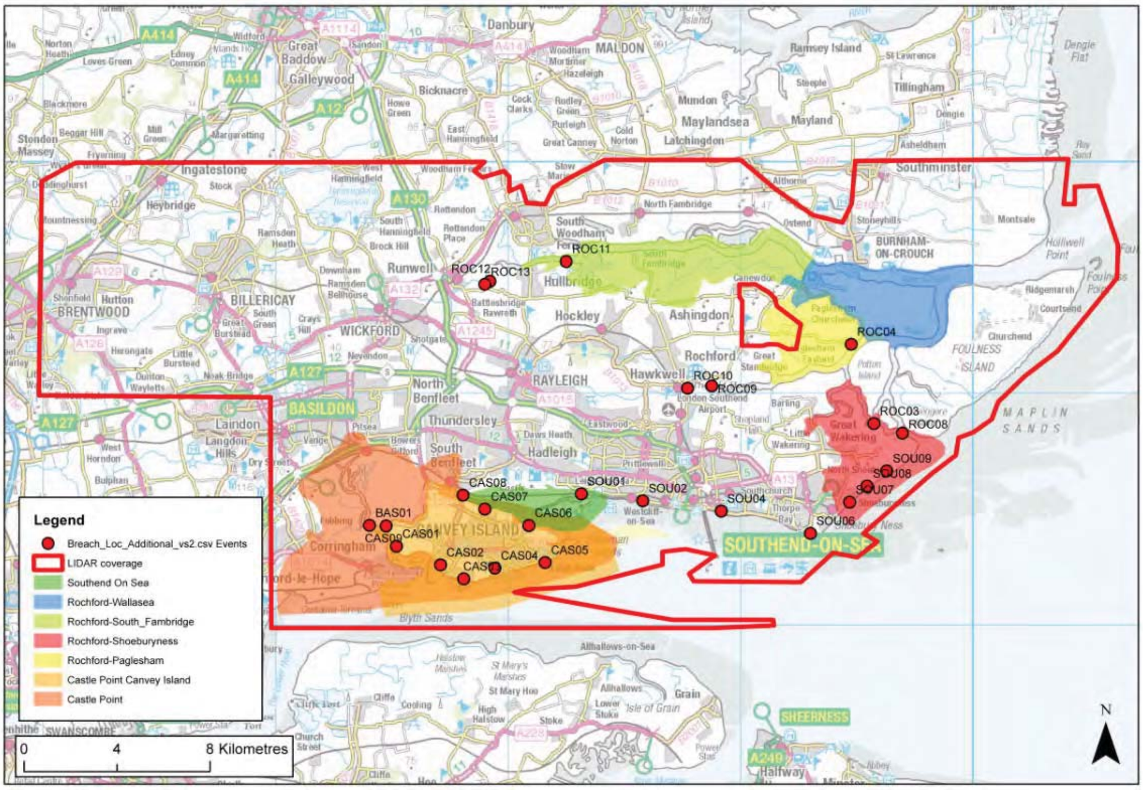

Figure D-1 Study Area with the identified 25 breach locations.

Information received / requested

Information requested or carried forward from the previous SFRA relevant to the breach modelling is summarised in Table D-1.

Table D-1 Information received / carried forward relevant to South Essex breach modelling

Dataset	Description and use in breach modelling	Format
Light Detecting and Ranging Data (LiDAR) – 0.25m, 0.5m, 1m and 2m resolution flown in 2015	Terrain data obtained from Environment Agency	ASCI
OS 1 to 10,000 raster mapping	Background mapping obtained from the relevant local Council authorities to be used in flood mapping	JPEG
OS MasterMap Data	Background mapping obtained from the relevant local Council authorities to be used to apply roughness to ground surfaces	GIS / CAD
South Essex administrative boundary	Boundary condition used in flood mapping	GIS
2017 SFRA Breach Locations / Details	Breach locations to be modelled as part of the Level 1 SFRA (2017)	Excel
Levels Flows	Maximum flows and levels for 1 in 20 year, 1 in 75 year, 1 in 100 year, 1 in 20 year CC and 1 in 100 year CC for any river discharges i.e. Crouch / Roach Estuaries.	Excel / GIS
Requirements for Hazard Mapping v5_EA Breach modelling methodology	Specification for breach modelling provided by the Environment Agency	PDF
Thames Tidal Defences, Joint Probability Modelling (2008)	Extreme water levels in the Tidal Thames to be used as the boundary conditions in the breach modelling	Excel
As built drawings of sluice structures	To inform breach widths	PDF
Environment Agency Fluvial and Coastal Models	Model files including relevant input data and supporting metadata	Digital
BGS	Geological and permeability maps	Digital

