Southend-on-Sea Borough Council

Strategic Flood Risk Assessment

Level 2 Report – Final Version

November 2010

Prepared on behalf of:

Revision Schedule

Strategic Flood Risk Assessment: Level 2
November 2010

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Executive Summary

Planning Policy Statement 25: Development and Flood Risk (PPS25) encourages Local Planning Authorities to undertake a Strategic Flood Risk Assessment (SFRA) as part of the evidence base for development of their Local Development Framework (LDF).

PPS25 outlines a two staged approach to the completion of a SFRA as follows:

- Level 1 SFRA – Enables the application of the Sequential Test
- Level 2 SFRA – Increased scope of the SFRA for sites where the Exception Test is required

A Level 1 SFRA was completed on behalf of Southend-on-Sea Borough Council (BC) in September 2010. This Level 2 SFRA provides a more detailed assessment of flood risk to inform the Exception Test and concentrates on the Southend Central (including seafront area) Area Action Plan and London Southend Airport Joint Area Action Plan (JAAP) areas.

The Level 1 SFRA has confirmed that the two main sources of flooding within the study area are tidal flooding from the Thames Estuary (resulting from a failure of a flood defence or overtopping of a defence) and fluvial flooding from the Prittle Brook, Eastwood Brook and Willingale watercourse.

Detailed hydrodynamic breach and overtopping modelling has been completed as part of the Level 2 SFRA to provide a greater level of detail regarding the variation of residual flood risk within Flood Zones across Southend-on-Sea BC area. Results show that the Southend-on-Sea seafront and the southern extent of the Central Area are at residual risk of flooding in the event of a breach in the flood defences and via overtopping of the existing defences. Hazard and depth maps produced as part of this study should be used to inform development within the Southend Central AAP boundary.

The Southend Airport JAAP is not at risk from tidal flooding. The greatest flood risk in this location is posed by fluvial flooding from the Eastwood Brook. Environment Agency hydraulic modelling of this watercourse should be used to steer development within this JAAP boundary.

Environment Agency 'Areas Susceptible to Surface Water Flooding' maps illustrate that surface water flood risk is present across the Borough to varying degrees. Within the Southend Central AAP potential surface water flooding hotspots include: Victoria Avenue in the Baxter Avenue area, the junction of Southchurch Road and Queensway, between Southchurch Road and Boscombe Road and between Southchurch Road and Tyrrel Drive.

Within the Southend Airport JAAP, potential surface water flooding hotspots include the north west of the JAAP including the proposed development at Aviation Way, Airport MRO Northside and MRO Northside Extension

Reference should be made to the Southend-on-Sea BC Surface Water Management Plan for detailed surface water modelling results and further details on the mechanics of surface water flooding locally (this report is anticipated in Spring 2011). Site-specific Flood Risk Assessments (required for all development proposals on sites greater than 1ha) should refer to council and water utility historic flood records to establish the level of potential surface water flood risk to any future development in these locations.

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Acronyms & Abbreviations

ABBREVIATION	DEFINITION
AAP	Area Action Plan
AONB	Area of Outstanding Natural Beauty
BGS	British Geological Survey
CFMP	Catchment Flood Management Plan
CLG	Communities and Local Government
Defra	Department for Environment, Flood and Rural Affairs
DEM	Digital Elevation Model
DPD	Development Plan Document
FRA	Flood Risk Assessment
GIS	Geographical Information System
IDB	Internal Drainage Board
LDDs	Local Development Documents
LDF	Local Development Framework
LDS	Local Development Scheme
LiDAR	Light Detection and Ranging
LPA	Local Planning Authority
PCPS 2004	Planning and Compulsory Purchase Act 2004
PPS	Planning Policy Statement
RBMP	River Basin Management Plan
RFRA	Regional Flood Risk Appraisal
RPG	Regional Planning Guidance
RSS	Regional Spatial Strategy (East of England Plan)
SA	Sustainability Appraisal
SAC	Special Area for Conservation
SFRA	Strategic Flood Risk Assessment
SoSBC	Southend-on-Sea Borough Council
SPA	Special Protection Area
SPD	Supplementary Planning Document
SPZ	Source Protection Zone
SUDS	Sustainable Drainage Systems
SWMP	Surface Water Management Plan
WCS	Water Cycle Study
WFD	Water Framework Directive

Glossary

TERM	DEFINITION
Aquifer	A source of groundwater comprising water-bearing rock, sand or gravel capable of yielding significant quantities of water.
Catchment Flood Management Plan	A high-level planning strategy through which the Environment Agency works with their key decision makers within a river catchment to identify and agree policies to secure the long-term sustainable management of flood risk.
Culvert	A channel or pipe that carries water below the level of the ground.
Flood Defence	Infrastructure used to protect an area against floods as floodwalls and embankments; they are designed to a specific standard of protection (design standard).
Floodplain	Area adjacent to river, coast or estuary that is naturally susceptible to flooding.
Flood storage	A temporary area that stores excess runoff or river flow often ponds or reservoirs.
Fluvial flooding	Flooding by a river or a watercourse.
Freeboard	Height of flood defence crest level (or building level) above designed water level
Groundwater	Water that is in the ground, this is usually referring to water in the saturated zone below the water table.
Inundation	Flooding.
Local Development Framework (LDF)	The core of the updated planning system (introduced by the Planning and Compulsory Purchase Act 2004). The LDF comprises the Local Development Documents, including the development plan documents that expand on policies and provide greater detail. The development plan includes a core strategy, site allocations and a proposals map.
Local Planning Authority (LPA)	Body that is responsible for controlling planning and development through the planning system.
Mitigation measure	An element of development design which may be used to manage flood risk or avoid an increase in flood risk elsewhere.
Overland Flow	Flooding caused when intense rainfall exceeds the capacity of the drainage systems or when, during prolonged periods of wet weather, the soil is so saturated such that it cannot accept any more water.
Overtopping	In the context of this report overtopping refers to the overflow of water that would result when the crest height of a flood defence is lower than the still water level. This does not refer to overtopping through wave actions.
Risk	The probability or likelihood of an event occurring.
Sewer flooding	Flooding caused by a blockage or overflowing in a sewer or urban drainage system.
Sustainable drainage system	Methods of management practices and control structures that are designed to drain surface water in a more sustainable manner than some conventional techniques.
Sustainable development	Development that meets the needs of the present without compromising the ability of future generations meeting their own needs.
1 in 100 year event	Event that on average will occur once every 100 years. Also expressed as an event, which has a 1% probability of occurring in any one year.
1 in 100 year design standard	Flood defence that is designed for an event, which has an annual probability of 1%. In events more severe than this the defence would be expected to fail or to allow flooding.

1 in 200 year event	Event that on average will occur once every 200 years. Also expressed as an event that has a 0.5% probability of occurring in any one year.
1 in 200 year design standard	Flood defence that is designed for an event, which has an annual probability of 0.5%. In events more severe than this the defence would be expected to fail or to allow flooding.
Flood Zone 1	Low Probability - Flood Zone comprising land assessed as having a less than 1 in 1000 annual probability of river or sea flooding in any one year (<0.1%)
Flood Zone 2	Medium Probability – Land assessed as having between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% - 0.1%) or between 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5% - 0.1%) in any year.
Flood Zone 3a	High Probability – Land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%) or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year/
Flood Zone 3b	Functional Floodplain - Land where water has to be stored or flow in times of flood.

1 Introduction

1.1 Overview

1.1.1 Planning Policy Statement 25: Development and Flood Risk (PPS25) published in March 2010 emphasises the active role Local Planning Authorities (LPAs) should have in ensuring flood risk is considered at all stages of strategic land use planning. PPS25 encourages LPAs to undertake a Strategic Flood Risk Assessment (SFRA) as part of the evidence base for development of their Local Development Framework (LDF).

1.1.2 PPS25 outlines a two staged approach to the completion of a SFRA being:

- Level 1 SFRA – Enables the application of the Sequential Test
- Level 2 SFRA – Increased scope of the SFRA for sites where the Exception Test is required

1.1.3 A Level 1 SFRA was completed on behalf of Southend-on-Sea Borough Council (BC) in September 2010. The Level 1 SFRA provides a strategic overview of the potential sources of flooding across Southend-on-Sea BC and forms the evidence base for undertaking the Sequential Test (to be completed by the LPA).

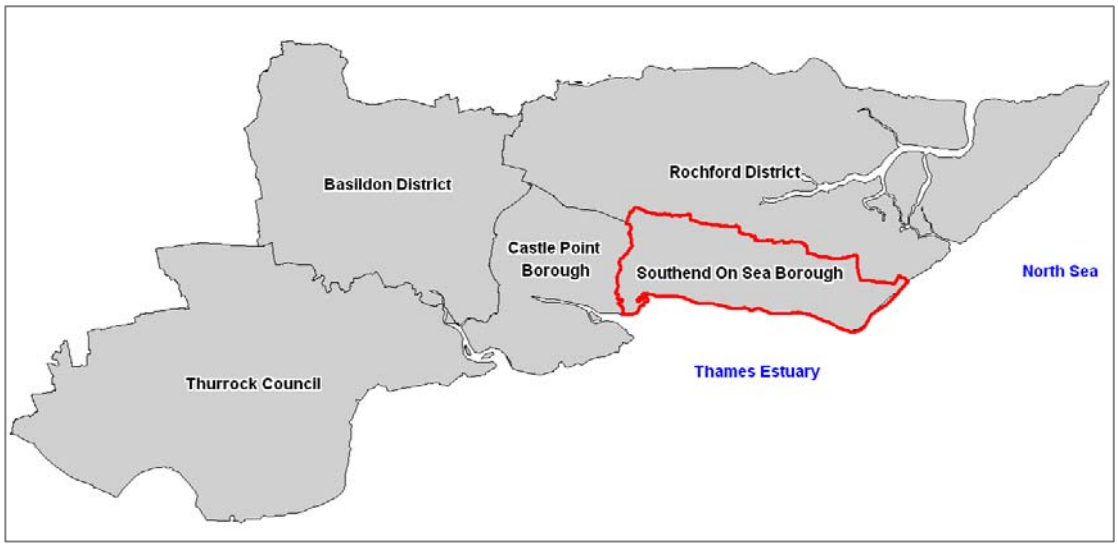
1.1.4 Southend-on-Sea BC has a large coastal frontage and due to the nature of flooding across the study area, it is not possible to allocate all proposed development in accordance with the sequential approach i.e. by steering development to areas at lowest risk of flooding. Therefore, more information with regard to flood risk within the PPS25 Flood Zones is required to inform potential site allocations.

1.1.5 This Level 2 SFRA provides a more detailed assessment of flood risk within the floodplain for areas where pressure to develop has been highlighted (including the Central Area and London Southend Airport). The deliverables from the Level 2 SFRA should be read in conjunction with the Level 1 SFRA and will provide Southend-on-Sea BC with information for completion of the Exception Test.

1.2 Study Area

1.2.1 The total study area is defined by the administrative area of Southend-on-Sea BC located in southeast Essex (Figure 1-1). The total study area covers 42km^2. The Thames Estuary forms the southern boundary of the Borough, to the north is Rochford District and to the west is Castle Point Borough.

Figure 1-1 Southend-on-sea SFRA Study Area



1.2.2 The borough is relatively densely populated except for a small strip of land on the northern edge and the Shoeburyness area in the south-eastern corner of the Borough. Land use is predominantly residential with some ex-Ministry of Defence (MOD) land on the eastern coastline. The Borough is served by two railway lines which connect Southend-on-Sea to London.

1.2.3 Following completion of the Level 1 SFRA and discussion of the findings with the LPA, it was decided that a Level 2 SFRA was required to concentrate on the two Area Action Plans in the Borough:

- London Southend Airport Joint Area Action Plan
- Southend Central Area Action Plan

1.2.4 Whilst this Level 2 SFRA report concentrates on these two areas, hydraulic modelling outputs have been provided for the whole of the borough which can be used to assess flood risk at other locations should further development sites come forward. This will ensure that sufficient information is available to inform the review of the Core Strategy which is scheduled for the coming year.

1.3 Level 2 Objectives

1.3.1 The aim of this Level 2 SFRA is to provide sufficiently detailed information regarding the nature of flood risk posed to Southend-on-Sea BC, taking into account the presence of current flood risk management measures to enable the application of the Exception Test. This will be achieved through the following objectives:

- Provide information on the location, standard of protection and condition of existing flood defences and future policy with regard to these defences;

- Carry out 2D hydrodynamic modelling of nine breach locations along the Southend-on-Sea BC frontage for the 0.5% (1 in 200 year) and 0.1% (1 in 1000 year) tidal flood events taking account of 100 years of climate change until 2110;
- For each breach scenario, provide mapping of the following information:
    i. The depth of flooding;
    ii. The flood hazard based on the depth and velocity of flood water;
    iii. The time to inundation;
- Carry out 2D hydrodynamic modelling of overtopping of existing tidal flood defences for the 0.5% (1 in 200 year) and 0.1% (1 in 1000 year) tidal flood events taking account of 100 years of climate change until 2110 to highlight where flood defences fall below these return periods;
- Build upon the Level 1 SFRA data to provide a more detailed analysis of flood risk in the Central Area and London Southend Airport development envelopes.
- Provide guidance on the application of the PPS25 Exception Test for potential development sites; and,
- Advise on the requirements of site-specific Flood Risk Assessments (FRAs) in the light of findings from the Level 2 SFRA.

2 PPS25 Exception Test

2.1 Background

2.1.1 The Exception Test should only be applied, where necessary, after the Sequential Test has been applied. The purpose of the Exception Test is to provide a method of managing flood risk while still allowing necessary development to occur. The Exception Test is likely to be required within the coastal frontage of Southend-on-Sea located in Flood Zones 2 and 3, where development is necessary for regeneration purposes.

2.1.2 The Exception Test comprises three criteria, all three of which must be satisfied before a development may be considered appropriate within an area of medium or high flood risk. The three criteria are:

2.1.3 **Part A** - It must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk;

2.1.4 **Part B** - The development should be on developable previously developed land, or if it is not on previously developed land, there must be no reasonable alternative sites on developable, previously developed land;

2.1.5 **Part C** - A Flood Risk Assessment (FRA) must demonstrate that the development will be safe without increasing flood risk elsewhere and will reduce flood risk overall.

2.2 Application

2.2.1 Southend-on-Sea Borough Council have identified the specific needs to develop within the Southend-on-Sea Town Centre and the London Southend Airport and surrounding environs. Accordingly, local planning policies and Area Actions Plans have been developed for these areas.

2.2.2 In the light of these AAPs, it has been established that the application of the Sequential Test will be focused within these AAP areas rather than the administrative area of the entire borough.

Part A – Wider Sustainability to the Community

2.2.3 It must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk.

2.2.4 It is the role of the developer or Southend-on-Sea BC to consider the proposal against the sustainability criteria of the Sustainability Appraisal (SA) (Scott Wilson 2007) in order to determine whether the site will satisfy Part A of the Exception Test. Should a development fail to score positively against the SA, Southend-on-Sea BC should consider whether the use of planning conditions or Section 106 Agreements could make it do so.

Part B – Redevelopment of Previously Developed Land

2.2.5 In order to satisfy Part B of the Exception Test, the development must be on developable previously developed land or, if it is not on previously developed land, it must be demonstrated that there are no reasonable alternative sites on developable previously developed land.

2.2.6 Planning Policy Statement 3: Housing states that in order to be considered 'developable', sites should 'be in a suitable location for housing development, (or the proposed use), and there should be a reasonable prospect that the site is available for, and could be developed at the point envisaged'.

2.2.7 Planning Policy Statement 3: Housing defines 'previously developed' land as 'land which is, or was occupied by a permanent structure, including the curtilage of the developed land and any associated fixed surface infrastructure.'

