Tendring District Council

Harwich Strategic Flood Risk Assessment

Final Level 1 Report
April 2008





Prepared for

Tendring District Council

Revision Schedule

Strategic Flood Risk Assessment Level 1
April 2008

Rev	Date	Details	Prepared by	Reviewed by	Approved by
0	Feb 08	Draft	**Tom Edwards** Flood Risk Consultant	**Jon Robinson** Associate Director	**Jon Robinson** Associate Director
1	Apr 08	Final	**Tom Edwards** Flood Risk Consultant	**Jon Robinson** Associate Director	**Jon Robinson** Associate Director

Scott Wilson
6 – 8 Greencoat Place
London
SW1P 1PL

Tel +44(0)20 7798 5000
Fax +44(0)20 7798 5001

www.scottwilson.com

Abbreviations

Acronym	Definition
AONB	Area of Outstanding Natural Beauty
CFMP	Catchment Flood Management Plan
CLG	Communities and Local Government
DEM	Digital Elevation Model
DPD	Development Plan Documents
DTLR	UK Department of Transport, Local Government and Regions
EA	Environment Agency for England and Wales
FRA	Flood Risk Assessment
FRIS	Flood Reconnaissance Information System
GIS	Geographical Information Systems
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
LPD	Local Planning Documents
ODPM	Office of the Deputy Prime Minister
PCPA 2004	Planning and Compulsory Purchase Act 2004
PPG25	Planning Policy Guidance Note 25: Development and Flood Risk
PPS25	Planning Policy Statement 25: Development and Flood Risk
RFRA	Regional Flood Risk Appraisal
RPG	Regional Planning Guidance
RSS	Regional Spatial Strategy
SAR	Synthetic Aperture Radar
SAC	Special Area of Conservation
SA	Sustainability Appraisal
SFRA	Strategic Flood Risk Assessment
SPA	Special Protection Area
SPG	Supplementary Planning Guidance
SSSI	Site of Special Scientific Interest
SuDS	Sustainable Drainage Systems
TDC	Tendring District Council

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).
Flood plain	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	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.
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.

Table of Contents

1 Non-Technical Summary

1.1 Introduction

The study area covers the town of Harwich and the surrounding area within the administrative area of Tendring District Council in the county of Essex.

The study area is characterised by a central band of higher ground which has been heavily developed, with surrounded by lower lying marshland to the south and the Ramsey River floodplain to the north. The Harwich peninsula protrudes into the North Sea and contains significant urban development upon relatively low lying land.

The main sources of flooding are the River Stour Estuary and North Sea which provide the dominant source of flooding in the area. Flood defences have been constructed to protect the area from tidal flooding, however these will be overtopped by storm surges if sea levels rise as currently predicted. Additional flood risk management measures are therefore likely to be required in the future.

The Ramsey River discharges into the River Stour Estuary via a pumping station. The significant volume of storage provided by the relatively rural, undeveloped floodplain reduces the impacts of pumping station failure. Contingency measures are also in place to minimise the likelihood of such a scenario occurring, which include a stand-by pump and independent back-up generator.

The study area was previously flooded during the North Sea storm surge in January/February 1953, which affected much of the east coast of England. The Ramsey River also caused flooding during 1958 although precise details are unknown. In addition to these tidal and fluvial sources, this study considers the risks associated with groundwater, surface water and artificial flood sources. The risk of sewer flooding is being assessed by the ongoing Haven Gateway Water Cycle Study, and has therefore not been considered within this study.

1.2 SFRA Background

Scott Wilson Ltd was commissioned by Tendring DC to undertake a Strategic Flood Risk Assessment (SFRA) of Harwich. This project has been carried out in collaboration with the Environment Agency's Anglian Region.

1.3 SFRA Report Layout

In accordance with the Practice Guide Companion to PPS25 recommendations, the SFRA has been structured in a two level approach. This report forms a Level 1 SFRA, providing an overview of the flood risk issues in Harwich to enable application of the Sequential Test.

Hydrodynamic modelling has been completed along the North Sea and River Stour Estuary frontage to assess the tidal flood risks as a result of a failure and overtopping of the tidal defences. The modelling results provide a greater level of information, and enable the residual risk (i.e. in the event of a defence failure and/or overtopping) to be categorised into high, medium and low hazard.

Surface water, groundwater and artificial flood sources have been investigated in order to assess the risk of flooding originating from these sources. The Environment Agency and Tendring DC has supplied various pieces of information for the Level 1 SFRA.

1.4 SFRA Planning Objectives

The primary objective of the study was to enable Tendring DC to undertake the Sequential Test inline with Government's flood risk and development policy document - Planning Policy Statement (PPS) 25: Development and Flood Risk - to inform the development of their emerging Local Development Framework (LDF) documents.