Dataset	Description and use in breach modelling	Format
ECC Historical Flooding Events	Historical Flooding Events	GIS/CAD
Flood Defence Information	AIMS data source, provides description of defence location and elevation.	Excel / GIS / CAD / Digital

Methodology

Software

2D modelling of the breach scenarios is required to provide flood hazard information suitable for use in a SFRA. It is proposed to use the most up to date version of MIKE by DHI available at the start of the project; currently Version 2017.

The MIKE21 model is specifically oriented towards establishing flow patterns in complex water systems, such as coastal waters, estuaries and floodplains using a flexible mesh (FM) approach. The flexible mesh model has the advantage that the resolution of the model can be varied across the model area. A further advantage of using Mike by DHI is to be consistent with the previous SFRA (2010).

Breach Parameters

Locations

A review of the proposed breach locations was carried out during a workshop with the Environment Agency representative from the Partnership & Strategic Overview team, Local Council Project Manager, representatives from the Environment Agency Asset Performance Team (February 2017). The proposed breach locations were reviewed to ensure that these are appropriate.

Widths and time of closure

The breach widths are stated in Table D-2 and are consistent with the Environment Agency's methodology60 and shown below. If applicable, sluice and outfall structures provided by the Environment Agency will also be used to inform the selection of breach widths. It will be assumed that the breach is 'open' for the duration of three tidal cycles (36 hours); this is the same duration of the previous SFRA breach models (2010).

Table D-2 Environment Agency (2005) 'Requirements for Hazard Mapping v5_EA Breach modelling methodology'

Location	Defence type	Breach width (m)	Time to Closure (hrs)
Open coast	Earth bank	200	72
	Dunes	100	72
	Hard	50	72
Estuary	Earth bank	50	72
	Hard	20	72
Tidal river	Earth bank	50	72
	Hard	20	72
Fluvial river	Earth bank	40	36
	Hard	20	36

Breach Invert Level

The invert level of the breach will be determined through an interrogation of the LiDAR on the landward side of the breach location. As a rule of thumb the lowest ground level within a radius the same width as the breach will be used as the breach invert level. For example, in the breach shown in Figure D2 below, the width is 20 m and the invert level is proposed to be set to 2.3 m AOD.

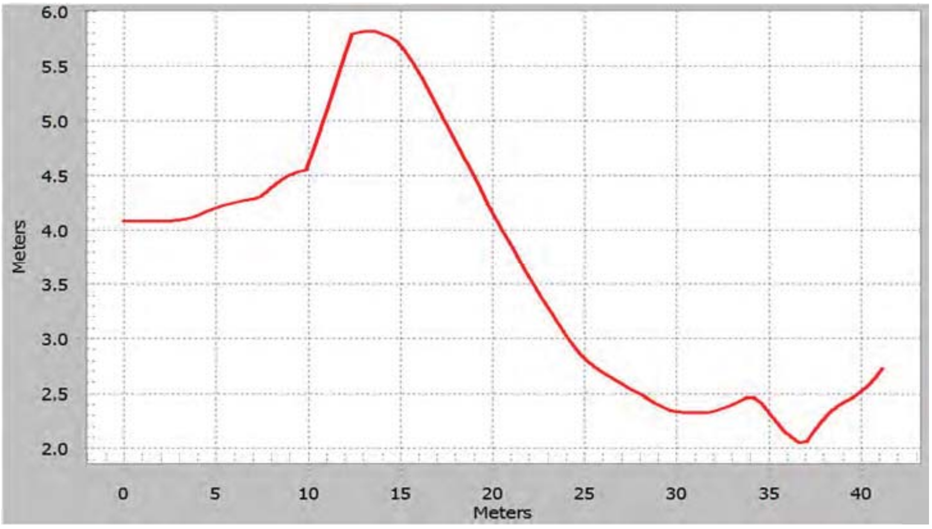

Figure D-2 Example cross-section profile through breach

It is expected that the breach invert levels will be the same or similar to the previous SFRA models, but these will be reviewed, taking into consideration at a high level the degree of scour expected into the floodplain. The breach invert level will be set within the 2D domain. The same level will be set throughout the model simulation, which is a conservative assumption.