2.2.8 The definition includes defence buildings, but excludes:

- Land that is or has been occupied by agricultural or forestry buildings.
- Land that has been developed for minerals extraction or waste disposal by landfill purposes where provision for restoration has been made through development control procedures.
- Land in built-up areas such as private residential gardens, parks, recreation grounds and allotments, which, although it may feature paths, pavilions and other buildings, has not been previously developed.
- Land that was previously-developed but where the remains of the permanent structure or fixed surface structure have blended into the landscape in the process of time (to the extent that it can reasonably be considered as part of the natural surroundings).

2.2.9 There is no presumption that land that has been previously-developed is necessarily suitable for housing development nor that the whole of the curtilage should be developed.

2.2.10 The Southend Central AAP will satisfy Part B of the Exception Test as it is re-development of the existing central area. The Airport JAAP is not located on previously developed land; however it is considered that it could be shown that there are no reasonable alternative sites on developable previously developed land suitable to locate the new airport and associated development.

Part C – Safe from Flood Risk

2.2.11 A Site-specific FRA must demonstrate that the development will be safe, without increasing flood risk elsewhere, and where possible, will reduce flood risk overall. It must consider the risks throughout the design life of the development. The PPS25 Practice Guide recommends that for residential development a minimum design life of 100 years is specified, unless there is specific justification for considering a shorter period. For non-residential developments, the design life is considered to be 75 years.

2.2.12 The PPS25 Practice Guide provides details on the definition of 'safe' in Chapter 6 – Risk Management by Design, and Chapter 7 – Residual Risk and requires consideration of the following issues in order to demonstrate safety:

- Residual flood risk throughout development lifetime i.e. defence/pumping station failure or defence overtopping
- Access and egress routes
- Flood warning and evacuation procedures

2.2.13 Part C of the Exception Test will be informed on a site-specific basis and Chapter 5 outlines the issues that will need to be addressed as part of a site-specific FRA for submission with the planning application.

2.2.14 It is emphasised that the definition of safe should be clarified and agreed between Southend-on-Sea BC, Emergency Planners, and the Environment Agency as part of the FRA process, and may require additional considerations depending on the precise nature of the proposed development and potential flood risk.

Windfall Sites

2.2.15 Windfall Sites are sites which become available for development unexpectedly and are therefore not included as allocated land in a planning authority's development plan.

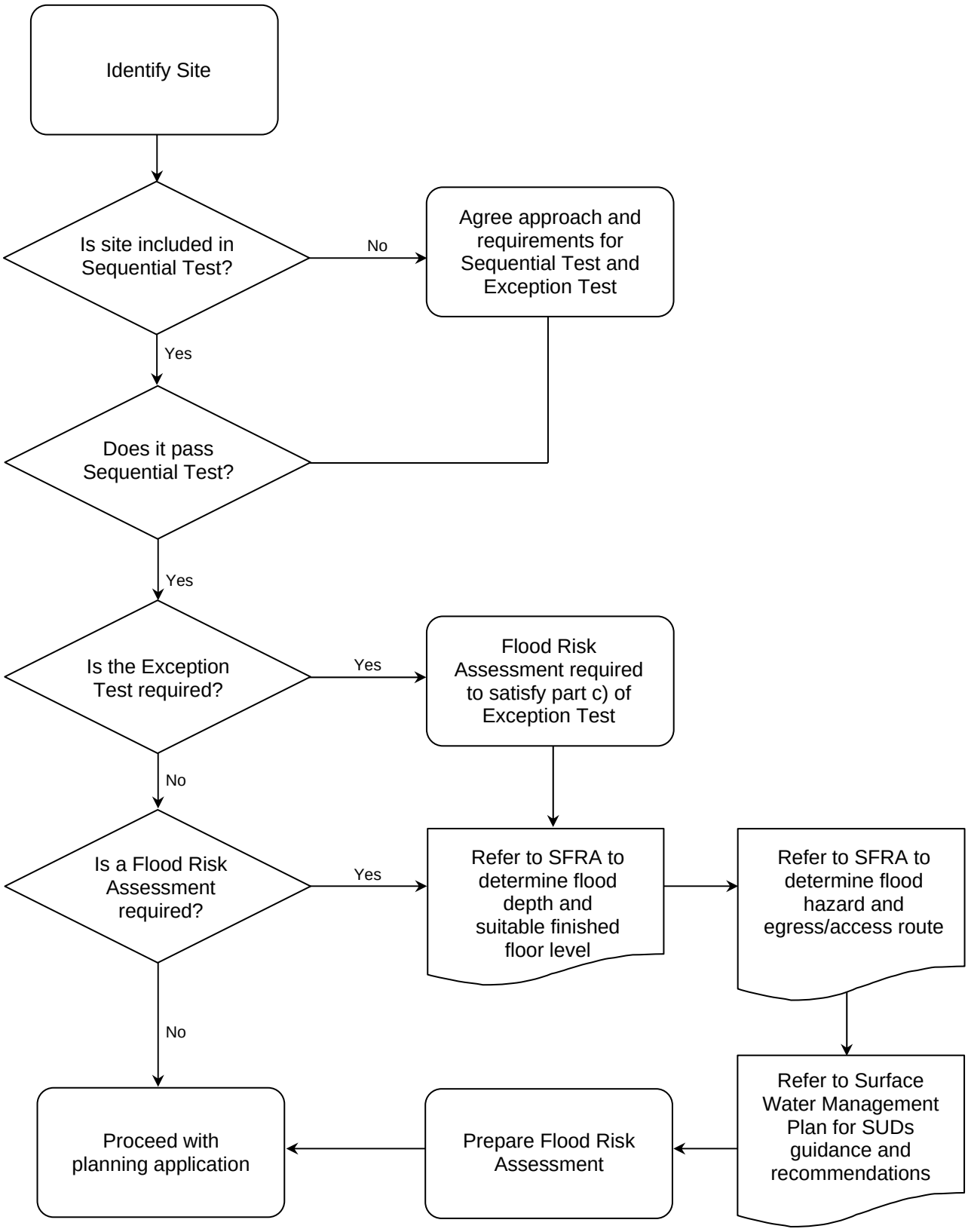
2.2.16 Should a site become available that has not been allocated as part of the LDF process, the Sequential Test should be applied on an individual site basis and the developer will need to provide evidence to the LPA that they have adequately considered other reasonably available sites across the Borough. This will involve considering windfall sites against other sites allocated as suitable for housing plans.

2.2.17 The following steps should be followed for windfall sites:

1. Identify if the Sequential Test is required; Paragraph D.15 of PPS25 states that if the application is minor development or for a change of use (unless involving caravans, camping, chalets, mobile homes or gypsy and traveller sites), the Sequential and Exception Tests are not required. However, the application will still need to meet the requirements for FRAs and flood risk reduction as set out in Table D.1 of PPS25.
2. If the Sequential Test is required, identify which Flood Zone the site is located within using the Environment Agency flood maps.
3. Agree scope and considerations for the site-specific Sequential Test and, where necessary, Exception Test with the LPA and Environment Agency.

2.2.18 Figure 2-1 presents a summary of the procedure that should be followed from identifying a development site through to submission of planning application.

Figure 2-2-1 Application of the Sequential and Exception Tests



3 Level 2 SFRA – Methodology

3.1 Overview

3.1.1 The Level 1 SFRA has confirmed that the two main sources of flooding within the Study Area are tidal flooding from the Thames Estuary and fluvial flooding from the Prittle Brook, Eastwood Brook and Willingale watercourse.

3.1.2 Detailed hydrodynamic modelling has been undertaken to provide a greater level of detail regarding the variation of the residual flood risk within Flood Zones in the Southend-on-Sea BC area. Modelling has been undertaken to simulate breaches in flood defences as well as the potential for overtopping of the defences.

3.1.3 The breach and overtopping modelling is at a strategic level and should be used to inform the development of AAPs and large sites for regeneration and development. This should form a 'stepping-stone' for site-specific FRAs, considering the recommendations presented throughout the Level 1 and 2 SFRAs.

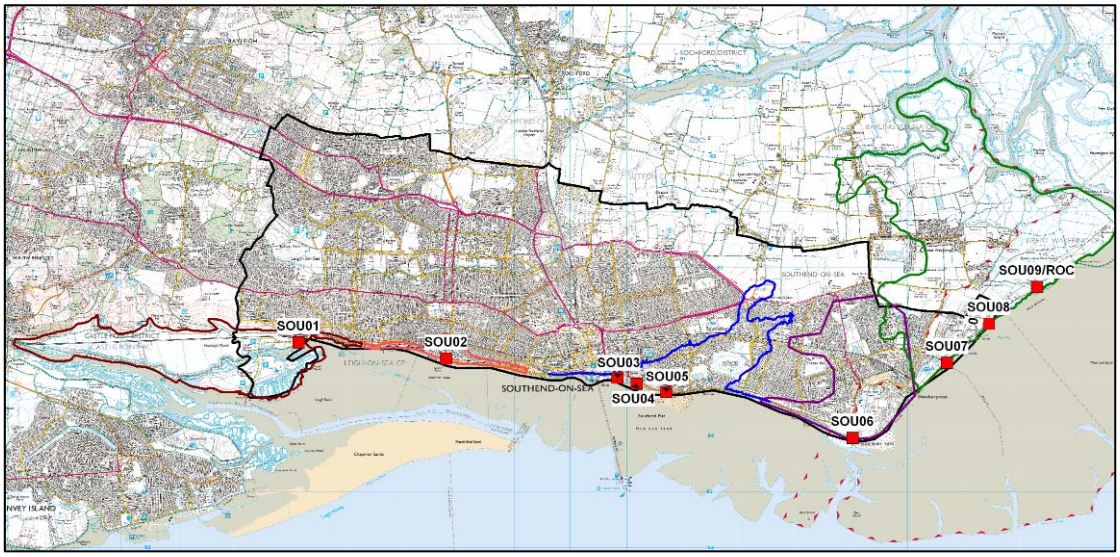
3.2 Modelling Methodology

3.2.1 Residual risk is defined as the remaining risk after risk reduction measures have been taken into account. Residual risk therefore includes breaches in flood defences and overtopping of defences.

3.2.2 Along the Southend-on-Sea frontage, some of the existing defences fall below the 1 in 200 year standard and are therefore likely to be overtopped by floodwater during this flood event. It is noted that whilst overtopping is a residual risk, because a flood defence is in place, in this case the risk posed to parts of Southend-on-Sea is a real risk. However, the depth of water will be reduced by the presence of the defence and the floodplain extent will be greatly reduced than if there were no defences present.

3.2.3 Hydrodynamic breach and overtopping modelling has been completed at 9 locations along the Southend-on-Sea BC frontage as illustrated in Figure 3-1.

Figure 3-1 Breach Locations and Flood Cells



3.2.4 Details of the nine breach locations are included in Table 3-1 below and a detailed modelling methodology is included in Appendix A.

3.2.5 Breach modelling has previously been undertaken in this area as part of the Thames Gateway South Essex SFRA. Modelling results included in this Level 2 SFRA study supersede those in the TGSE report as they use revised water levels provided by the Environment Agency and improved modelling techniques now available.

Table 3-1 Breach Locations and Characteristics

Code	Flood Cell	Easting	Northing	Breach Width (m)
SOU01	Hadleigh Marsh	583160	185661	50
SOU02	Chalkwell	585796	185365	20
SOU03	City Beach	588834	185034	20
SOU04	City Beach	589174	184919	20
SOU05	City Beach	589705	184776	20
SOU06	East Southend	593018	183955	20
SOU07	Shoeburyness/Great Wakering	594700	185300	200
SOU08	Shoeburyness/Great Wakering	595445	185998	200
SOU09/ROC	Shoeburyness/Great Wakering	596298	186654	200

3.2.6 The following flood events were simulated for each of the nine **breach** locations:

- A tidal flood event with 0.5% probability (return period of 1 in 200 yr), 2010;
- A tidal flood event with 0.5% probability (return period of 1 in 200 yr) with CC to 2110;
- A tidal flood event with a probability of 0.1% (return period of 1 in 1000 yr), 2010;
- A tidal flood event with a probability of 0.1% (return period of 1 in 1000yr) with CC to 2110.

3.2.7 The following two flood events were simulated for **overtopping**:

- A tidal flood event with a 0.5% probability (1 in 200 yrs) with climate change to 2110;
- A tidal flood event with a 0.1% probability (1 in 1000 yrs) with climate change to 2110.

3.2.8 It is noted that the overtopping scenarios

3.3 Modelling Outputs

3.3.1 Results from the modelling include details of flood depth, flood hazard and time to inundation which can be used to enable more detailed consideration of the sequential approach within Flood Zones.

3.3.2 Flood hazard, depth and time to inundation data will also enable part c) of the Exception Test to be addressed (see Section 2.0) and will help to inform the production of an emergency flood response plan for the area. Each of the modelling outputs is discussed in more detail below.

Maximum Flood Depth

3.3.3 The maximum flood depth is obtained from the water level achieved at each point in the model, minus the LiDAR topographic level at that point. This has been processed for both the current day and the climate change scenarios to 2110.

3.3.4 The flood depths experienced during each breach have been mapped together (on a single composite map), using the maximum values at each point in the floodplain. These are included in figures within Appendix C.

Hazard Rating

3.3.5 Flood hazard is a function of the flood depth and flow velocity at a particular point in the floodplain, combined with a suitable debris factor. Each element within the model is assigned one of four hazard categories, Extreme, Significant, Moderate or Low. The derivation of hazard categories is based on Flood Risks to People FD2320 (DEFRA & EA, 2005), using the following equation:

Flood Hazard Rating = ((v+0.5)*D) + DF

Where *v = velocity (m/s)*

D = depth (m)

DF = debris factor

3.3.6 The depth and velocity outputs from the 2D hydrodynamic modelling are used in this equation, along with a suitable debris factor. For this SFRA, a precautionary approach has been adopted inline with FD2320; a debris factor of 0.5 has been used for depths less than and equal to 0.25m, and a debris factor of 1.0 has been used for depths greater than 0.25m.

Table 3-2 Hazard categories based on Defra Research Paper FD2320 (DEFRA & EA 2005)

Flood Hazard			Description
	HR < 0.75	**Low**	**Caution** – Flood zone with shallow flowing water or deep standing water
	0.75 ≥ HR ≤ 1.25	**Moderate**	**Dangerous for some** (i.e. children) – Danger: flood zone with deep or fast flowing water
	1.25 > HR ≤ 2.0	**Significant**	**Dangerous for most people** – Danger: flood zone with deep fast flowing water
	HR > 2.0	**Extreme**	**Dangerous for all** – Extreme danger: flood zone with deep fast flowing water

3.3.7 Hazard outputs have been processed for the following flood events:

- 0.5% and 0.1% (1 in 200 year and 1 in 1000 year event) present day (2010)
- 0.5% and 0.15 (1 in 200 and 1 in 1000 year event) with climate change (2110)

3.3.8 The hazard outputs for each of the nine breach locations have been mapped together (on a single composite map), using the maximum hazard rating at each point in the floodplain. These are shown in the Figures included in Appendix C.

Time to Inundation

3.3.9 Time to inundation, is the time it takes floodwaters to spread across the floodplain following a breach in defences. Any overtopping prior to the breach event has been classified as 'overtopping prior to breach event' illustrated on the composite maps as a hatched area.

3.3.10 Time '0' is set to the time when the breach occurs and water can flow through the breach. This means that the <1 hour band encompasses all areas that are inundated (wet) within the first hour of water travelling through the breach and onto the floodplain. Further bands have been produced to show wet 'cells' at: 1-4 hours, 4-8 hours, 8-12 hours, and for each 4 hour interval up to 20 hours. This data has been processed for both the present day and climate change scenarios.

3.3.11 The outputs for time to inundation for each of the 9 breach scenarios have been mapped together (on a single composite map). This mapping is included in Appendix C.