PPS25 requires Tendring DC to review flood risk across their district, steering all development towards areas of lowest risk. Development is only permissible in areas at risk of flooding in exceptional circumstances where it can be demonstrated that there are no reasonably available sites in areas of lower risk, and the benefits of that development outweigh the risks from flooding. Such development is required to include mitigation/management measures to minimise risk to life and property should flooding occur.

The Strategic Flood Risk Assessment is the first step in this process, assisting in the development of the LDF's by identifying flood risk areas and outlining the principles for sustainable development policies, informing strategic land allocations and integrating flood risk management into the spatial planning of the area. The SFRA thereby forms an essential reference tool providing the building blocks for future strategic planning.

The Sequential Test

The process of the Sequential Test outlined in PPS25 aims to steer vulnerable development to areas of lowest flood risk. The SFRA aims to facilitate this process by identifying the variation in flood risk across Harwich allowing an area-wide comparison of future development sites with respect to flood risk considerations.

Harwich has been delineated into the Flood Zones outlined in PPS25 as Flood Zone 1, low probability, Flood Zone 2, medium probability and Flood Zone 3a, high probability. In addition, Flood Zone 3b, functional floodplain, has also been mapped. Table D.1 of PPS25 provides information on which developments might be considered to be appropriate in each Flood Zone, subject to the application of the Sequential Test and the Exception Test with a site-specific Flood Risk Assessment demonstrating safety.

In accordance with PPS25 Tendring DC will use this SFRA to complete their Sequential Test process for their spatial strategies. This identifies the flood risks and development vulnerability in order to assess the suitability of each development location, and where possible steers more vulnerable developments to areas of lower flood risk.

The Exception Test

Where it can be demonstrated that the Sequential Test is passed, it will also be necessary in some circumstances for Tendring DC to demonstrate that all three elements of the Exception Test are satisfied.

1.5 Way Forward

The risk of flooding posed to properties within the study area arises from a number of different sources including tidal flooding, river flooding, groundwater and surface water flooding. There is also a risk of flooding from sewers however this has not been assessed as part of this study.

A spatial planning solution to flood risk management should be sought wherever possible. It is necessary for Tendring DC to consider, through the PPS25 Sequential Test, how to steer vulnerable development away from areas affected by flooding. This should also take into consideration other relevant strategies and studies in the area seeking to reduce flooding to those already at risk within their areas.

Where other planning considerations must guide the allocation of sites and the Sequential Test has been satisfied, further studies can be carried out to assist Tendring DC and developers to meet the Exception Test. These will be detailed in a Level 2 SFRA following completion of the Sequential Test by Tendring DC.

Engagement with the Emergency Planning Team and emergency services is imperative to minimise the risk to life posed by flooding within Harwich. It is recommended that the currently adopted flood risk response plan is reviewed in light of the findings and recommendations of the SFRA.

1.6 A living Document

The SFRA has been completed in accordance with PPS25 and the current guidance outlined in the draft Development and Flood Risk: A Practice Guide Companion to PPS25 'Living Draft' (Feb 2007).

The SFRA has been developed by building heavily upon existing knowledge with respect to flood risk within Harwich. More detailed modelling of the Ramsey River may significantly improve current knowledge of fluvial flood risk within Harwich over time, and may alter predicted flood extents. This may therefore influence future development control decisions within these areas.

In summary, it is imperative that the SFRA is adopted as a 'living' document and is reviewed regularly in light of emerging policy directives and an improving understanding of flood risk within Harwich.

2 Introduction

2.1 Overview

The Planning and Compulsory Purchase Act 2004 (PCPA 2004) requires Local Development Documents (LDDs) to undergo a Sustainability Appraisal (SA), which assists Planning Authorities in ensuring that their policies fulfil the principles of sustainability.

Strategic Flood Risk Assessments (SFRAs) constitute a component of the SA process and should be used in the review of LDDs or in their production.

The release of Planning Policy Guidance Note 25: Development and Flood Risk in July 2001 (PPG25) (DTLR, 2001) introduced a new emphasis on flood risk. This increased the responsibility of Local Planning Authorities (LPAs) to ensure that flood risk is understood and managed effectively using a risk-based approach as an integral part of the planning process.

PPG25 was superseded (7th December 2006) by Planning Policy Statement 25: Development and Flood Risk (PPS25) (CLG, 2006). This re-emphasises the active role that LPAs should have in ensuring that flood risk is considered in strategic land use planning. PPS25 requires LPAs to undertake SFRAs and to use the findings to inform land use planning. In February 2007, a 'living draft' of the Practice Guide Companion to PPS25 was released for consultation. Although this is a consultation document, it provides a suggested approach to the production of SFRAs that should be considered.