Extreme Water Levels (Boundary Conditions)

Design tide boundaries

Each of the breach models is required to simulate:

- A tidal flood event with a return period of 1 in 200 years (present day 2016);
- A tidal flood event with a return period of 1 in 200 years (with climate change 2116);
- A tidal flood event with a return period of 1 in 1000 years (present day 2016);

Extreme water level data for use in this modelling will be based on the Environment Agency Thames Tidal Defences Joint Probability Extreme Water Levels Final Modelling Report (April 2008) for the Thames Estuary, CFB Extreme Sea Levels (2011) for the North Sea coast, and the Crouch Roach Levels (2011) for Crouch estuary. Where extreme water level points are present within close proximity to the breach location, unmodified water levels will be used. Where a significant distance (more than 250m) is present between the modelled nodes and the breach locations, modelled water levels will be interpolated (based on chainage) to provide a more appropriate water level.

As shown in Figure D3 a series of 3 typical spring tides spanning a period of 1.5 days (36 hours) will be included in all tidal breach scenarios. The surge will be gradually applied (Figure D3) with the maximum surge effect occurring on the second high tide (about 18 hrs after the start of the simulation). The model will then continue to run for the remainder of the 36hr simulation period.

For the 0.5% (1 in 200 year) and 0.1% (1 in 1000 year) AEP 2116 scenarios, the recommended climate change factors (UKCP09 medium emissions 95%tile) will be applied to generate the extreme water levels with allowances for sea level rise for the 2116 scenarios. The Thames Tidal Defences Joint Probability Extreme Water Levels (2008) and Anglian Region Extreme Tide Levels (2007) data contains modelling extreme water levels up to 2115 and therefore one year of climate change will need to be applied.