3.4 Limitations

Flood Depth and Hazard Rating

3.4.1 It should be noted when using flood hazard zone maps that they **represent the hazard arising from one or more specific breach locations, and that the hazard will almost certainly vary spatially if the breach locations are moved.** This is also the case for the flood depth maps and time to inundation maps.

3.4.2 Other limitations that should be noted include:

- Not all possible breach locations have been considered. The modelling study had to be limited to those locations thought most likely to lead to flood risk for specific development areas.
- Breach width and depth, though based on Environment Agency guidance, are arbitrary and do not necessarily represent the actual dimensions of a possible breach in a given location.
- Changes in inundation extent or hazard zone are non-linear to changes in breach location.
- Hazard mapping is developed as a product of the depth, velocity and a debris factor from a particular breach event or combined breach event within a given flood cell. These hazard classifications do not indicate a change in the flood probability.

Time to Inundation

3.4.3 The values presented for time to inundation are indicative only. The modelling methodology used for this study produces results from a breach occurring prior to the second and largest tidal cycle. This allows water to overtop where defences are below the water level during the first tidal cycle. The modelling method also allows the rapid inundation of land immediately behind the breach where water has accumulated on the seaward side of the breach.

4 Level 2 SFRA – Flood Risk Review

4.1 Introduction

4.1.1 Hydraulic breach modelling was completed at 9 locations along the Southend-on-Sea BC frontage. Breach modelling results show that flood risk to the west of the Central Area is largely confined to land in close proximity to the sea. On reaching Hadleigh Marsh and Two Tree Island, the area of landward inundation increases covering the majority of the island. To the east of the Southend Central Area, the area of landward inundation should a breach in the flood defences occur increases substantially, reflecting the lower lying topography of the Southchurch Park area, before becoming largely confined to the seafront.

4.1.2 Hydraulic modelling of overtopping was completed along the tidal frontage of Southend-on-Sea BC and results largely mirror those described above. In addition, time to inundation plans highlight areas where overtopping occurs prior to a breach, these areas include Leigh Marsh in the west and a narrow strip of land along sections of the seafront in the Central Area.

4.1.3 This Level 2 SFRA includes the production of mapping illustrating flood depth, flood hazard and time to inundation which has been compared in two broad areas of development in order that the sequential approach can be applied within Flood Zones.

4.1.4 Southend-on-Sea BC has identified two AAPs for potential development:

- Southend Central AAP
- London Southend Airport JAAP

4.1.5 A strategic level assessment of flood risk in these two areas, posed by each form of flooding as outlined in PPS25 is included in Section 4.2 (Southend Central AAP) and 4.3 (Airport JAAP) below.

4.2 Existing Flood Defences

4.2.1 All flood defences along the Southend-on-Sea BC frontage in the vicinity of the Southend Central AAP are maintained by the Council, with the majority being built by the Environment Agency as part of the Thames Tidal Defences project under the Thames Barrier and Flood Protection Act (1972).

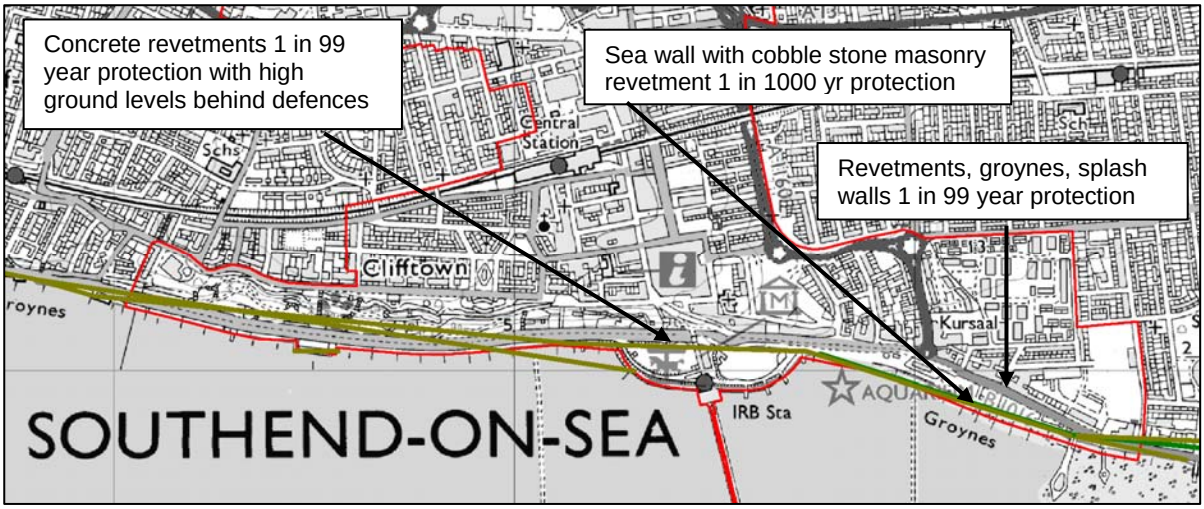
4.2.2 The defences along the Southend-on-Sea BC frontage offer a varying standard of protection ranging from protection less than the 1% annual probability event (1 in 100 year) present day to protection up to the 0.1% annual probability flood (1 in 1000 year) including an allowance for climate change (see Figure 7 Level 1 SFRA, extract included in Figure 4-1 below).

4.2.3 The range in the protection afforded by the defences is due to varying defence types, from formal walls and flood defence barriers in urban areas to earth embankments in the more rural eastern and western extents of the borough.

4.2.4 Figure 4-1 below is an extract from Figure 7 included in the Level 1 SFRA which illustrates the standard of protection offered by flood defences based on Environment Agency National Flood

and Coastal Defence Data (NFCDD). Figure 4-1 is centred on the Central Area and illustrates that in places (including to the east of the Central Area) more than one defence is in existence e.g. revetments, groynes and splash walls provide protection to the 1 in 99 year standard with a sea wall providing protection to the 0.1% annual probability (1 in 1000 year) standard.

Figure 4-1 Flood Defences in the Central Area (extract from Figure 7 Level 1 SFRA)



(Source: Southend-on-Sea BC Level 1SFRA March 2010)

4.2.5 The photos below illustrate the varied type of defences in the vicinity of the Central Area.

Typical sea wall along the coastal frontage

A ramped access in the sea wall defences

A tarmac access road on the seaward side, kerbs at the seafront

Brick protective walls and raised brick seawall

4.2.6 The Level 1 SFRA report includes an assessment of the standard of defence using crest heights from LiDAR. Figure 15 and 16 included in the Level 1 SFRA illustrate the areas of Southend-on-Sea BC which could be affected by overtopping during the 0.5% (1 in 200) and 0.1% (1 in 1000) annual probability event for both the present day and climate change situation to 2110.

4.2.7 Crest heights of flood defences have been taken from details obtained on site visits and through interrogation of LiDAR data. In the vicinity of the Southend Central AAP, crest heights range from 5.61mAOD to 5.86mAOD.

4.2.8 Results show that large areas of land are at risk of overtopping in the far western extent of the Borough at Leigh Marsh and far eastern extent at Shoeburyness. In addition, a small section of land directly behind the flood defences is at risk under the 0.5% annual probability event to 2110 along the majority of the seafront. Due to ground levels rising steeply behind the flood defences in the Central Area, flooding due to overtopping is largely confined to the Esplanade; however, ground levels in the Southchurch Park make this area more vulnerable to overtopping.

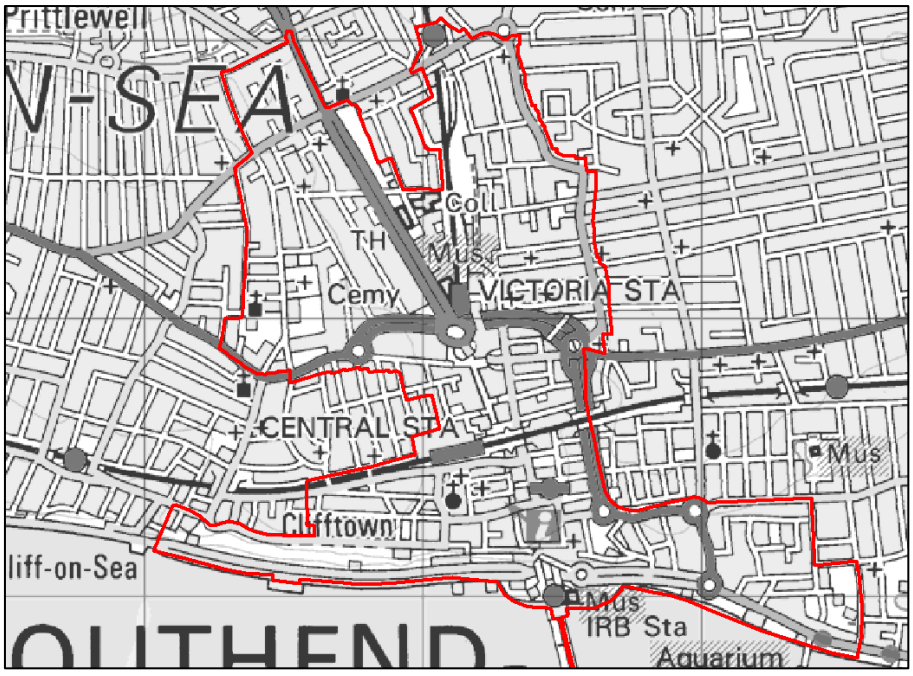
4.2.9 Southend-on-Sea BC falls into the Environment Agency's Catchment Flood Management Policy Unit 2 where flood defence policy is for further action to be taken to reduce flood risk.

4.3 Southend Central AAP

4.3.1 The regeneration of Southend Central Area is a key objective for Southend-on-Sea BC. The central area is a major retail, employment and commercial centre serving a catchment population of over 325,000 people. Improving the accessibility, amenity and attractiveness of the Central Area will be key to achieving regeneration and delivering a renaissance of the Central Area.

4.3.2 Once adopted, the Southend Central Area AAP will provide a comprehensive planning policy framework for all future planning decisions to 2021. The Southend Central Area AAP boundary is illustrated in Figure 4-2 below and extends from the B1015 (East Street) in the north to the seafront at the Eastern Esplanade.

Figure 4-2 Southend-on-Sea Central Area AAP



Fluvial Flood Risk

4.3.3 Figure 4-3 below highlights that there are no 'main river' watercourses which fall under the responsibility of the Environment Agency within the Southend Central AAP area. The nearest main river watercourses are the Prittle Brook and the Willingale watercourse which are described below.

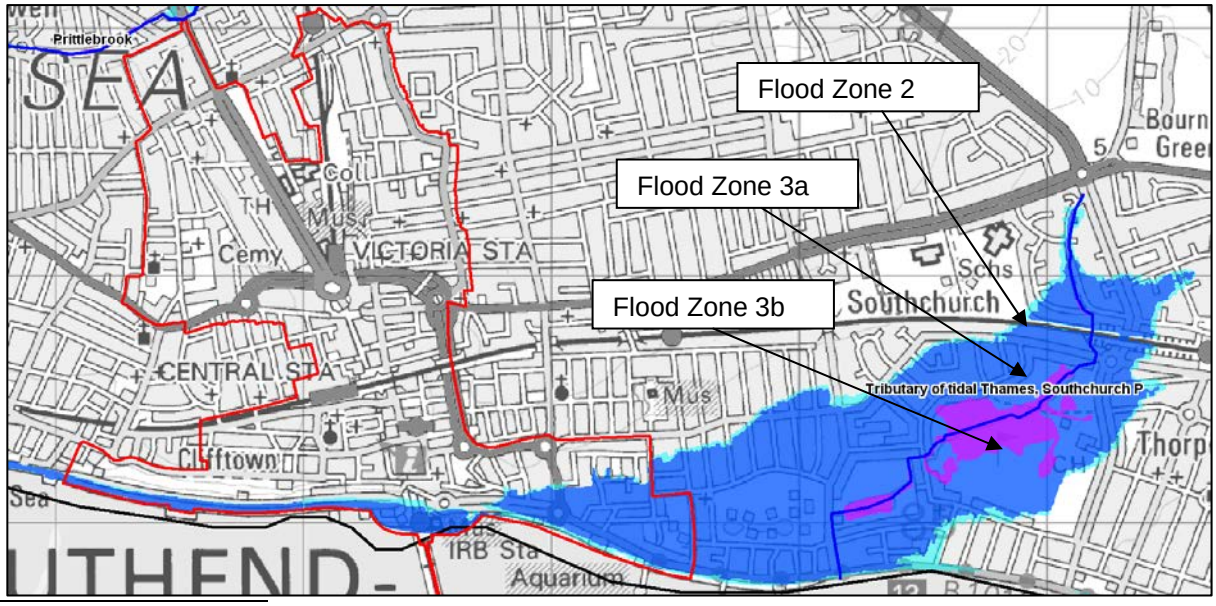
4.3.4 The Prittle Brook is located to the north west of Southend Central AAP. The fluvial flood risk along this watercourse is small and has been further reduced due to the Prittle Flood Relief tunnel which diverts high flows from the brook to the River Thames. The Prittle Flood Relief tunnel provides a 1% (1 in 100) annual probability standard of protection.

4.3.5 A tributary of the tidal Thames at Southchurch (sometimes referred to as the Willingale watercourse) is located to the south east of the AAP area. This watercourse flows through Thorpe Bay golf club and Southchurch Park East to its outlet at the Anglian Water pumping station at Lifstan Way/Eastern Esplanade.

4.3.6 The Environment Agency has recently completed a flood risk study of the Willingale watercourse. Results showed that from the upstream limit there is no flooding until Thorpe Hall Golf Course. At this point, the flood outlines become extensive for all return periods. While the main river itself is not located within the AAP boundary, the Environment Agency Flood Zones highlight that the south eastern corner of the AAP is located partly within Flood Zone 3a and Flood Zone 2 associated with this watercourse.

4.3.7 Environment Agency modelled flood outlines show that several properties on Lifstan Way and Shaftesbury Avenue are at risk of fluvial flooding. There are a total of 53 properties within the 0.1% probability (1 in 1000 year outline) but none for any of the lower return periods[1]. It should be noted that the Environment Agency flood outlines also outline the area of tidal flooding in the absence of flood defences so flood risk at this location may be via a combination of both flood risk via fluvial flooding and a residual risk from tidal flooding.

Figure 4-3 Environment Agency modelled flood outlines: Southchurch / Willingale



[1] Environment Agency Anglian Region – Southend Watercourse Additional Return Periods Final Report Aug 2008

4.3.8 While there are no main rivers highlighted within the AAP boundary, there may still be some drainage channels and ordinary watercourses for which riparian owners have responsibility. Reference should be made to the Southend-on-Sea BC Surface Water Management Plan anticipated in Spring 2011, for further details on the location of ordinary watercourses across the study area.

Surface Water Flood Risk

4.3.9 The Environment Agency has started to gather and publish information on surface water flood risk across the UK in the form of an 'Areas Susceptible to Surface Water Flooding Map'. This information is based on pluvial modelling which uses ground level data and is available to planners to be used to identify areas within the Southend Central AAP where the further assessment of surface water flood risk will be required as part of any site-specific planning application. This data is continually being improved and refined by collecting details about past floods from LPAs, water utilities and the general public.

4.3.10 It should be noted that the Areas Susceptible to Surface Water Flooding dataset has been produced using a simplified method that excludes urban sewerage and drainage systems, excludes buildings, and uses a single rainfall event. The mapping is primarily intended for use by Local Resilience Forums (LRFs) and to inform emergency planning, but has recently been released for use in SFRAs to inform the most strategic levels of land use planning. It is not intended for use in allocating individual sites or determining individual planning applications. This mapping has the following limitations:

1) The mapping does not show the interface between the surface water network, the sewer systems and the water courses;

2) It does not show the susceptibility of individual properties to surface water flooding;

3) The mapping has significant limitations for use in flat catchments;

4.3.11 In the light of these limitations, it is recommended that the mapping be used only as an initial review of surface water flooding in order to identify areas requiring further investigation.