To assist Planning Authorities in their strategic land use planning SFRAs should present sufficient information to enable LPAs to apply the Sequential Test to their proposed development sites. The Sequential Test seeks to guide development to areas of lowest flood risk or, where necessary, to ensure development vulnerability is appropriate to the flooding probability of an area. To achieve this, SFRAs should have regard to river catchment-wide flood issues and also involve a – '*process which allows the Local Planning Authority to determine the variations in flood risk across and from their area as the basis for preparing appropriate policies for flood risk management for these areas'*.

In addition where development sites cannot be located in accordance with the Sequential Test as set out in PPS25 (i.e. to steer development to low risk sites): "*The scope of the SFRA should be increased to provide the information necessary for the application of the Exception Test.*"

2.2 Aim of the SFRA

Scott Wilson was commissioned to develop an SFRA for the Harwich area. The primary purpose of the SFRA is to determine the variation in flood risk across the area. Robust information on flood risk is essential to inform and support Tendring DC's revised flooding policies in their emerging Local Development Framework (LDF).

2.3 SFRA Objectives

To achieve the aims of the SFRA, a staged approach is proposed, in keeping with guidance presented in the Practice Guide Companion to PPS25. The objectives of this SFRA are to:

- Identify the extent of all PPS25 Flood Zones but focus on areas within Flood Zone 3 and areas where new development is likely to be concentrated;

- Identify areas at risk of flooding from all flood sources present in the study area;
- Provide evidence-based reports which inform Tendring DC's Local Development Framework and other Development Planning Documents about managing potential flood risk and are also suitable to inform the Sustainability Appraisal of related documents;
- Advise Tendring DC on suitable polices to address flood risk management in a consistent manner across Harwich;
- Advise Tendring DC on the requirements of site specific flood risk assessments based on local conditions and policy recommendations;
- Advise Tendring DC on the objectives of Sustainable Drainage Systems throughout the study area; and,
- Present sufficient information to inform Tendring DC of the flood considerations necessary in emergency planning.

2.4 SFRA Structure

The Practice Guide Companion to PPS25 recommends that SFRAs are completed in two consecutive stages. This provides Tendring DC with tools throughout the LDF and SFRA process sufficient to inform decisions regarding development sites. The two stages are:

- Level 1 SFRA
- Level 2 SFRA

This report is intended as a Level 1 SFRA to present sufficient information to enable Tendring DC to apply the PPS25 Sequential Test to potential development sites within Harwich and, where there are no 'more reasonably' available sites, to assist in identifying if application of the PPS25 Exception Test will be necessary and can be satisfied.

Level 1 SFRA – Study Area, Flood Source Review & Data Review

The objective of the Level 1 SFRA is to collate and review available information on flood risk for the study area. Information has been sought from a variety of stakeholders including the Environment Agency, Anglian Water and Tendring DC.

The deliverables from the Level 1 SFRA should be used by Tendring DC to complete the Sequential Test. Where the Sequential Test identifies the potential need to apply the Exception Test, further data collection and/or analysis may need to be carried out in a Level 2 report. This report presents the findings of a Level 1 SFRA study.

Level 2 SFRA

The purpose of a Level 2 SFRA is to facilitate the application of the Exception Test.

The Level 2 SFRA will use information obtained in the Level 1 SFRA where suitable, and additional works where necessary, to generate sufficient information for the application of the Exception Test to those sites which cannot be located in lower flood risk zones through application of the Sequential Test.

The Exception Test is the application of a three part test, as set out in PPS25. The test considered the wider sustainability benefits of the development, whether the site is where possible located on previously developed land, and the flood risks to the development to ensure it is safe and doesn't increase flood risk elsewhere (see Section 7).

This information will supplement the Level 1 SFRA to provide Tendring DC with an evidence base sufficient to inform the strategic planning of Harwich.

3 The Harwich SFRA Study Area

The study area is defined by the ward boundary of Harwich, located within the greater administrative area of Tendring DC (Figure 1). The study area covers approximately 8km^2 of land and includes the heavily developed peninsula area in addition to more rural areas that lie further south. A number of rivers and seas are located within the study area and a brief summary of each is below:

3.1 Local Rivers and Seas

North Sea

The North Sea forms the eastern boundary of the study area. Extreme water levels can be generated by Intense low pressure systems can artificially increase sea levels due to the pressure differential in addition to wind and wave action, with the combined effect referred to as a storm surge. The height of the surge typically increases as the weather system travels south, and the North Sea becomes narrower and shallower causing a funnelling effect. The highest water levels in the North Sea will be generated when storm surges are combined with high spring tides generated by gravitational forces. Extensive flood defences have been constructed to protect Harwich from tidal flood events of this nature.