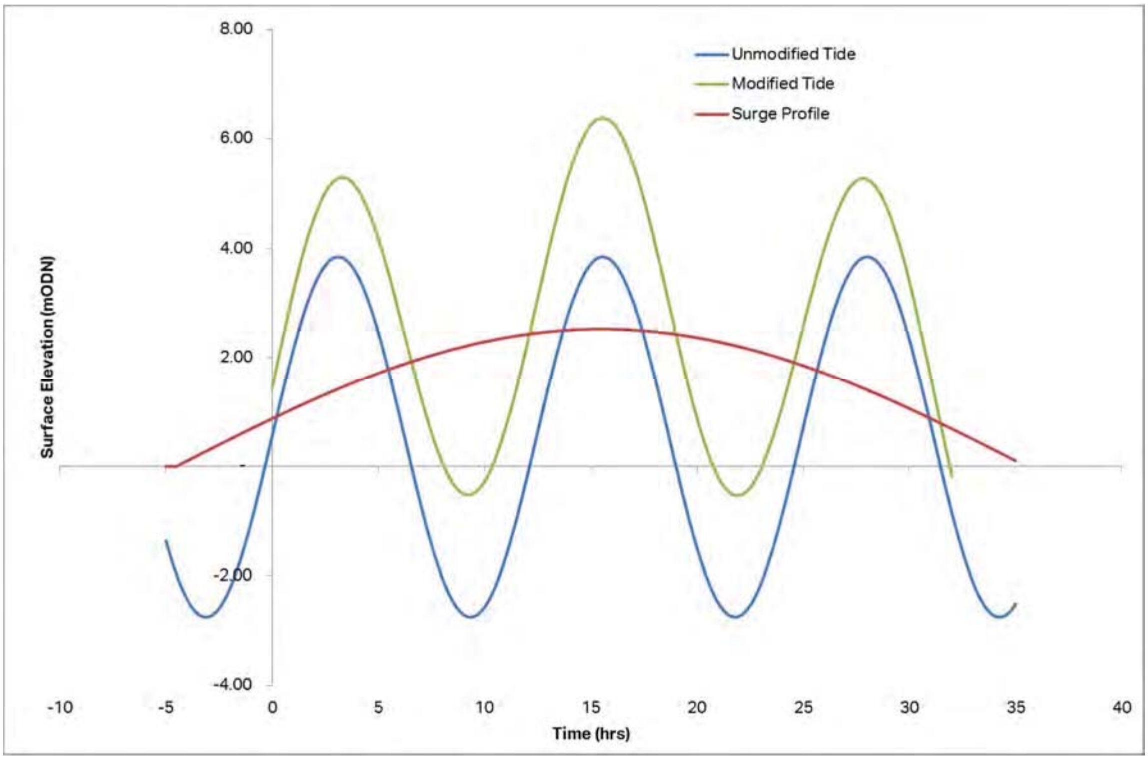

Figure D-3 Example Tide Curve Including Surge Profile

Skew Surge Analysis

The addition of the surge skew analysis as described in the UKCP09 guidance has been reviewed for the study area. A slight negative surge component is predicted for these areas in South Essex. However, given the very small negative magnitude (<1mm) increment for each return period, the level of uncertainty and to ensure consistency with previous studies, these slight modifications to the tidal boundary have been excluded from this strategic analysis. This assumption provides a slightly more conservative boundary condition which is not considered significant and within the level of uncertainty of the modelling study.

Application of boundaries to MIKE by DHI

The design boundary conditions will be applied directly to the 2D model using a boundary file containing Height / Time (HT) information of the tidal cycles. The boundary will be applied across the seaward extent of the model domain.

Flood Cells

The extent of the 2D models has been defined by adopting a flood cell approach. A flood cell is defined through a review of the LiDAR data against the extreme water levels and includes all land that is at a lower elevation than the extreme water level.

Model Topography

Flexible meshes were developed to define the topography of the land within each flood cell, using the MIKE21 program's mesh generator application which creates a mesh of triangular elements covering the defined 'flood cell' - the land that has an elevation below the peak tidal level with the potential to flood.

One of the advantages of the flexible mesh application is that the element size within the mesh can be varied depending upon the complexity of the floodplain, features of interest, and the location of topographic features which are thought to have a significant impact on flood propagation. The mesh elements are forced to follow the alignment of the features ensuring the elevations of important features are picked up during the mesh generation. For example, control lines would be placed along each side of a road/ditch/topographic feature. In this way, the mesh is 'forced' to follow the features accurately and use level values at very specific points.

Considering these models are for strategic and not site specific purposes, small features such as culverts and small drainage ditches will not be included within the mesh. Taking into account the size of the study areas, the determination of all culverts and small features is outside the scope of the study.