4.3.12 In order to assist with the verification of this dataset, records of surface water and sewer flooding supplied by Anglian Water and Southend-on-Sea Borough Council have been overlaid on the dataset in Figure 9. Supporting information from the Catchment Flood Management Plan and an appreciation of the local topography has also been drawn upon to assist with the verification of the data.

4.3.13 Figure 9 in the Level 1 SFRA identifies land south of Southchurch to be more susceptible to surface water flooding, which is to be expected given the topographic depression in which it is located. In addition, corridors around the course of the Prittle Brook and the Eastwood Brook are shown to be susceptible to surface water flooding as surface water flows are channelled into the watercourses. A significant area of ponding is also identified immediately to the south of the A1559 near the Essex Golf Club which may be the result of the constriction of surface water flows through the subway.

4.3.14 Datasets provided by Anglian Water and Southend-on-Sea Borough Council record incidents of flooding at South of Chalkwell, Southend Town Centre, south of Prittlewell and to the south of

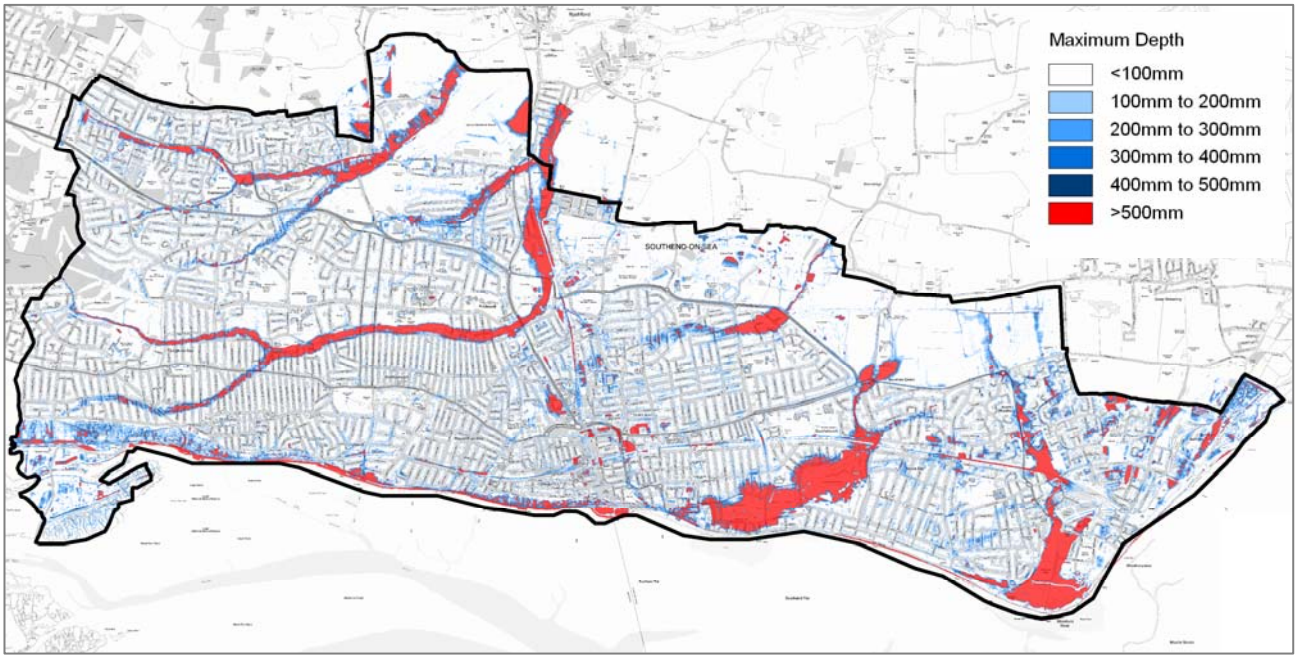
the London Southend Airport. These incidents correlate relatively well with the Areas Susceptible to Surface Water Flooding dataset.

4.3.15 In addition to these datasets, draft outputs from pluvial modelling currently being undertaken as part of the Surface Water Management Plan for Southend-on-Sea BC have been used to verify the existing data, an extract is provided in Figure 4-4. It is noted that these are draft outputs. The modelling includes 1-D structures at Mucking Hall, the Prittle Brook; however this iteration of the modelling does not represent the presence of the Prittle Tunnel and therefore provides an overestimate of the downstream extent of flooding along the Prittle Brook corridor.

4.3.16 The key patterns of surface water flooding across the borough shown through this draft pluvial modelling correlate with the Areas Susceptible to Surface Water Flooding dataset and provide confidence when using this dataset for the purposes of a high level review afforded by this SFRA.

4.3.17 For further, more detailed, assessment of surface water flooding across the borough the reader is referred to the Surface Water Management Plan currently being prepared on behalf of Southend-on-Sea Borough Council.

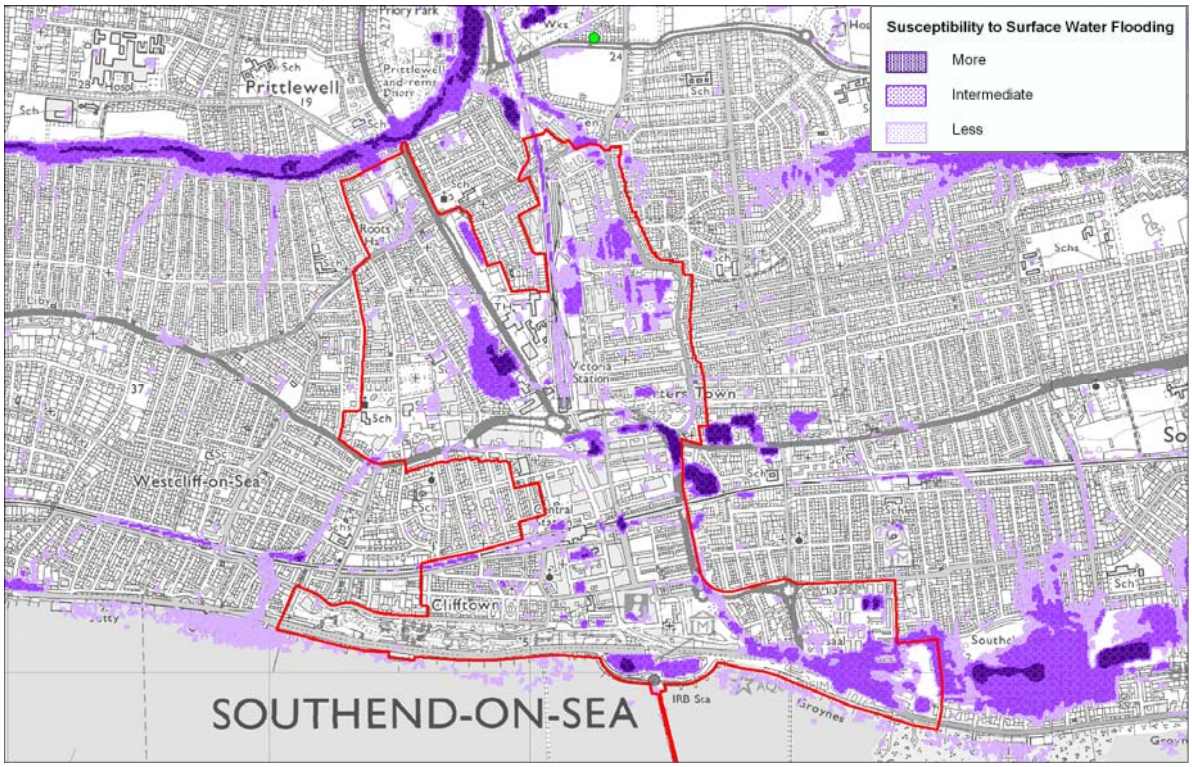
Figure 4-4 Draft Pluvial Modelling Output, from Southend-on-Sea SWMP



4.3.18 The Environment Agency 'Areas Susceptible to Surface Water Flooding' map, which has been verified the Level 1 SFRA and is shown in Figure 4-5 highlights small hotspots within the Southend Central AAP boundary where the risk of surface water flooding may be greater. These areas include Victoria Avenue in the Baxter Avenue area, the junction of Southchurch Road and Queensway, between Southchurch Road and Boscombe Road and between Southchurch Road and Tyrrel Drive. It is anticipated that these areas may be located in parts of the Central Area with lower ground levels causing any surface water runoff to pool here.

4.3.19 It should be noted that the Areas Susceptible to Surface Water flooding maps are a 'worst case scenario' as the modelling does not take into account existing drainage infrastructure.

Figure 4-5 Environment Agency Areas Susceptible to Surface Water Flooding



4.3.20 A FRA (required for all sites greater than 1ha, or sites known to have surface water flooding issues) should refer to council and water utility historic flood records to establish the level of potential surface water flood risk to any future development in these locations. Reference should also be made to the Southend-on-Sea BC Surface Water Management Plan which is anticipated in Spring 2011; this will include refined pluvial modelling and a more detailed surface water assessment.

Tidal Flood Risk

4.3.21 Detailed breach and overtopping modelling has been considered for tidal sources at 9 locations along the Southend-on-Sea BC seafront. These identify the residual flood risks associated with a failure in the flood defence via a breach or overtopping of the defences.

4.3.22 Three of the nine breach locations are located in close proximity to the central area (SOU03, SOU04, and SOU05) and the potential flood risk in terms of depth of flood water, flood hazard and time to inundation at these three locations has been assessed in terms of the potential impact on the Southend Central AAP. In addition, overtopping results are included for both depth and hazard. The results are described below.

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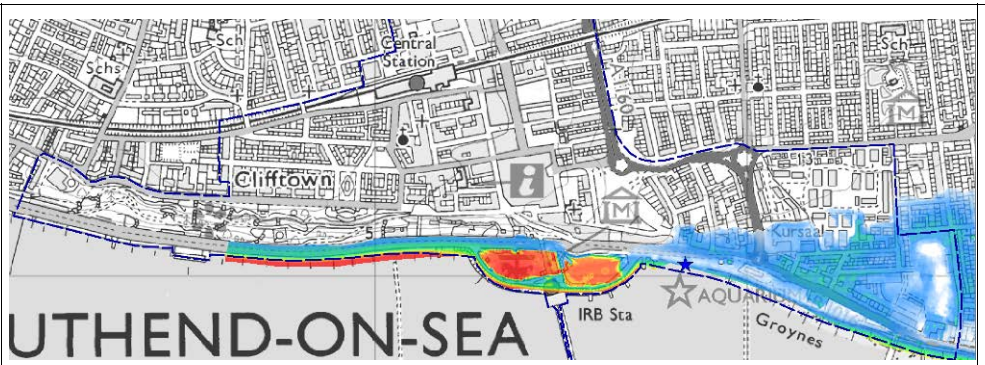
Max Depth

Breach (Residual Risk)

Breach SOU03

Breach in the 0.5% probability (1 in 200 year) climate change event to 2110.

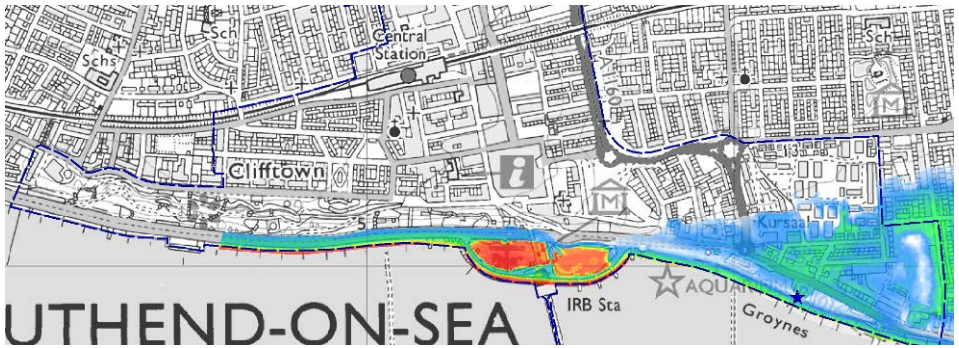
Breach location adjacent to Hartington Road within the Southend Central AAP



Breach SOU04

Breach in the 0.5% probability (1 in 200 year) climate change event to 2110

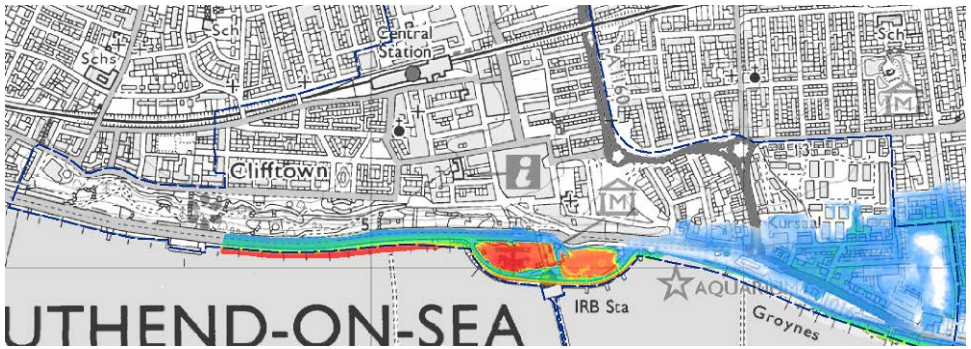
Breach location south of Burdett Road within the Southend Central AAP.



Breach SOU05

Breach in the 0.5% probability (1 in 200 year) climate change event to 2110

Breach location to the east of the Southend Central AAP boundary south of Camper Road (beyond the eastern extent of this plan)



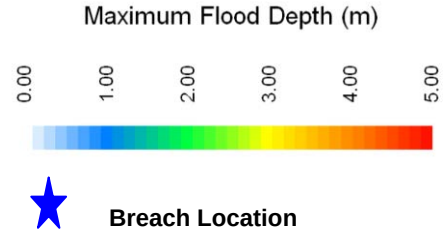
There is a minor difference between the depth and area of inundation between breach locations SOU03, SOU04 and SOU05.

Following a breach of defences at any of the three locations, a depth of floodwater of up to 4.5m could be experienced in the Southend Central AAP at Adventure Island and Southend Pier. The Western Esplanade is at a higher ground level and prevents water from extending north towards the Central Area.

Ground levels in the south eastern corner of the Southend Central AAP are lower. The worst case scenario is created if a breach of defences was to occur at location SOU04, when flood water could be expected to a depth of 2m at the eastern boundary of the AAP in the vicinity of Victoria Road.

Depths of between 1m and 2m may also be experienced along the Eastern Esplanade in the vicinity of Beresford Road and Burnaby Road if a breach were to occur at SOU04.

Shallower depths of between 0m and 1m may be experienced across the south eastern corner if a breach were to occur at any of the three breach locations within this flood cell.



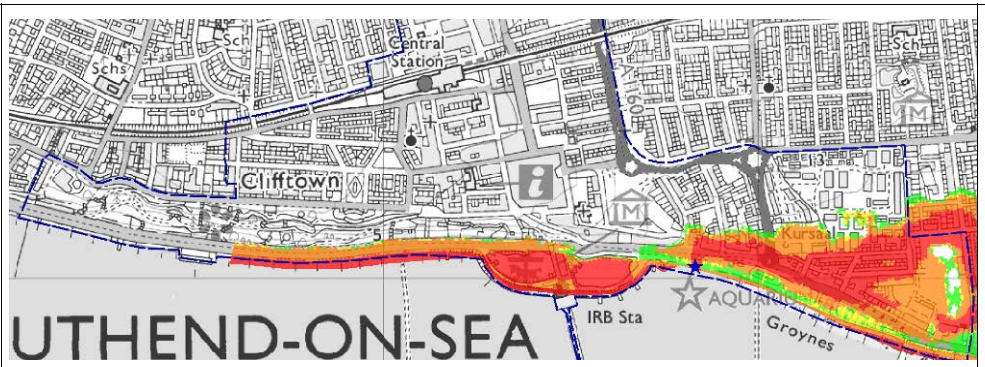
Max Hazard

Breach (Residual Risk)

Breach SOU03

Breach in the 0.5% probability (1 in 200 year) climate change event to 2110.