River Stour Estuary

The River Stour Estuary forms the northern boundary of the study area and joins the North Sea at Harwich peninsula. The River Stour Estuary is therefore a potential source of tidal flood risk, however extensive flood defences are located along the banks of the estuary to protect Harwich from tidal flooding.

Ramsey River

The Ramsey River drains a predominantly rural catchment of approximately 27km^2. The discharge from the Ramsey River is pumped over the railway line and into the North Sea/River Stour Estuary in the vicinity of Harwich International Port. Flooding could therefore potentially occur when flows from the catchment exceed the capacity of the pumping station. There is also a residual risk that mechanical or electrical failure could prevent the pumps from operating which could cause the river to back-up and potentially flood the surrounding area.

3.2 Hydrogeology/Groundwater

The Solid and Drift deposit geology of the area has been established from BGS mapping which has been reproduced as Figures 2A and 2B. The Solid geology of the area is dominated by London Clay which is present throughout Harwich with the exception of some localised pockets of Red Crag Sand Formation and Thanet Sand & Lambeth Group. The Drift deposit geology consists of Alluvium in the north and east of the study area in the vicinity of the River Stour Estuary and North Sea floodplains. Alluvium is also present within the Ramsey River floodplain. Alluvium consists of Clays, Silts, Sands and Gravels therefore permeability is highly variable depending on the exact composition of the material, although as this material has been deposited in river beds they tend to be relatively impermeable.

The Kesgrave Formation, which consists of Sands and Gravels is found throughout areas of high ground across a central band of the study area. The Drift deposits in some parts of the study area are not indicated on the BGS 1:50,000 scale mapping, however the larger scale 1:625,000 mapping indicates that 'Rock' is present throughout the area. It would therefore appear that no significant quantity of superficial material has been deposited above the underlying London Clay in these areas.

The Groundwater Vulnerability maps have been examined to determine the hydrogeological properties of Harwich and the surrounding area. The maps show that minor aquifers are located beneath the Sand and Gravels in the central band across Harwich, and no other aquifers are shown elsewhere. This is to be expected and is consistent with the presence of London Clay throughout these areas.

3.3 Sewers

Sewer systems are present throughout the study area. Modern sewer systems are typically designed to accommodate rainfall events with a 1 in 30 year return period. Older sewer systems were often constructed without consideration of a design standard therefore some areas may be served by Victorian sewers with an effective design standard of less than 1 in 30 years. Consequently rainfall events with a return period greater than 1 in 30 years would be expected to result in flooding of some parts of the sewer system.

In addition, as towns and villages expand to accommodate growth, their original sewer systems are rarely upgraded, eventually becoming overloaded and reducing their effective design standard. Compounding this problem are the effects of climate change. Climate change is forecast to result in milder wetter winters and increased rainfall intensity in summer months. This combination will increase the pressure on existing sewer systems effectively reducing their design standard, leading to more frequent flooding.

3.4 Overland flow

Areas of steep ground have the potential to generate runoff which can present a flood source to immediate lower lying areas. This source of flooding is often exacerbated when steep ground is combined with impermeable subsoils and/or significant areas of development with associated hard standing areas.

3.5 Surface Water

Surface water flooding typically arises as a result of intense rainfall, often of short duration, that is unable to soak into the ground or enter drainage systems. It can run quickly off land and result in local flooding. Large areas of impermeable surfaces that are typically created during development, such as car parks and paving areas will generate large volumes of surface water runoff during rainfall events.

In developed areas overland flow typically tends to occur when surface water cannot enter overloaded drainage systems during significant rainfall events. There is therefore an inherent link between sewer flooding and overland flow/surface water flooding.

3.6 Artificial Sources

Artificial sources include any water bodies not covered by the previous categories. These typically include canals, lakes, reservoirs etc of which there are none located within Harwich.

3.7 History of Flooding in the area

The Environment Agency retains records of flooding which have occurred in Harwich from the Ramsey River in September 1958 and the River Stour Estuary/North Sea in January/February 1953. These records are held as GIS layers which are presented in Figure 3. The outlines indicate areas that were subjected to flooding during each individual flood event. No additional records have been provided by Tendring DC.

It should be noted that historic flooding information can often be anecdotal and is unlikely to include records of antecedent conditions giving rise to the flooding (therefore typically not attributed to a flood source) or reference to a flood return period.

The source of the 1958 flooding on the Ramsey River is unknown, however the North Essex CFMP states that fluvial floods tend to be caused either by long periods of rain, generally in the winter months, or short duration, high intensity storms, generally during the summer. It would therefore appear more likely that the flooding in September 1958 was caused by an intensive rainfall event, although this assumption cannot be substantiated. Modifications to the channel and pumping station have since been undertaken to alleviate flooding from the Ramsey River.