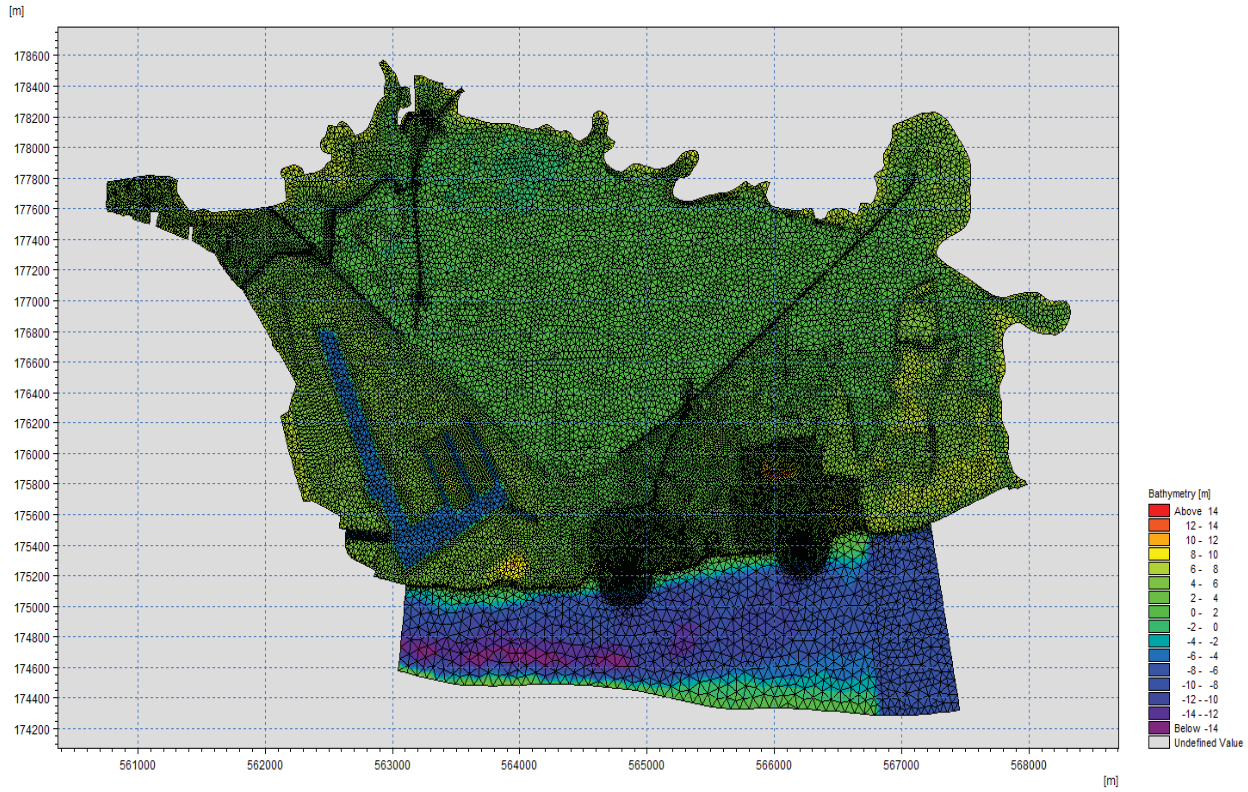

Figure D-4 Example MIKE Flexible Mesh Flood Cell

Where surface features, for example embankments, are not represented in the model topography, additional MIKE by DHI geometry files will be used for definition. Model interpolated defence crest levels will be validated against the information received from AIMS and the Environment Agency topographic spot level data, a review of the model defence heights will be undertaken to ensure that these levels are consistent.

Defences / Barriers

The defences along the coastline are variable in standard. Defence heights have been determine from the most appropriate and accurate supplied data (AIMS). This data was triangulated and used to determine the height of the defences in the areas where available.

Roughness

A specify varying Manning's roughness coefficients will be used throughout the model extent according to land use. Hydraulic roughness represents the conveyance capacity of the land or riverbed where flows are occurring. Within the MIKE21 model, hydraulic roughness is defined by the dimensionless Manning's 'n' roughness coefficient.

A number of material roughness classifications will be applied within the study area, for example water - 0.03 (for the river), urbanised - 0.08, rural/non-urbanised land - 0.04, road - 0.02, and rail - 0.03. The distribution of these factors has been defined using aerial photography, OS maps and knowledge gained by the site visit in order to vary the conveyance rates throughout the flood cell domain.

Buildings

Representation of buildings in hydraulic modelling varies from assuming no buildings are present, increasing the roughness across a building polygon to blocking buildings completely out of the floodplain, thus assuming no water would flow through.

The Environment Agency methodology document60 does not specify how buildings should be represented. Raising buildings as solid blocks assumes that no flow can pass through the buildings which can be considered an over-conservative assumption. Therefore it is proposed for this SFRA modelling that buildings will not be represented. This approach is consistent with the previous investigation.

Naming convention and folder structure

The breach names have been updated to provide a clear distinction between the 2009 and 2016 models. The model folder structure will follow the standard MIKE by DHI modelling structure.

Outputs

All of the results have been post-processed to provide maximum asci grids for flood depth, flood hazard and maximum current speeds. These outputs will be used to create the necessary mapping for the SFRA.