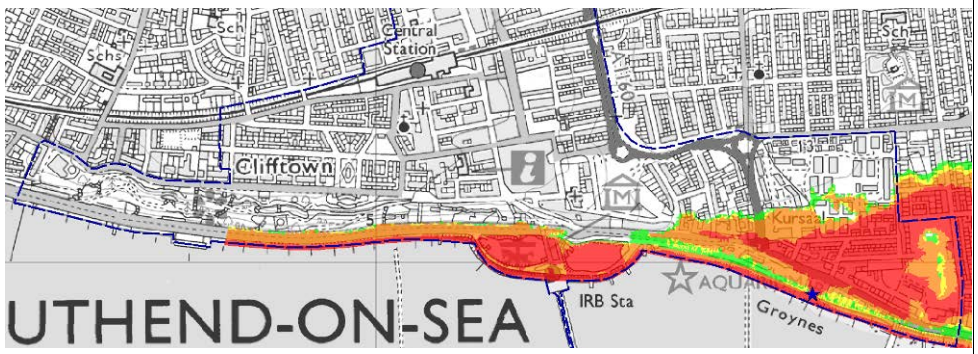
Breach location adjacent to Hartington Road within the Southend Central AAP



Breach SOU04

Breach in the 0.5% probability (1 in 200 year) climate change event to 2110

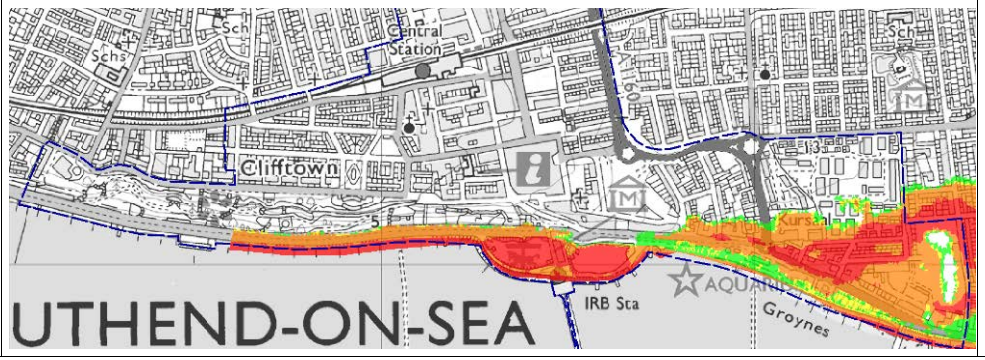
Breach location south of Burdett Road within the Southend Central AAP.



Breach SOU05

Breach in the 0.5% (1 in 200 year) climate change event to 2110

Breach location to the east of the Southend Central AAP boundary south of Camper Road (beyond the eastern extent of this plan).



The flood hazard varies slightly between breach locations SOU03, SOU04 and SOU05.

The greatest hazard in this flood cell is likely if a breach were to occur at SOU04.

Extreme hazard is experienced in Adventure Island, and follows the Eastern Esplanade in the vicinity of Beresford Road and Burnaby Road.

If a breach were to occur at SOU03, the extreme hazard extends further to the west along Marine Parade.

If a breach were to occur at SOU05 the area of extreme hazard is reduced being limited to Adventure Island and a corridor of land between Beresford Road and Northumberland Ave.

Flood Hazard Rating

- Extreme Hazard
- Significant Hazard
- Moderate Hazard
- Low Hazard

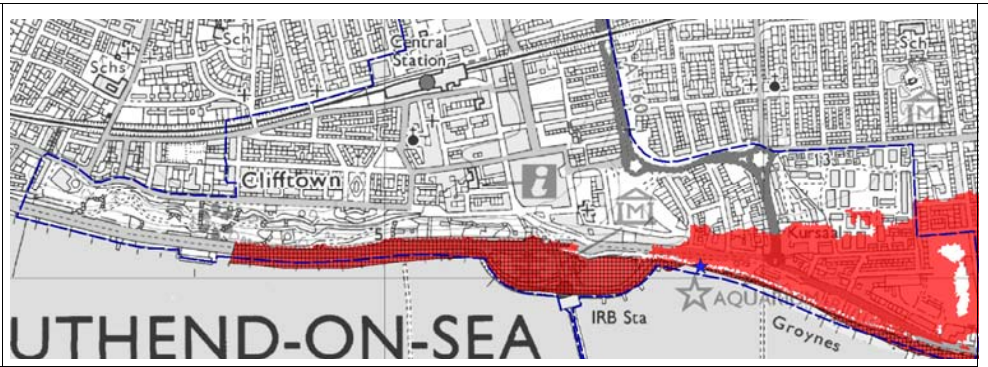
★ **Breach Location**

Time to Inundation

Breach (Residual Risk)

Breach SOU03

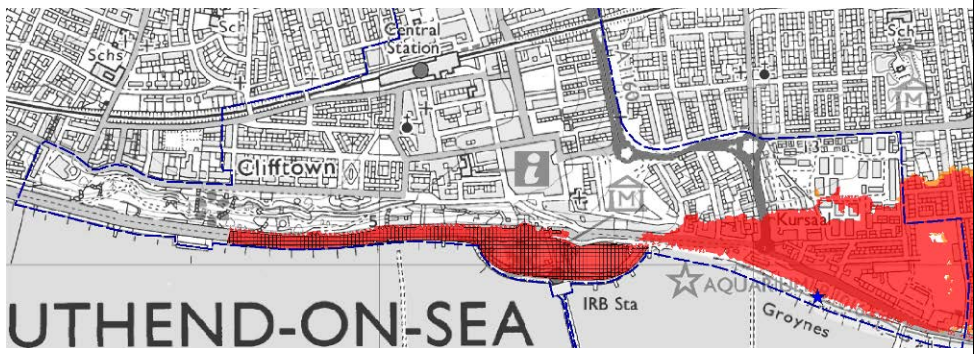
Breach and overtopping in the 0.5% (1 in 200 year) climate change event to 2110. Breach location adjacent to Hartington Road within the Southend Central AAP.



Breach SOU04

Breach and overtopping in the 0.5% (1 in 200 year) climate change event to 2110

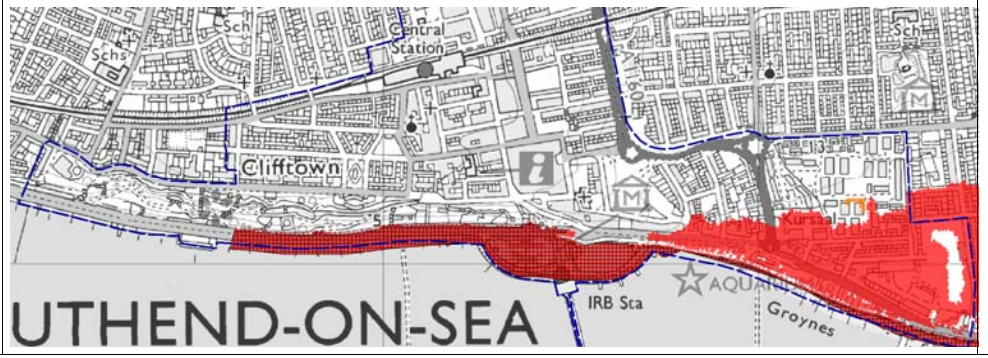
Breach location south of Burdett Road within the Southend Central AAP.



Breach SOU05

Breach and overtopping in the 0.5% (1 in 200 year) climate change event to 2110

Breach location to the east of the Southend Central AAP boundary south of Camper Road (beyond the eastern extent of this plan).



Time to inundation mapping shows that the south eastern corner of the Southend Central AAP will be inundated with flood water. This to be expected in areas close to the sea front/breach location.

Modelling results vary very slightly between breach locations with flooding experienced within 1 hour from a breach at any of the three locations (SOU03, SOU04, SOU05).

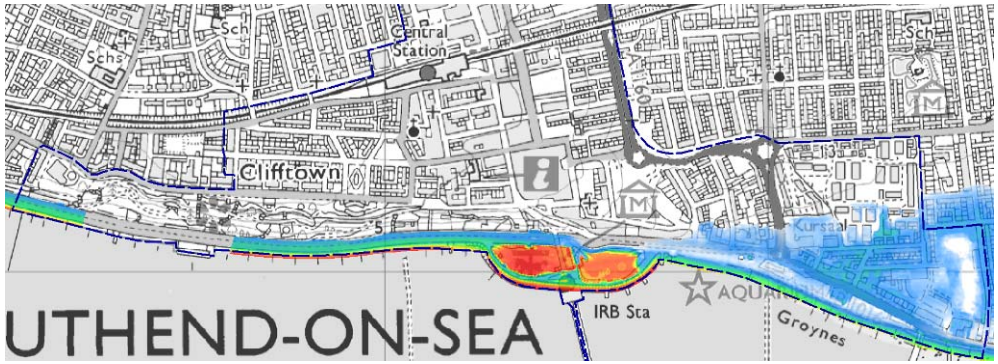
Time to inundation mapping is more useful for steering development in locations further from the point of breach where there is greater variance in time to inundation caused by ground levels, building location etc.

The time to inundation modelling also highlights that overtopping will occur prior to a breach which would impact the Adventure Island area of the Central Area .

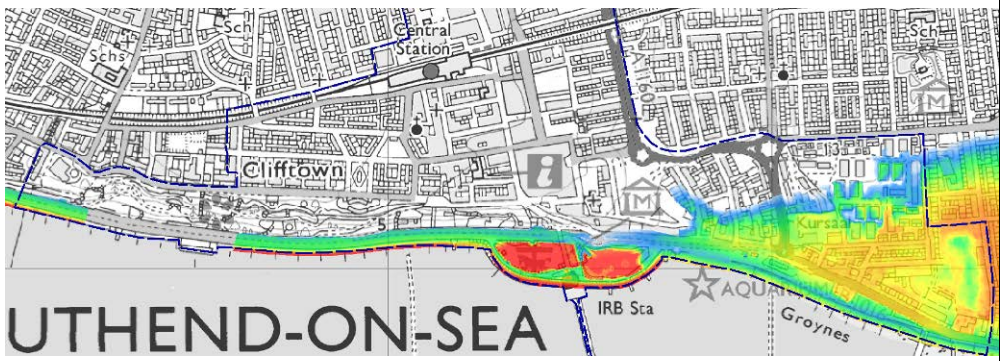
Depth

Overtopping (Residual Risk)

0.5% (1 in 200 year) climate change event



0.1% (1 in 1000 year) climate change event



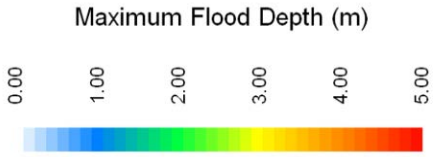
These figures show the impact of overtopping of defences in the event of a severe tidal flood event. Overtopping is technically a residual risk, because the flood defences are in place; however the risk posed is a real risk.

Modelled results show that in the 0.5% probability event, overtopping of flood defences in the vicinity could lead to flooding of the south eastern corner of the Central Area to a depth of approximately 0m to 1m. The Adventure Island part of the Central Area would be most severely affected with a depth of flood water to a maximum of 5m.

Results for the 0.1% probability event show that overtopping of defence in the vicinity of the Central Area would again lead to flooding in the south eastern corner. Flood water under this scenario could range between 0m and 4m.

This is a real risk of flooding; the main solution to mitigate this risk to existing development would be to raise the height of flood defences in the area to prevent overtopping.

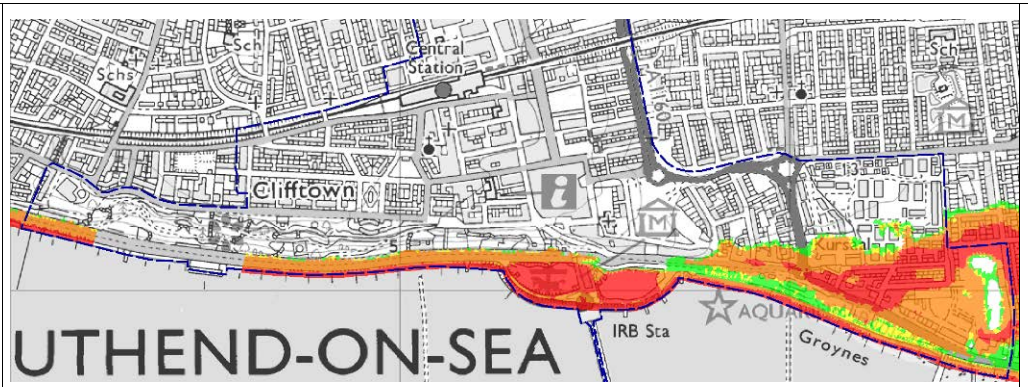
The flood extent roughly follows the historic flood event boundary provided by the Environment Agency – see Figure 2 Level 1 SFRA.



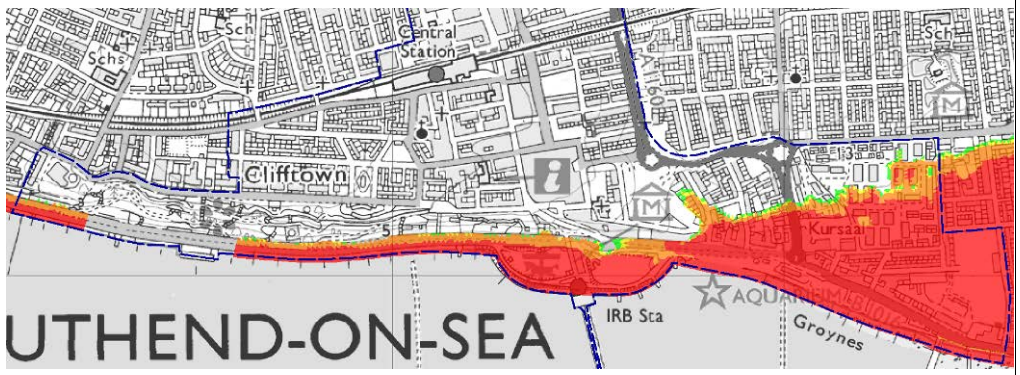
Hazard

Overtopping (Residual Risk)

0.5% (1 in 200 year) climate change event



0.1% (1 in 1000 year) climate change event.



These figures show the impact of overtopping of defences in the event of a severe tidal flood event. Overtopping is technically a residual risk, because the flood defences are in place; however the risk posed is a real risk.

Modelled results show that in the 0.5% probability event, overtopping of flood defences in the vicinity of the Central Area could lead to flooding of the south eastern corner with a hazard ranging from low hazard with pockets of extreme hazard.

Results for the 0.1% probability event show that overtopping of defence in the vicinity of the Central Area would again lead to flooding in the south eastern corner. Flood hazard in this scenario increases to an extreme hazard for the majority of the south eastern corner of the Central Area.

This is a real risk of flooding; the main option to mitigate this risk to existing development would be to raise the height of flood defences in the area to prevent overtopping.

The flood extent roughly follows the historic flood event boundary provided by the Environment Agency – see Figure 2 Level 1 SFRA.

Flood Hazard Rating

- Extreme Hazard
- Significant Hazard
- Moderate Hazard
- Low Hazard

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Groundwater flood risk

4.3.23 The South Essex Catchment Flood Management Plan states that groundwater flooding is not a major issue in this area. The majority of the Southend Central AAP is underlain by river terrace deposits of silt and clay with smaller pockets of river terrace deposits of sand and gravel. The seafront is underlain by London Clay and the Willingale watercourse area is tidal flat deposits. The presence of London clay reduces the risk of groundwater flooding as it creates an impermeable barrier between the ground surface and the underlying aquifer (where present).