Tidal flooding occurred along the east coast of England during the night of 31st January 1953 when an intense depression developed in the North Sea and sent a storm surge south down the English coast, causing extreme water levels. In total, 307 people in the UK were killed and almost 100,000 hectares of eastern England were flooded. The vast scale of the flooding prompted a wide review of flood protection measures and led to significant defence construction or upgrades to existing defences.

4 Policy Context

4.1 Introduction

This chapter provides a summary of both national and regional policies that provide direction and guidance with respect to flood risk. The information presented in the SFRA should be used by Tendring DC to establish robust policies in relation to flood risk as part of their emerging Local Development Framework (LDF).

4.2 National Policies

Making Space for Water

In 2004 the Government's Making Space for Water strategy set out a new national direction for flood risk management planning in England over the next 20 years. The report recognised the requirement for a holistic approach between the various responsible bodies, including flood defence operating authorities, sewerage undertakers and highways authorities, to achieve sustainable development. The report also highlighted the need for a more integrated approach to urban drainage. The protection of the functional floodplain forms an integral aspiration of the strategy.

In January 2007 details of 15 new pilot studies were released that will aim to identify the causes and consider the most suitable ways to manage urban drainage and reduce future flooding taking climate change into consideration. It is hoped the outcome of these studies will culminate in guidance on how to approach urban flood risk and integrated drainage, which will be released in Autumn 2008.

Amongst several other key drivers[1], the Making Space for Water document intended to improve the manner in which land use planning was undertaken. Since 2004 the particular goals alluded to in this document have been achieved. The Environment Agency's role as a statutory consultee has been extended in areas that are at risk of flooding. An integral part of this new direction for flood risk management planning in England was the production of a new Planning Policy Statement (PPS). As discussed within the Making Space for Water document itself, the intention was 'to replace and improve the operational effectiveness of', Planning Policy Guidance Note (PPG) 25. The overriding document PPS25 was released in December 2006 and is discussed below.

Planning Policy Statement 25: Development & Flood Risk

Planning Policy Statement 25 requires that local councils must do the following, when preparing the local development framework:

1. Allocate all sites in accordance with the 'Sequential Test', reduce the flood risk and ensure that the vulnerability classification of the proposed development is appropriate to the flood zone classification;
2. Flood Risk Assessments (FRAs) should be undertaken for all developments within Flood Zones 2 and 3 and sites with identified flood sources to assess the risk of flooding to the

[1] Including coastal erosion, management of water in a rural setting, improved provision of data and research and an improved incorporation of the three pillars of sustainable development (i.e. economic, social and environmental) in risk management activities.

development and identify options to mitigate the flood risk to the development, site users and surrounding area;

3. Flood Risk Assessments are required for all major developments in Flood Zone 1. These are residential developments consisting of sites greater than 0.5 ha or greater than 10 dwellings and commercial developments that are greater than 1 ha or have a floor area greater than 1000 m^2.
4. Flood Risk to development should be assessed for all forms of flooding;
5. Where floodplain storage is removed, the development should provide compensatory storage on a level for level and volume for volume basis to ensure that there is no loss in flood storage capacity.

The PPS25 document aims to ensure that flood risk is taken into account at all stages in the planning process from the inception of regional and local policy through to individual development control decisions.

The document seeks to avoid inappropriate development in areas at risk of flooding and to direct development away from areas of high risk through the application of the sequential approach and the precautionary principle. It is acknowledged that, in some exceptional circumstances, it might not be possible to deliver available sites in lower risk zones through the sequential approach. Here policy will aim to ensure that the development will be safe, without increasing flood risk elsewhere and, where possible, reducing flood risk overall.

4.3 Regional Policies

Draft East of England Plan

The Draft East of England Plan or Regional Spatial Strategy (RSS, East of England Regional Assembly, 2004) sets out the regional strategy for planning and development in the East of England to the year 2021. The Plan provides policy direction for matters such as economic development, housing, the environment, transport, and waste management. The Draft Plan was first issued in December 2004 however revisions and modifications have subsequently been made in response to consultations. Publication of the final East of England Plan was anticipated in early 2008.

A key objective of the East of England Plan is to minimise the risk of flooding within the region. The Draft Plan states that the coastline is naturally dynamic, with strong natural processes in operation. This principally relates to coastal erosion, which can result in increased stress on flood defences. Consequently, climate change is highlighted as a key issue that will need to be addressed, due to its contribution to increasing sea levels.

The Draft Plan states that climate change will be inevitable over the period of this strategy and for many years into the future. It will impact on existing development and natural resources and must influence our decisions about the location of future development.