Table D-3 Breach Characteristics

ID	Code	Breach Name	Easting	Northing	Defence Type	Breach Width (m)
1	BAS01/CAS	Flood barrier, Fobbing Horse, Vange Creek	574044.7	184305.5	Hard defence - barrier	width of barrier-45
2	CAS01	Upper Horse	575200	183400	Hard defence with earth embankment	20
3	CAS02	Canvey Village, Lower Horse	577100	182600	Hard defence with earth embankment	20
4	CAS03	STW	578100	182000	Hard defence with earth embankment	20
5	CAS04	Canvey Island Golf Course	579437.5	182463	Hard defence with earth embankment	20
6	CAS05	Leigh Beck	581600	182700	Hard defence with earth embankment	20
7	CAS06	Sunken Marsh	580900	184300	Hard defence with earth embankment	20
8	CAS07	Castle Point Golf Course	579008.6	185005	Hard defence with earth embankment	20
9	CAS08	Benfleet Creek Flood Barrier	578067.6	185605	Hard defence - barrier	width of barrier-45
10	CAS09	Easthaven Barrier	574757	184282	Hard defence - barrier	width of barrier-45
11	SOU01	Hadleigh Marsh	583160	185661	Earth (estuary)	50
12	SOU02	Chalkwell	585796	185365	Hard (estuary)	20
13	SOU04	City Beach	589174	184919	Hard (estuary)	20
14	SOU06	East Southend	593018	183955	Hard (estuary)	20
15	SOU07	Shoeburyness/Great Wakering	594700	185300	Earth (open coast)	200
16	SOU08	Shoeburyness New Ranges	595445	185998	Earth Embankment	200
17	SOU09	Morrin's Point	596298	186654	Earth Embankment	200
19	ROC03	Oxenham Farm	595745	188694.5	Earth Embankment	50
20	ROC04	Paglesham Eastend	594767.5	192116.8	flood gate	50
21	ROC07	South Fambridge	585500	196200	Earth Embankment	50
22	ROC08	Havengore Bridge	596978	188287	Earth Embankment	20
23	ROC09	Stambridge Mills Sluice	588767	190318	Earth Embankment	20
24	ROC10	Horesome Green Pub	587730	190219	Earth Embankment	20
25	ROC11	Brandyhole Yacht Club	582507	195695	Earth Embankment	20
26	ROC12	Beeches No 3	579220	194842	Earth Embankment	20
27	ROC13	Pats Rill	579007	194706	Earth Embankment	20

Appendix E South Essex Breach Mapping

Basildon Borough

Figure E1 Basildon Borough Breach Maximum Flood Depth – 2016, 0.5% AEP, with barrier
Figure E2 Basildon Borough Breach Maximum Flood Hazard – 2016, 0.5% AEP, with barrier
Figure E3 Basildon Borough Breach Maximum Flood Depth – 2016, 0.5% AEP, without barrier
Figure E4 Basildon Borough Breach Maximum Flood Hazard – 2016, 0.5% AEP, without barrier
Figure E5 Basildon Borough Breach Maximum Flood Depth – 2116 with climate change, 0.5% AEP, with barrier
Figure E6 Basildon Borough Breach Maximum Flood Hazard – 2116 with climate change, 0.5% AEP, with barrier
Figure E7 Basildon Borough Breach Maximum Flood Depth – 2116 with climate change, 0.5% AEP, without barrier
Figure E8 Basildon Borough Breach Maximum Flood Hazard – 2116 with climate change, 0.5% AEP, without barrier
Figure E9 Basildon Borough Breach Maximum Flood Depth – 2016, 0.1% AEP, with barrier
Figure E10 Basildon Borough Breach Maximum Flood Hazard – 2016, 0.1% AEP, with barrier
Figure E11 Basildon Borough Breach Maximum Flood Depth – 2016, 0.1% AEP, without barrier
Figure E12 Basildon Borough Breach Maximum Flood Hazard – 2016, 0.1% AEP, without barrier
Figure E13 Basildon Borough Breach Maximum Flood Depth – 2116 with climate change, 0.1% AEP, with barrier
Figure E14 Basildon Borough Breach Maximum Flood Hazard – 2116 with climate change, 0.1% AEP, with barrier
Figure E15 Basildon Borough Breach Maximum Flood Depth – 2116 with climate change, 0.1% AEP, without barrier
Figure E16 Basildon Borough Breach Maximum Flood Hazard – 2116 with climate change, 0.1% AEP, without barrier
Figure E17 Breach BAS01 Time to Inundation – 2116 with climate change, 0.1% AEP with barrier

Castle Point Borough

Figure E18 Castle Point Borough Breach Maximum Flood Depth – 2016, 0.5% AEP, with barrier
Figure E19 Castle Point Borough Breach Maximum Flood Hazard – 2016, 0.5% AEP, with barrier
Figure E20 Castle Point Borough Breach Maximum Flood Depth – 2016, 0.5% AEP, without barrier
Figure E21 Castle Point Borough Breach Maximum Flood Hazard – 2016, 0.5% AEP, without barrier
Figure E22 Castle Point Borough Breach Maximum Flood Depth – 2116 with climate change, 0.5% AEP, with barrier
Figure E23 Castle Point Borough Breach Maximum Flood Hazard – 2116 with climate change, 0.5% AEP, with barrier
Figure E24 Castle Point Borough Breach Maximum Flood Depth – 2116 with climate change, 0.5% AEP, without barrier
Figure E25 Castle Point Borough Breach Maximum Flood Hazard – 2116 with climate change, 0.5% AEP, without barrier
Figure E26 Castle Point Borough Breach Maximum Flood Depth – 2016, 0.1% AEP, with barrier
Figure E27 Castle Point Borough Breach Maximum Flood Hazard – 2016, 0.1% AEP, with barrier
Figure E28 Castle Point Borough Breach Maximum Flood Depth – 2016, 0.1% AEP, without barrier
Figure E29 Castle Point Borough Breach Maximum Flood Hazard – 2016, 0.1% AEP, without barrier
Figure E30 Castle Point Borough Breach Maximum Flood Depth – 2116 with climate change, 0.1% AEP, with barrier
Figure E31 Castle Point Borough Breach Maximum Flood Hazard – 2116 with climate change, 0.1% AEP, with barrier