4.3.24 There have been no groundwater flooding incidents reported to the Environment Agency within the Southend-on-Sea BC boundary and there is only one record of groundwater flooding reported to the Council between 1998 and 2005. This was related to the flooding of a basement in the south seafront area.

4.3.25 There is little recorded information currently available on groundwater flooding. The proposed Phase 2, 3 and 4 Surface Water Management Plan (anticipated in Spring 2011) will provide a greater level of detail and should be referred to as part of a site-specific FRA.

Flood Risk Assessment Guidance – Southend Central AAP

4.3.26 General guidance to the content of site-specific Flood Risk Assessments (FRAs) as outlined in Section 5 of this report should be adhered to in the Central Area. Specifically FRAs in the north of the Central Area should concentrate on the potential impact of surface water flood risk on the site included in the Level 1 SFRA report. In addition, the potential impact of the site on local surface water drainage should be addressed including outlines of the use of SUDs schemes.

4.3.27 Site-specific FRAs in the south of the Central Area should include reference to breach modelling and fluvial flood zones associated with the Willingale watercourse where necessary. An assessment of the surface water flood risk posed to the site and created by any potential development should also be made including details of SuDS schemes to be implemented.

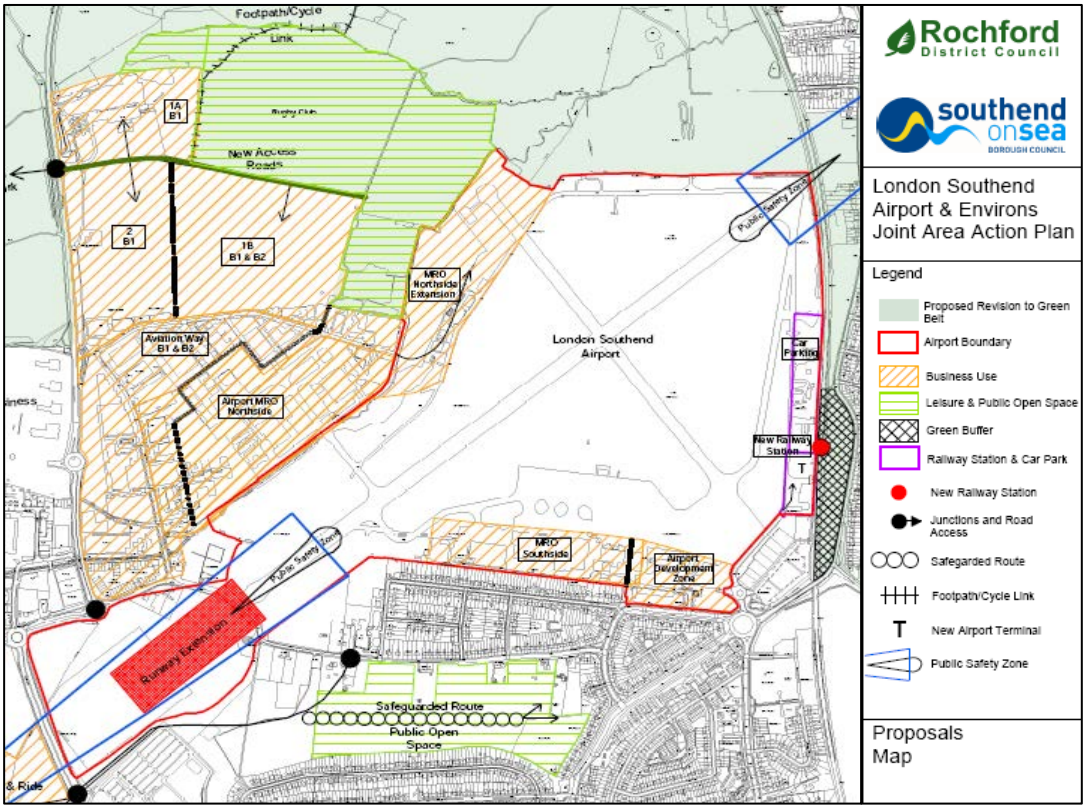
4.3.28 For all FRAs in the Central Area, historic flood records (where available) should be referred to in order to verify the potential surface water flood risk. A site visit should also be used to assess and ground truth the data.

4.3.29 A site-specific FRA should make reference to breach modelling for potential development in the south of the Central Area to inform Part C of the Exception Test.

4.4 London Southend Airport and Environs Joint Area Action Plan

4.4.1 Southend-on-Sea BC and Rochford District Council are in the process of preparing a planning framework to guide development at the proposed London Southend Airport and the neighbouring employment areas. This planning framework is known as the Joint Area Action Plan (JAAP) and is illustrated in Figure 4-6 below. The two Councils have published their 'Preferred Option' for development which has been used as a basis to make a strategic assessment of flood risk which is described below.

Figure 4-6 London Southend Airport JAAP



Fluvial Flood Risk

Environment Agency Flood Zones

4.4.2 The Eastwood Brook is a Main River which flows in a south west to north east direction to the north west of the Southend Airport JAAP area as illustrated in Figure 4-7 below.

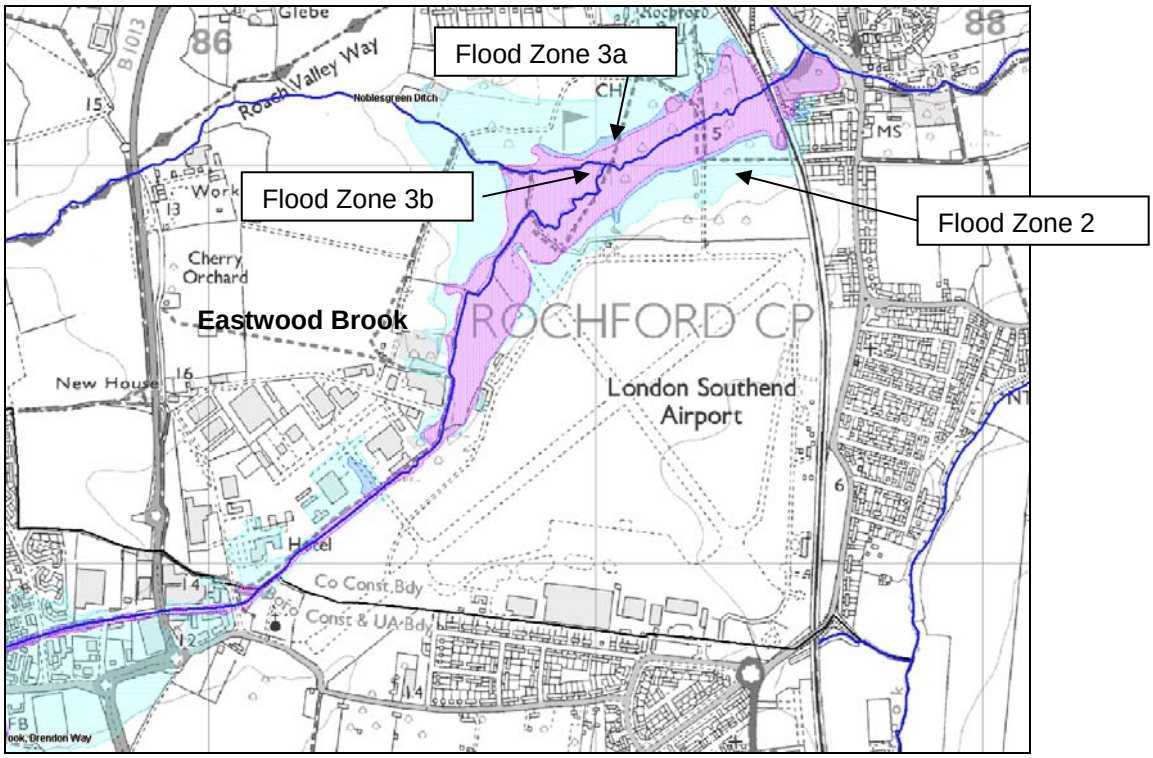
4.4.3 The JAAP outlines development for business uses to the north west of the airport adjacent to the Eastwood Brook (MRO Northside Extension). This area is currently shown to lie within Flood Zone 3b associated with the Eastwood Brook. Flood Zone 3b is defined as the functional floodplain and only water-compatible (mainly water-based) uses and essential infrastructure, as defined by Table D2 of PPS25, are considered appropriate in this location.

4.4.4 Airport MRO Northside is also proposed for business use. A small section of the potential development area adjacent to the Eastwood Brook is located in Flood Zone 3b, with small pockets of Flood Zone 3a and Flood Zone 2. A sequential approach to the development layout would have to be applied in this location to ensure that no development is located in Flood Zone 3b, and less vulnerable uses are located in Flood Zone 3a and Flood Zone 2.

4.4.5 The northern half of Aviation Way B1 and B2 is located within Flood Zone 1. However, the southern half of this plot, adjacent to the Eastwood Brook contains some small pockets of Flood Zone 2, 3a and 3b. A sequential approach to the development layout would have to be applied in order to steer development into the lower areas of flood risk.

4.4.6 A detailed FRA will be required for all development located in Flood Zone 2, 3a or 3b including Aviation Way, Airport MRO Northside and MRO Northside Extension.

Figure 4-7 Environment Agency modelled Flood Outlines – Eastwood Brook.



(*Source: Southend-on-Sea BC Level 1 SFRA March 2010)*

Environment Agency Modelled Fluvial Flood Depths

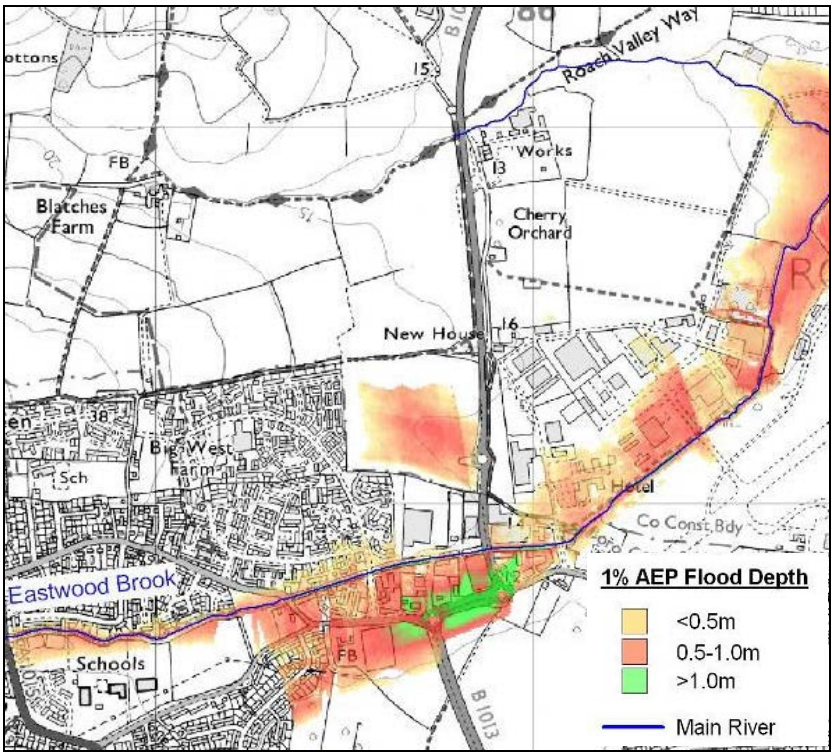
4.4.7 The Environment Agency has recently completed a flood risk study for the Eastwood Brook. The flooding mechanism for this watercourse is described as *'overtopping of river banks leading to low velocity flooding in most areas with flood depths ranging between 0.3m and 0.5m'* (Table 3.17 included in the Catchment Flood Management Plan).

4.4.8 The Environment Agency has assigned this watercourse a 'high priority' natural channel maintenance regime and they provide flood warning with a 2 hour lead time.

4.4.9 With reference to the fluvial flood depth map for Eastwood reproduced in Figure 4-7 below and Figure 4-5 Development Layout, it can be seen that flood depths may reach 1.0m within the proposed 'Airport MRO Northside' development area. Depth modelling is not included in the CFMP for the northern extent of the JAAP but Figure 4-8 suggests that depths may also be greater than 1.0m in the area identified for the 'MRO Northside Extension'.

4.4.10 It should be noted that the airport has previously experienced flooding from the Eastwood Brook including in 1981 when the brook burst its banks leading to flooding of the airport hanger.

Figure 4-8 Fluvial flood extent and depth for Eastwood (1% or 1 in 100 year probability)



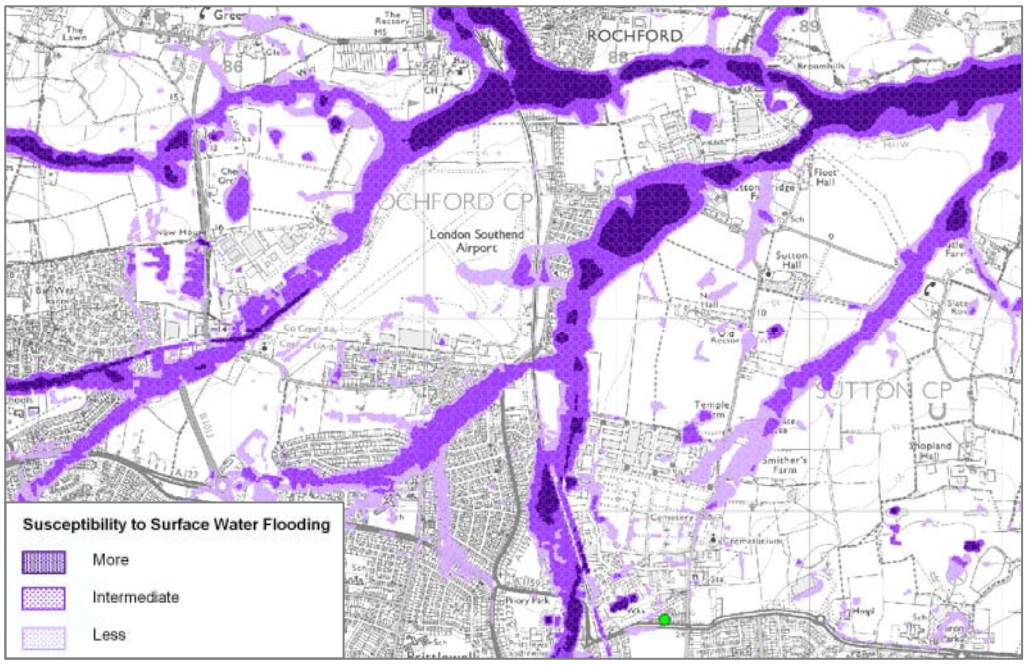
(Source South Essex CFMP – Final Plan August 2008, EA.)

Surface Water Flood Risk

4.4.11 The Environment Agency published maps to illustrate 'Areas Susceptible to Surface Water Flooding' in July 2009. This data has been created to provide an overview to where the potential for flooding from surface water needs particular assessment.

4.4.12 The Environment Agency Areas Susceptible to Flood Risk maps (extract included in Figure 4-9) highlight that surface water flooding may be an issue to the north west of the JAAP including the proposed development at Aviation Way, Airport MRO Northside and MRO Northside Extension. The surface water flood maps use ground levels in the modelling, therefore, areas of potential surface water flooding often follow river corridors. This is the case at the airport JAAP where the Eastwood Brook and Prittle Brook corridor is highlighted as being at surface water flood risk. In addition, there are smaller pockets of potential risk illustrated to the east of the runway, local to the proposed new railway station building.