Areas now at risk from flooding will become more vulnerable and there will be new areas at risk. The draft Plan states that sea levels in the region may be between 22 and 82 centimetres above the current level by 2080, which is expected to have significant impacts on coastal and low-lying areas. Water is likely to become scarcer during the summer months adding to the supply-demand issues already faced in this, the driest of the English regions. The Draft Plan also notes that changes in biodiversity may occur in response to climate change and that climate change is also likely to cause disruption in international trade and the region's vulnerability to this needs to be reduced.

The Draft Plan states that the East of England as a whole will provide at least 508,000 additional dwellings between 2001 and 2021, hence careful planning will be required to ensure the impact of climate change is accounted for when assessing flood risks. Tendring DC is required to provide a minimum of 8,500 additional dwellings by 2021, however this is throughout Tendring DC's entire administration area therefore the likely scale of development within Harwich is not currently known.

Haven Gateway Sub-Regional Strategy

The core strategy within the Draft Plan applies to all parts of the region and in most cases should be sufficient to guide LPAs in preparation of LDDs. However in some circumstances sub-area policies are required to amplify the spatial strategy and resolve matters that cannot be left to the local level. Harwich lies within one of these areas, referred to as The Haven Gateway which spans part of northeast Essex and southeast Suffolk.

The sub-regional strategy for the Haven Gateway aims to achieve transformational development, which will develop a diverse economy, support scientific/academic/research institutions, whilst addressing unemployment and deprivation issues. The strategy recognises that Harwich International Port is a key employer within the study area and includes recommendations to support appropriate Port expansion to stimulate economic growth. The strategy also supports the regeneration initiatives in Harwich and prioritises transport infrastructure for port areas and urban centres.

4.4 Local Policies

The planning system is currently undergoing a period of major change. Every local planning authority is required to replace its current Local Plan with a new Local Development Framework under the requirements of the Planning & Compulsory Purchase Act 2004 which came into force on 28 September 2005. It is envisaged that the LDF will promote a more accessible and sustainable planning system in which local communities and other stakeholders will have more say in the planning issues which affect their locality.

Tendring District Local Plan 2007

The Tendring Local Plan 2007 was adopted in December 2007 and sets out the current plans for development within Harwich between 2007 and 2011. The plan contains a number of policies relating to flood risk and drainage including the following key policies:

- Policy QL3 – Minimising and Managing Flood Risk; ensures that flood risk is taken into account at all stages of the planning process, and includes completion of the PPS25 Sequential Test, and where exceptionally required, the Exception Test.
- Policy COM 32 – Sea Defences; states that soft engineering defences will be used where possible rather than traditional hard engineering methods. Development that would affect the integrity of tidal or fluvial defences will not be permitted.
- Policy COM33 – Flood protection; states no development will be permitted on the seaward side of defences including temporary structures such as holiday chalets and caravans. On land between the first line of defence and the main defence, siting of temporary structures may be permitted following consultation with the Environment Agency. However any permissions will be subject to time occupancy conditions to prevent occupancy during the winter period.
- Policy COM34 – Unstable Land; states that development will not be permitted along the coast where there is a significant likelihood of land instability occurring during the lifetime of the development.

- Policy COM35 – Managed Re-alignment; states that proposals for soft engineering sea defences including managed re-alignment and beach recharge will be encouraged to ensure sustainable flood management.
- Policy EN13 – Sustainable Drainage Systems; states that development proposals should incorporate measures for the conservation and sustainable use of water, which will normally include Sustainable Drainage Systems (SuDS) for managing surface water run-off.

Local Development Framework

The adopted Local Plan will eventually be replaced by the Local Development Framework, which is currently programmed to be adopted in 2011. This study will form part of the evidence base for preparation of the LDF. Tendring DC is currently carrying out the initial stages of LDF preparation which involves evidence gathering and undertaking scoping sustainability appraisals.

4.5 Environment Agency Policies

Catchment Flood Management Plan (CFMP)

Catchment Flood Management Plans are high level strategic planning documents that provide an overview of the main sources of flood risk and how these can be managed in a sustainable framework for the next 50 to 100 years. The Environment Agency engages stakeholders within the catchment to produce policies in terms of sustainable flood management solutions whilst also considering the land use changes and effects of climate change.

North Essex Catchment Flood Management Plan (January 2007)

The North Essex CFMP aims to set policies for flood risk management at a catchment scale taking into account the increased risk of flooding due to climate change. The CFMP divides North Essex into five major catchments and Harwich is located within the 'Coastal Streams' catchment. The report includes flood risk policy recommendations for each catchment area, with the following policies recommended for main settlements and rural areas respectively.