Figure E32	Castle Point Borough Breach Maximum Flood Depth – 2116 with climate change, 0.1% AEP, without barrier
Figure E33	Castle Point Borough Breach Maximum Flood Hazard – 2116 with climate change, 0.1% AEP, without barrier
Figure E34.a	Breach CAS01 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E34.b	Breach CAS02 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E34.c	Breach CAS03 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E34.d	Breach CAS04 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E34.e	Breach CAS05 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E34.f	Breach CAS06 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E34.g	Breach CAS07 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E34.h	Breach CAS08 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E34.i	Breach CAS09 Time to Inundation - 2116 with climate change, 0.1% AEP

Rochford District

Figure E35.a,b,c,d	Rochford District Breach Maximum Flood Depth – 2016, 0.5% AEP,
Figure E36.a,b,c,d	Rochford District Breach Maximum Flood Hazard – 2016, 0.5% AEP
Figure E37.a,b,c,d	Rochford District Breach Maximum Flood Depth – 2116 with climate change, 0.5% AEP
Figure E38.a,b,c,d	Rochford District Breach Maximum Flood Hazard – 2116 with climate change, 0.5% AEP
Figure E39.a,b,c,d	Rochford District Breach Maximum Flood Depth – 2016, 0.1% AEP,
Figure E40.a,b,c,d	Rochford District Breach Maximum Flood Hazard – 2016, 0.1% AEP
Figure E41.a,b,c,d	Rochford District Breach Maximum Flood Depth – 2116 with climate change, 0.1% AEP
Figure E42.a,b,c,d	Rochford District Breach Maximum Flood Hazard – 2116 with climate change, 0.1% AEP
Figure E43.a	Breach ROC03 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E43 b	Breach ROC04 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E43.c	Breach ROC07 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E43.d	Breach ROC08 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E43.e	Breach ROC09 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E43.f	Breach ROC10 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E43.g	Breach ROC12 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E43.h	Breach ROC13 Time to Inundation - 2116 with climate change, 0.1% AEP

Southend-on-Sea Borough

Figure E44.a,b,c	Southend-on-Sea Borough Breach Maximum Flood Depth – 2016, 0.5% AEP,
Figure E45.a,b,c	Southend-on-Sea Borough Breach Maximum Flood Hazard – 2016, 0.5% AEP
Figure E46.a,b,c	Southend-on-Sea Borough Breach Maximum Flood Depth – 2116 with climate change, 0.5% AEP
Figure E47.a,b,c	Southend-on-Sea Borough Breach Maximum Flood Hazard – 2116 with climate change, 0.5% AEP
Figure E48.a,b,c	Southend-on-Sea Borough Breach Maximum Flood Depth – 2016, 0.1% AEP,
Figure E49.a,b,c	Southend-on-Sea Borough Breach Maximum Flood Hazard – 2016, 0.1% AEP
Figure E50.a,b,c	Southend-on-Sea Borough Breach Maximum Flood Depth – 2116 with climate change, 0.1% AEP
Figure E51.a,b,c	Southend-on-Sea Borough Breach Maximum Flood Hazard – 2116 with climate change, 0.1% AEP
Figure E52.a	Breach SOU01 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E52.b	Breach SOU02 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E52.c	Breach SOU04 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E52.d	Breach SOU06 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E52.e	Breach SOU07 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E52.f	Breach SOU08 Time to Inundation - 2116 with climate change, 0.1% AEP
Figure E52.g	Breach SOU09 Time to Inundation - 2116 with climate change, 0.1% AEP