Figure 4-9 Environment Agency Areas Susceptible to Surface Water Flooding



(Source Southend-on-Sea BC Level 1 SFRA, September 2010)

Tidal Flood Risk

4.4.13 Detailed breach and overtopping modelling has been considered for tidal sources at 9 locations along the Southend seafront. These identify the flood risks associated with a failure in the flood defence, through a breach and by overtopping. Modelling at all 9 locations has highlighted that the London Southend Airport site is not at risk of tidal flooding from the Thames Estuary or North Sea.

Groundwater Flood Risk

4.4.14 The South Essex Catchment Flood Management Plan states that groundwater flooding is not a major issue in this area. The presence of London clay reduces the risk of groundwater flooding as it creates an impermeable barrier between the ground surface and the underlying aquifer (where present).

4.4.15 The Southend Airport JAAP is underlain by river terrace deposits of silt and clay, with sand and gravel river terrace deposits following the Eastwood Brook corridor to the west of the JAAP. There have been no groundwater flooding incidents reported to the Environment Agency or the Council within the Southend Airport JAAP area.

4.4.16 There is little recorded information currently available on groundwater flooding. The proposed Phase 2, 3 and 4 Surface Water Management Plan (anticipated in Spring 2011) may provide a greater level of detail and should be referred to as part of a site-specific FRA.

Flood Risk Assessment Guidance – Southend Airport JAAP

4.4.17 A site-specific FRA should include details of the proposed surface water drainage system including storm water storage. As the Eastwood Brook is adjacent to the proposed development area in the north west, it seems logical that surface water drainage be discharged to this watercourse. It should be noted that there is potential that if a rainfall event co-insides with the Eastwood Brook being in flood, the outfall for the development drainage system may become surcharged. This could cause surface water to back up into the development site causing surface water flooding.

4.4.18 Any discharge to a main river watercourse will require consent from the Environment Agency and will require attenuation to discharge at a flow rate to be confirmed with the Environment Agency (potentially Greenfield runoff rate).

4.4.19 As part of a site-specific FRA, historic flood records where available should be referred to in order to verify the potential surface water flood risk. A site visit should also be used to assess and ground truth the data.

4.5 Flood Risk Summary

4.5.1 Table 4-1 below provides a flood risk summary for both the Southend Central AAP and the Southend Airport JAAP areas.

Table 4-1 Flood Risk Summary Key: ✓ = Increased Risk ✗ = Low Risk

	Fluvial	Tidal	Surface Water	Groundwater	Artificial
Southend Central AAP	✓ Small risk of fluvial flooding in the south eastern corner of the AAP associated with the Willingale watercourse	✓ Southern and south-eastern extent of the AAP at residual risk of tidal flooding	✓ EA mapping highlights areas at greater risk from SW flooding	✗ Low risk of groundwater flooding due to local geology. Investigate further as part of a site-specific FRA	✗ There are no artificial water bodies/canals etc in the vicinity of the Central Area
Southend Airport JAAP	✓ Partly Located within Flood Zone 2,3a and 3b associated with the Eastwood Brook	✗ Not at risk from tidal flooding	✓ EA mapping highlights areas at greater risk from SW flooding	✗ Low risk of groundwater flooding due to local geology. Investigate further as part of a site-specific FRA	✗ There are no artificial water bodies/canals etc in the vicinity of the airport

5 Site-Specific Flood Risk Assessment Guidance

5.1 Overview

5.1.1 The Level 1 and 2 SFRAs for Southend-on-Sea BC provide a comprehensive assessment of the flood risk posed to the study area. The Level 2 report provides more in-depth information about the nature of the potential residual risks and hazards from tidal sources including analysis of the Southend Central AAP and Southend Airport JAAP in relation to flood risk. However, these SFRA documents have a strategic scope and therefore it is essential that site-specific FRAs are also developed for individual development proposals and that where necessary and appropriate, suitable mitigation measures are incorporated. FRAs should use findings from the SFRAs to inform the assessment.

5.1.2 This section presents recommendations and guidance for site-specific FRAs prepared for submission with planning applications in Southend-on-Sea BC.

5.2 When is a Flood Risk Assessment Required?

5.2.1 The Environment Agency provides flood risk standing advice for applicants and agents on their website http://www.environment-agency.gov.uk/research/planning/82587.aspx. This includes information on when a FRA is required and advice on the contents of FRAs for various development types in Flood Zones 1, 2 and 3.

5.2.2 In the following situations a FRA should always be provided with a planning application:

1. The development site is located in Flood Zones 2 or 3;
2. The area of the proposed development site area is 1 hectare or greater in Flood Zone 1. This is to ensure surface water generated by the site is managed in a sustainable manner and does not increase the burden on existing infrastructure and/or flood risk to neighbouring property. Surface water management will also need to be considered as part of the FRA for sites of 1 hectare or greater in Flood Zone 2 and 3; and
3. The development site is located in an area known to have experienced flooding problems from any flood source.

5.3 What does a Flood Risk Assessment require?

5.3.1 The PPS25 Practice Guide (CLG 2009) sets out a staged approach to site-specific FRA with the findings from each stage informing both the next level and the site Masterplan, throughout the development process. The staged approach comprises three stages:

- Level 1 Screening Study
- Level 2 Scoping Study
- Level 3 Detailed Study

Table 5-1 Stages of the Site-Specific FRA, PPS25 Practice Guide, CLG 2009

FRA Level	Description of Report Content
Level 1 **Screening Study**	The Level 1 FRA is intended to identify any flooding or surface water management issues related to the development site that may require further investigation. The study should be based on readily available existing information, including: • SFRA, • Environment Agency Flood Maps, • Standing Advice The Level 1 FRA will determine the need for a Level 2 or 3 FRA.
Level 2 **Scoping Study**	Where the Level 1 FRA indicates that the site may lie in an area at risk of flooding, or may increase flood risk elsewhere due to runoff, a Level 2 FRA should be carried out. This report will confirm sources of flooding which may affect the site and should include the following; • Appraisal of available and adequacy of existing information; • Qualitative appraisal of the flood risk posed to the site, the potential impact of the development on flood risk on and off the site; • An appraisal of the scope of possible measures to reduce the flood risk to acceptable levels. This Level may identify that sufficient quantitative information is already available to complete a FRA appropriate to the scale and nature of the development.
Level 3 **Detailed Study**	Undertaken if the Level 2 FRA concludes that further quantitative analysis is required in order to assess flood risk issues related to the development site. This Level should include: • Quantitative appraisal of the potential flood risk to the development; • Quantitative appraisal of the potential impact of development on the site under investigation on flood risk on and off the site; Quantitative demonstration of the effectiveness of any proposed mitigation measures.

5.3.2 At all stages, Southend-on-Sea BC and where necessary the Environment Agency and Anglian Water should be consulted to ensure the FRA provides the necessary information to fulfil the requirements for Planning Applications.

5.4 Scope of Works

5.4.1 When informing developers of the requirements of a FRA for a development site, consideration should be given to the position of the development relative to flood sources, the vulnerability of the proposed development and its scale.

5.4.2 The Environment Agency provides flood risk standing advice for applicants and agents on their website http://www.environment-agency.gov.uk/research/planning/82587.aspx[2] which includes a matrix to determine the level of assessment that is required based on Flood Zone classification and development type. Within this matrix are links to FRA guidance notes and advice for applicants as to which data they will need to purchase from the Environment Agency in order to carry out their FRA.

Flood Risk Assessment Content

5.4.3 Annex E of PPS25 presents the minimum requirements for a FRA. These include:

- Consider the risk of flooding off-site arising from the development in addition to the risk of flooding on-site to the development;
- Identify and quantify the vulnerability of the development to flooding from different sources and identify potential flood risk reduction measures;
- Assess the remaining 'residual' risk after risk reduction measures have been taken into account and demonstrate that this is acceptable for the particular development;
- Consider the vulnerability of those that could occupy and use the development, taking account of the Sequential and Exception Tests and the vulnerability classification, including arrangements for safe access as prescribed by PPS25 and associated guidance;
- Consider the ability of the soil to receive surface water runoff generated on site, and how it would be stored and managed, along with how the proposed layout of development may affect drainage systems; and
- All calculations must fully account for current climate change scenarios and their effect on flood zoning and risk.

5.5 Risks of Developing in Flood Risk Areas

5.5.1 Developing in flood risk areas can result in significant risk to a development and site users. It is possible to reduce the risk through the incorporation of mitigation measures; however, these do not remove the flood risk altogether and developments situated in the floodplain will always be at risk from flooding. This creates Health and Safety considerations, possible additional costs and potential displacement of future residents during flood events, which could result in homes and businesses being uninhabitable for substantial periods of time.

5.5.2 The guidance in this chapter should identify the requirements of a FRA and the main flood risks posed to the site; additional issues to consider include the following:

- Failure to consider wider plans prepared by the Environment Agency or other operating authorities may result in a proposed scheme being objected to;
- Failure to identify flood risk issues early in a development project could necessitate redesign of the site to mitigate flood risk;

[2] http://www.environment-agency.gov.uk/research/planning/82587.aspx accessed 29.04.10

- Failure to adequately assess all flood risk sources and construct a development that is safe over its lifetime could increase the number of people at risk from flooding and/or increase the risk to existing populations;
- Failure to mitigate the risk arising from development may lead to claims against the developer if an adverse effect can be demonstrated (i.e. flooding didn't occur prior to development) by neighbouring properties/residents;
- Properties may be un-insurable and therefore un-mortgageable if flood risk management is not adequately provided for the lifetime of the development;
- By installing SuDS without arranging for their adoption or maintenance, there is a risk that they will eventually cease to operate as designed and could therefore present a flood risk to the development and/or neighbouring property;
- The restoration of river corridors and natural floodplains can significantly enhance the quality of the built environment whilst reducing flood risk. Such an approach can significantly reduce the developable area of sites or lead to fragmented developments, however positive planning and integration throughout the master planning process should resolve these potential issues.

5.6 Development Control Recommendations

Development Behind Existing Defences

5.6.1 Paragraph G2 of PPS25 states that *"Following application of the Sequential Test and Exception Test (see Annex D),* ***development should not normally be permitted where flood defences, properly maintained and in combination with agreed warning and evacuation arrangements, would not provide an acceptable standard of safety taking into account climate change****. Low-lying tidal and coastal areas are particularly vulnerable, due to the residual risk of defences being overtopped or breached, resulting in fast flowing and deep water flooding. Planning authorities should take these hazards fully into account when drafting Local Development Documents (LDDs) and considering planning applications, recognising that the Environment Agency is not obliged to maintain defences. Risks will be greatest close to such defences, and local planning authorities should seek opportunities to set back developments. Planning authorities should take into account the need for access to maintain defences when considering planning applications in areas close to them".*

5.6.2 For developments proposed in areas at risk of flooding, either as a result of a breach in flood defences or overtopping, the following items should be addressed as part of a FRA in order to demonstrate that proposed developments are 'safe' in line with PPS25.

5.6.3 It should be noted that the specific definition of a 'safe' development will vary for each individual site, based on location and development vulnerability. It is therefore recommended that developers consult the Environment Agency on a site by site basis to establish an appropriate definition of 'safe' development for specific sites.

5.6.4 In addition, it is important that the use of techniques such as these do not exacerbate flooding elsewhere within the flood cell.

Access and Egress

5.6.5 PPS25 requires that safe access and egress is provided to enable the evacuation of people from the development, at or above the 1 in 100 year (1%) fluvial and the 1 in 200 year (0.5%) tidal flood event, and also up to the 1 in 1000 year (0.1%) flood event. This also provides emergency services with access during a flood event and would enable flood defence authorities to carry out essential duties during periods of flood.

5.6.6 Wherever possible, access routes should be provided/located above the design flood levels (see above). Where this is not possible limited depths of flooding may be appropriate, provided that the proposed access is designed with appropriate signage and other measures to make it safe. The acceptability of the proposed access should be assessed using Table 13.1 of Defra Research document FD2320/TR2: FRA Guidance for New Developments which takes into account the flood depth, velocities and risk of debris within the water. The access/egress route must fall within the "white cells" of this document. Where this is not achievable, early consultation with the emergency planner should be sought.

5.6.7 This assessment should also consider the following:

- The vulnerability and mobility of those in danger of flooding; development for highly vulnerable users e.g. disabled or the elderly, should be located away from high-risk areas. Whilst the Sequential Test accounts for the vulnerability of the intended use of the development, no specific consideration is made for the vulnerability of the end users of the site. A proposed residential development for highly vulnerable end users (elderly, physically impaired etc) will still fall under the 'More Vulnerable' classification in Table D.2 of PPS25 and the Sequential and Exception Tests will apply accordingly. Where development for highly vulnerable end users cannot be avoided, safe and easy evacuation routes are essential.
- The time to peak inundation mapping relates to the amount of time it takes for a flood event to reach its maximum level, flow or height. Flood events with a very short time to peak provide very little time and opportunity for evacuation. This is typically the case if a defence structure is breached or fails because the inundation will be rapid, resulting in a short time to peak for the areas local to the breach. On the other hand, during tidal events, should a breach occur early in the tidal cycle, the time to peak could be a lot slower which would allow evacuation procedures to be put in place. Typically, areas immediately adjacent to a breach location will have a shorter time to peak than areas set back from the flood defence.

5.6.8 Due to the low lying topography and location of Southend-on-Sea BC adjacent to the River Thames, it may not be possible for all developments to be proposed in areas where both safe access and egress can be guaranteed during a flood. This is likely to be the case in parts of the Southend Central AAP at the seafront. In this situation, the potential implications for development should be considered by assessing the following:

- Probability of flooding;
- Expected flood hazard;
- Likelihood of occupancy during flooding, based on the proposed use;

- Acceptability of disruption based on the proposed use;
- Availability of safe refuge;
- Potential for the provision of key services (e.g. water, electricity, telecommunications); and,
- Expected duration of inundation.

5.6.9 The findings within this Level 2 SFRA should, where appropriate, be used to assess proposed access routes with respect to the criteria listed above.

Finished Floor Levels

5.6.10 Where development in flood risk areas is unavoidable, which in Southend-on-Sea BC includes parts of the seafront, the most common method of mitigating flood risk to people is to ensure habitable floor levels are raised above the maximum flood water level with an allowance of 300mm freeboard. This can substantially reduce the damage to property and risk of injury and fatalities.

5.6.11 In areas of minimal floodwater depth, raising finished floor levels may be included into the building design. Where the floodwater depth is more substantial, ground floor uses can be restricted to less vulnerable uses, such as commercial use, garage, utility areas and public space, with habitable areas above.

5.6.12 It should be noted that the Environment Agency are constantly reviewing their guidance based upon experience, increasing knowledge and the findings of new research. The above criteria are therefore subject to change in the future.

Sequential Approach

5.6.13 Paragraph D8 of PPS25 (CLG 2006) identifies the need for developers to apply the sequential approach when locating development within a site. This process should ensure that elements of the redevelopment that are of greater vulnerability are located in parts of the site at lowest risk.

Flood Warning and Emergency Plans

5.6.14 Whilst measures can be put in place to lessen the risk of flooding, it is impossible to eliminate risk completely. Warning people about the impending flooding is therefore one of the most important means of flood management, enabling people to prepare for flooding through taking steps to minimise damage to property and prevent loss of life.

5.6.15 The Environment Agency operates a flood warning service in areas at risk of flooding using easily recognisable codes, indicating the level of danger and response associated with the warning.

Flood Alert – Flooding is possible. Be prepared.

Flood Warning – Flooding is expected. Immediate action required.

5.6.16 In Southend-on-Sea BC, the flood warnings are disseminated through Flood Warnings Direct. Residents and businesses can sign up to FWD either online, or by calling Floodline on 0845 988 1188.

5.6.17 Southend-on-Sea BC is currently preparing a detailed Emergency Flood Plan specific to the risks and needs of their administrative area. The Plan will use the information generated by this SFRA to identify suitable evacuation routes and rest centres within the borough.