- Policy 4 – take further action to sustain flood risk at current level, responding to future increase in flood risk *(applicable to main settlements e.g. Harwich)*,
- Policy 3 – manage flood risk at current level *(applicable to rural areas elsewhere)*.

Essex Estuarine Strategies (EES)

The Environment Agency has commissioned the development of long term strategies for flood risk management for four estuary systems within Essex. These are the Roach & Crouch, Blackwater & Colne, Stour & Orwell, and Hamford Water.

Shoreline Management Plan (SMP)

Harwich lies with the 'Harwich to Canvey Island SMP Subcell 3d' and it is understood that the current plan was prepared during the 'first round' of SMPs and is awaiting review. It is also understood that the recommended policy in the current SMP is to hold the existing line of flood defence.

The Environment Agency has confirmed that the revised SMP will encompass appropriate estuary elements of the coast and as such will incorporate the Stour & Orwell EES. The revised Essex Shoreline Management Plan is programmed to commence in summer 2008 and is likely to take in excess of one year to complete. It is recommended that the results of the revised SMP are taken into account within future revisions of this SFRA.

4.6 Other Relevant Policies

Tendring DC Coast Protection Strategy (2002 – 2007)

Tendring DC includes approximately 60km of North Sea frontage. Tendring DC is responsible for maintenance and replacement works for 18.6km of this frontage under the Coast Protection Act 1984. A coastal strategy has been prepared to provide a framework for developing, appraising and implementing coastal defence works in a logical manner.

The strategy divides the frontage into a number of units and presents a Coastal Defence Action Plan for the next 5 years. The action plan for Harwich is to monitor and maintain the existing coastal defences whilst considering refurbishment needs to prioritise a programme of special maintenance works. The strategy is therefore in line with the policies presented with the CFMP and current SMP covering Harwich.

Sewers for Adoption (A Design and Construction Guide for Developers)

The Sewers for Adoption Guide is to be used by developers undertaking new development when planning, designing and constructing conventional foul and surface water gravity sewers, lateral drains and pumping stations intended for adoption under an Agreement made in accordance with Section 104 of the Water Industry Act 1991. The developer should consult the sewage undertaker and all other relevant bodies at the earliest opportunity before a planning application has been made, so that drainage arrangements can be agreed.

5 Data Collection and Review

This section describes the data collection process, presents the available data and discusses its benefits and limitations. A comprehensive record of all the data collected through the production of the Level 1 SFRA is presented in a data and contacts register in Appendix B.

The objective of this Level 1 report is to collate and review the information available relating to flooding in the study area and present this in a manner suitable for Tendring DC to apply the PPS25 Sequential Test within Harwich.

5.1 Project Approach

The Level 1 SFRA assessment methodology is based on using available existing information and data where suitable. Further investigations were required as part of the Level 1 SFRA to determine the variation in residual risk across areas protected by flood defences. Additional hydrodynamic modelling was therefore carried out to ensure that the sequential test for development plans in defended areas take residual flood risk into account.

5.1.1 Stakeholder Consultation

In the preparation of this Level 1 SFRA the following stakeholders were contacted to provide data and information:

- Tendring District Council;
- Environment Agency, and;
- Anglian Water.

5.1.2 Data/Information Requested

Information and data requested from the stakeholders was based on the following categories:

- Terrain Information e.g. LiDAR, SAR;
- Hydrology e.g. the main and ordinary watercourses;
- Hydrogeology e.g. groundwater vulnerability zones;
- Flood Defence e.g. flood walls/embankments, sluices;
- Environment Agency Flood Levels e.g. at flood monitoring points;
- Flood Risk Assessments e.g. on previous development sites;
- Environment Agency Flood Zone Maps;
- Local Authority Information e.g. Local Development Schemes; and,
- Drainage Standards.

5.2 Data Review / Overview

5.2.1 Flood Zone Maps

The Flood Zone Map for Harwich has been produced by extrapolating extreme tidal water levels onto a DTM of the study area in order to determine the extents of Flood Zones and 3. The present day (2008) Flood Zone map is shown in Figure 4.

The Flood Map shows the estimated extent of Flood Zones 2 and 3 (ignoring the presence of flood defences) for all main rivers and/or watercourses with identified critical drainage problems. The Flood Map gives a good indication of the areas at risk of flooding in the study area, but it does not provide detail on individual properties, or information on flood depth, speed or volume of flow. It also does not show flooding from other sources, such as groundwater, direct runoff from fields, or overflowing sewers.

5.2.2 Hydraulic Modelling

Hydraulic models enable the estimation of accurate floodplain extents and flood depths based on detailed topographic data of river channels including structures (bridges, culverts etc) and flood defences. The floodplain extents are compiled using rigorously developed statistically-derived flow estimates.