5.6.18 Evacuation Plans for individual developments should be prepared in conjunction with the Borough-wide Flood Plan to direct people to safety during times of flood. This may include details of an evacuation route away from the site to an area outside the floodplain, or to a place of safe refuge within the development itself.

5.6.19 When submitting FRAs for developments within flood risk areas, developers should make reference to this strategic Emergency Flood Plan to demonstrate that their development will not impact on the ability of Southend-on-Sea BC and the emergency services to safeguard the current population.

Flow Paths and Floodplain Compensation

5.6.20 Where development plans result in a reduction of the ***fluvial*** floodplain (encroachment into tidal floodplains do not require compensation storage), it is essential that new floodplain storage capacity is provided to compensate. The Environment Agency requires this to be provided on a 'Level for Level, Volume for Volume Basis'. This may need to be considered where land is raised to provide safe access and egress routes and may be applicable to areas within the Southend Airport JAAP.

5.6.21 Any raising of the land as part of the development, for example, to achieve safe access, will need to be carefully considered as part of the FRA to ensure that no obstruction is made to flood flow routes.

5.6.22 Potential overland flow paths should be determined and appropriate solutions proposed to mitigate the impact of the development, for example through the configuration of road and building layouts to preserve existing flow paths and improve flood routing whilst ensuring that flows are not diverted towards other properties.

Flood Resilient Construction

5.6.23 The Association of British Insurers in cooperation with the National Flood Forum has published guidance on how homeowners can improve the food resilience of their properties (ABI, 2004). These measures not only reduce flood risk to properties, by reducing residual risk, but can also improve the insurability of homes in flood risk areas. The guidance identifies the key flood resistant measures for different construction methods, further details can be found in the CLG's 2008 report, Improving the Flood Resilience of New Buildings and the ODPM's report 'Preparing for Floods' (ODPM, 2003b).

Future Flood Defences

5.6.24 Figure 15 and 16 included in the Level 1 SFRA should be used to focus future defence improvements along the Southend-on-Sea BC frontage in order to improve the level of protection to areas at risk of flooding through overtopping.

Recreation, Amenity and Ecology

5.6.25 Recreation, amenity and ecological improvements can be used to mitigate the residual risk of flooding either by substituting less vulnerable land uses or by attenuating flows or both. Examples include the development of parks and open spaces through to river restoration schemes. The aim of these techniques is to increase flood storage and the storage and conveyance of rainwater. Typical schemes include arrangements of pools, ponds and ditches.

Secondary Defences

5.6.26 Secondary defences are those that exist on the dry side of primary defences. Typically, their main function is to reduce the risk of residual flooding following a failure or overtopping of the primary defences.

5.6.27 Secondary defences can relocate floodwaters away from certain areas or reduce the rate of flood inundation following a residual event. Examples of secondary defences include embankments or raised areas behind flood defence walls, raised infrastructure e.g. railways or roads and, on a strategic level, canals, river and drainage networks. The latter are a form of secondary defence as they are able to convey or re-direct water away from flood prone areas even if this is not their primary function.

Land Raising

5.6.28 Land raising can have mixed results when used as a secondary flood alleviation measure. It can be an effective method of reducing flood inundation on certain areas or developments by raising the finished ground levels above the predicted flood level. However, it can result in the reduction in flood storage volume within the flood cell. As a result, floodwater levels within the remainder of the cell can be increased and flooding can be exacerbated elsewhere. Level for level compensatory storage should be provided where any loss of fluvial floodplain storage has occurred as a result of land raising or developing within the undefended floodplain.

5.6.29 Partial land raising can be considered in larger, particularly low lying areas such as marshlands. It may be possible to build up the land in areas adjacent to flood defences in order to provide secondary defences. However, again the developer should pay due regard to the cumulative effects of flooding such as increasing flood risk elsewhere.

5.6.30 It should also be remembered that although land raising may allow for development above the flood level, it may also create a 'dry island' which may still not overcome the issue of a safe access/egress route from the site. This must be considered where land raising is suggested as mitigation for developing in an area liable to flooding.

Sustainable Drainage Systems (SuDS)

5.6.31 Developers are required to reduce surface water runoff rates following development through the implementation of appropriate Sustainable Drainage Systems inline with the Management Train Hierarchy set out in the Level 1 SFRA (Scott Wilson September 2010). Developers should aim to achieve Greenfield runoff rates from their sites wherever possible. Reference should be made to the Southend-on-Sea Water Cycle Study and Phase 2, 3 and 4 Surface Water Management Plan (anticipated in Spring 2011) for further advice.

6 SFRA Maintenance and Updates

6.1 How to maintain and update the SFRA

6.1.1 For an SFRA to serve as a practical planning tool now and in the future, it will be necessary to undertake a periodic update and maintenance exercise. This section clarifies what specific actions are recommended to ensure correct maintenance and updating of the SFRA.

GIS Layers

6.1.2 GIS layers used in this SFRA have been created from a number of different sources, using the best and most suitable information available at the time of publishing. Should new Flood Zone information become available, the data should be digitised and geo-referenced within a GIS system. A copy of the current dataset should be created and backed up and the new data should then be merged or combined with the current data set.

6.1.3 For example, should updated modelled outlines delineating Flood Zone 3b on the Eastwood Brook become available, the current FZ3b outline should be edited to ensure that the newest data is displayed and that the old data is overwritten. Note that updating the Eastwood Brook Flood Zone 3b outline will not involve replacing the entire combined FZ3b GIS layer, only the section that has changed.

6.1.4 For other GIS layers such as the Historical Flood Outlines or the Sewer Flooding Information, it is likely that data will be added rather than be replaced. For example, where a new sewer flooding incident is reported in the catchment, a point should be added to the sewer flooding GIS layer rather than creating a new layer.

6.1.5 All GIS layers used in the SFRA have meta-data attached to them. When updating the GIS information, it is important that the meta-data is updated in the process. Meta-data is additional information that lies behind the GIS polygons, lines and points. For example, the information behind the SFRA Flood Zone Maps describes where the information came from, what the intended use was together with a level of confidence.

OS Background Mapping

6.1.6 The SFRA has made use of the OS 1:25000 and 1:50000 digital raster maps. Periodically these maps are updated. Under the HDC OS License, it is likely that these maps will be updated throughout the whole of the HDC GIS system. Updated maps are unlikely to alter the findings of the SFRA.

Data Licensing Issues

6.1.7 Prior to any data being updated within the SFRA, it is important that the licensing information is also updated to ensure that the data used is not in breach of copyright. The principal licensing bodies relevant to the SFRA at the time of publishing were the Environment Agency (Thames Region), Ordnance Survey and Anglian Water. Updated or new data may be based on datasets from other licensing authorities and may require additional licenses.

Flooding Policy and PPS25 Practise Guidance Updates

6.1.8 This SFRA was updated inline with policy and guidance that was current in October 2010, principally PPS25 (DCLG December 2009) and the accompanying Practice Guide (March 2010). Furthermore, guidance and recommendations issued in the Pitt Review (Pitt 2008) and the subsequent Flood and Water Management Act (2010) have been incorporated into this updated revision.

6.1.9 Should new flooding policy be adopted nationally, regionally or locally, the SFRA should be checked to ensure it is still relevant and updates made if necessary.

Stakeholder Consultation and Notification

6.1.10 The key stakeholders consulted in the SFRA were the Borough Council, Water Companies and the Environment Agency. It is recommended that a periodic consultation exercise is carried out with the key stakeholders to check for updates to their datasets and any relevant additional or updated information they may hold. If the SFRA is updated, it is recommended that the Environment Agency and the Emergency Planning Department are notified of the changes and instructed to refer to the new version of the SFRA for future reference.

Frequency of Updates and Maintenance

6.1.11 It is recommended that the SFRA is maintained on an annual basis. Should any changes be necessary, the SFRA should be updated and re-issued.

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Appendix A: Modelling Methodology

Appendix B: Index of Additional Maps

The following suite of maps has been provided to Southend-on-Sea Borough Council. The figures are labelled according to the information being displayed, for example *SOU01_0200yr2010_DEPTH* relates to breach SOU01, the 1 in 200yr return period for the present day, and is a maximum depth map.

Depth Mapping

SOU01_0200yr2010_DEPTH
SOU01_0200yr2110_DEPTH
SOU01_1000yr2010_DEPTH
SOU01_1000yr2110_DEPTH
SOU01_overtopping_0200yr2110_DEPTH
SOU01_overtopping_1000yr2110_DEPTH
SOU02_0200yr2010_DEPTH
SOU02_0200yr2110_DEPTH
SOU02_1000yr2010_DEPTH
SOU02_1000yr2110_DEPTH
SOU02_overtopping_0200yr2110_DEPTH
SOU02_overtopping_1000yr2110_DEPTH
SOU03_0200yr2010_DEPTH
SOU03_0200yr2110_DEPTH
SOU03_1000yr2010_DEPTH
SOU03_1000yr2110_DEPTH
SOU03-SOU05_overtopping_0200yr2110_DEPTH
SOU03-SOU05_overtopping_1000yr2110_DEPTH
SOU04_0200yr2010_DEPTH
SOU04_0200yr2110_DEPTH
SOU04_1000yr2010_DEPTH
SOU04_1000yr2110_DEPTH
SOU05_0200yr2010_DEPTH
SOU05_0200yr2110_DEPTH
SOU05_1000yr2010_DEPTH
SOU05_1000yr2110_DEPTH
SOU06_0200yr2010_DEPTH
SOU06_0200yr2110_DEPTH
SOU06_1000yr2010_DEPTH
SOU06_1000yr2110_DEPTH
SOU06_overtopping_0200yr2110_DEPTH
SOU06_overtopping_1000yr2110_DEPTH
SOU07_0200yr2010_DEPTH
SOU07_0200yr2110_DEPTH
SOU07_1000yr2010_DEPTH
SOU07_1000yr2110_DEPTH
SOU07_SOU09_overtopping_0200yr2110_DEPTH
SOU07_SOU09_overtopping_1000yr2110_DEPTH
SOU08_0200yr2010_DEPTH
SOU08_0200yr2110_DEPTH
SOU08_1000yr2010_DEPTH
SOU08_1000yr2110_DEPTH
SOU09_ROC_0200yr2010_DEPTH
SOU09_ROC_0200yr2110_DEPTH
SOU09_ROC_1000yr2010_DEPTH
SOU09_ROC_1000yr2110_DEPTH

Hazard Mapping

SOU01_0200yr2010_HAZARD
SOU01_0200yr2110_ HAZARD
SOU01_1000yr2010_ HAZARD
SOU01_1000yr2110_ HAZARD
SOU01_overtopping_0200yr2110_ HAZARD
SOU01_overtopping_1000yr2110_ HAZARD
SOU06_0200yr2010_ HAZARD
SOU06_0200yr2110_ HAZARD
SOU06_1000yr2010_ HAZARD
SOU06_1000yr2110_ HAZARD
SOU06_overtopping_0200yr2110_ HAZARD
SOU06_overtopping_1000yr2110_ HAZARD

SOU02_0200yr2010_ HAZARD
SOU02_0200yr2110_ HAZARD
SOU02_1000yr2010_ HAZARD
SOU02_1000yr2110_ HAZARD
SOU02_overtopping_0200yr2110_ HAZARD
SOU02_overtopping_1000yr2110_ HAZARD
SOU03_0200yr2010_ HAZARD
SOU03_0200yr2110_ HAZARD
SOU03_1000yr2010_ HAZARD
SOU03_1000yr2110_ HAZARD
SOU03-SOU05_overtopping_0200yr2110_ HAZARD
SOU03-SOU05_overtopping_1000yr2110_ HAZARD
SOU04_0200yr2010_ HAZARD
SOU04_0200yr2110_ HAZARD
SOU04_1000yr2010_ HAZARD
SOU04_1000yr2110_ HAZARD
SOU05_0200yr2010_ HAZARD
SOU05_0200yr2110_ HAZARD
SOU05_1000yr2010_ HAZARD
SOU05_1000yr2110_ HAZARD
SOU07_0200yr2010_ HAZARD
SOU07_0200yr2110_ HAZARD
SOU07_1000yr2010_ HAZARD
SOU07_1000yr2110_ HAZARD
SOU07_SOU09_overtopping_0200yr2110_ HAZARD
SOU07_SOU09_overtopping_1000yr2110_ HAZARD
SOU08_0200yr2010_ HAZARD
SOU08_0200yr2110_ HAZARD
SOU08_1000yr2010_ HAZARD
SOU08_1000yr2110_ HAZARD
SOU09_0200yr2010_ HAZARD
SOU09_0200yr2110_ HAZARD
SOU09_1000yr2010_ HAZARD
SOU09_1000yr2110_ HAZARD

Time to Inundation Mapping

SOU01_0200yr2010_TTI
SOU01_0200yr2110_TTI
SOU01_1000yr2010_TTI
SOU01_1000yr2110_TTI
SOU02_0200yr2010_TTI
SOU02_0200yr2110_TTI
SOU02_1000yr2010_TTI
SOU02_1000yr2110_TTI
SOU03_0200yr2010_TTI
SOU03_0200yr2110_TTI
SOU03_1000yr2010_TTI
SOU03_1000yr2110_TTI
SOU04_0200yr2010_TTI
SOU04_0200yr2110_TTI
SOU04_1000yr2010_TTI
SOU04_1000yr2110_TTI
SOU05_0200yr2010_TTI
SOU05_0200yr2110_TTI
SOU05_1000yr2010_TTI
SOU05_1000yr2110_TTI
SOU06_0200yr2010_TTI
SOU06_0200yr2110_TTI
SOU06_1000yr2010_TTI
SOU06_1000yr2110_TTI
SOU07_0200yr2010_TTI
SOU07_0200yr2110_TTI
SOU07_1000yr2010_TTI
SOU07_1000yr2110_TTI
SOU08_0200yr2010_TTI
SOU08_0200yr2110_TTI
SOU08_1000yr2010_TTI
SOU08_1000yr2110_TTI
SOU09_0200yr2010_TTI
SOU09_0200yr2110_TTI
SOU09_1000yr2010_TTI
SOU09_1000yr2110_TTI

Appendix C: Modelling Results – Composite Maps

The following maps are composite maps and therefore present the combined results from all modelled breach locations in the study area for a particular modelled scenario. Where modelled results overlap, the greatest maximum flood depth or hazard rating has been mapped.

Depth Mapping

Figure C1 Composite Maximum Flood Depth 200yr 2010 Breach and Overtopping
Figure C2 Composite Maximum Flood Depth 200yr 2110 Breach and Overtopping
Figure C3 Composite Maximum Flood Depth 200yr 2110 Overtopping

Figure C4 Composite Maximum Flood Depth 1000yr 2010 Breach and Overtopping
Figure C5 Composite Maximum Flood Depth 1000yr 2110 Breach and Overtopping
Figure C6 Composite Maximum Flood Depth 1000yr 2110 Overtopping

Hazard Mapping

Figure C7 Composite Maximum Flood Hazard 200yr 2010 Breach and Overtopping
Figure C8 Composite Maximum Flood Hazard 200yr 2110 Breach and Overtopping
Figure C9 Composite Maximum Flood Hazard 200yr 2110 Overtopping

Figure C10 Composite Maximum Flood Hazard 1000yr 2010 Breach and Overtopping
Figure C11 Composite Maximum Flood Hazard 1000yr 2110 Breach and Overtopping
Figure C12 Composite Maximum Flood Hazard 1000yr 2110 Overtopping

Time to Inundation Mapping

Figure C13 Composite Time to Inundation 200yr 2010 Breach
Figure C14 Composite Time to Inundation 200yr 2110 Breach

Figure C15 Composite Time to Inundation 1000yr 2010 Breach
Figure C16 Composite Time to Inundation 1000yr 2110 Breach