A hydraulic model of the Ramsey River has not been developed by the Environment Agency. However due to the nature of the Ramsey River this is not a significant area of concern. This is because the tidal Flood Zone mapping also covers the Ramsey River channel (within the study area), and it is considered that this mapping presents a more conservative scenario than the fluvial flood risk arising from run-off from the catchment. This has been confirmed through construction and development of a broad scale hydraulic model of the Ramsey River based on LiDAR data cross sections only, excluding the presence of structures.

Full details of the modelling methodology follows and the conclusions of the exercise are contained in Appendix C. In summary the modelling concludes that the peak fluvial flood levels are significantly lower than the extreme tidal levels used to produce the current Flood Zone mapping, hence the current mapping provides a conservative representation of the flood risks in the vicinity of the Ramsey River.

As the Ramsey River discharges into the North Sea via a pumping station, there is also a residual risk of flooding associated with failure of the pumping station. Again full details are presented within Appendix C however the exercise concluded that there is a low residual flood risk associated with this scenario.

5.2.3 Extreme Tidal Water Level Derivation

The extreme tidal water levels at the mouth of the River Stour Estuary at the confluence with the North Sea have been obtained from Eastern and Central Areas Report on Extreme Sea Levels, Royal Haskoning, February 2007, and confirmed by the Environment Agency. The levels within the report have been calculated through statistical analysis of over 500 years worth of tidal level record data along the east coast of England. The levels stated within the report are shown in Table 5-1 below.

Location	1 in 20 year present day (2008) mAOD	1 in 20 year + climate change (2108) mAOD	1 in 200 year present day (2008) mAOD	1 in 200 year + climate change (2108) mAOD	1 in 1000 year present day (2008) mAOD	1 in 1000 year + climate change (2108) mAOD
Harwich	3.36	4.35	3.89	4.91	4.26	5.28

Table 5-1: Extreme Tidal Water Levels

5.2.4 Historical Flooding Records

The Environment Agency has provided GIS outlines showing areas previously flooding by the Ramsey River in September 1958 and the River Stour Estuary/North Sea in January/February 1953, which are presented within Figure 3. No additional records have been provided by Tendring DC. It should be noted that as with all historic flooding records, this information is largely anecdotal and typically does not include a record of the antecedent conditions giving rise to the flooding (therefore typically not attributed to a flood source) or reference to a flood return period.

Fluvial flooding from the Ramsey River during 1958 was mainly constrained to the river corridor however some properties located by the A120/A136 roundabout in Harwich and further upstream in Ramsey were affected. Modifications to the channel and pumping station have since been undertaken to alleviate flooding from the Ramsey River.

Considerable tidal flooding was experienced along the east coast of England during January/February 1953. An intense low pressure system developed in the North Sea sending a storm surge south along the east coast. Existing flood defences were overtopped and a significant proportion of Harwich was flooded including coastal areas, the port and Harwich Town.

5.2.5 Flood Defences

Flood defences are typically engineered structures designed to limit the impact of flooding. Flood defences take several forms including bunds/embankments, canalised channels, culverts and flood storage areas.

Information on flood defences throughout the study area has been provided by the Environment Agency as a GIS layer of the National Flood and Coastal Defence Database (NFCDD), listing details of structures and flood defences. The NFCDD aims to provide the following information:

- The location, composition and condition of fluvial defences and watercourses referenced to identified risk areas,
- The types of asset (i.e. property, infrastructure, environmental) at risk within identified risk areas and including those protected by fluvial, tidal and coastal defences,
- The extent of floods related to different flooding scenarios (e.g. different return periods and different types of flood event such as overtopping or embankment failure).

The NFCDD details the asset reference, the location, level of protection that the structure provides and the geographic extent of the structure or defence. Details of all NFCDD flood defences in the study area are presented as a GIS layer and in Figure 5. The Environment Agency has also provided the following crest levels for existing flood defences as shown below in Table 5-2.

Location	Existing Flood Defence Crest Level (mAOD)
The Quay	4.4
Parkstone Ferry	4.7
Bathside Bay	5.0
King Quay Street	5.0
Wellington Road	4.7

Table 5-2: Existing Flood Defence Crest Levels

Tendring DC has also provided a copy of their Sea Defence Survey Report, completed in December 2006. The report contains information regarding the construction of the defences, their condition, maintenance history, estimated residual life plus photographs and sketches. The report is provides useful background information however does not contain any information regarding the crest elevation or design standard of any structure.

5.2.6 Topographic Data

The Environment Agency has provided Light Detection and Ranging (LiDAR) data for the study area. LiDAR is an airborne mapping technique which uses a laser to measure the distance between the aircraft and the ground. The data varies in accuracy depending on the nature of the terrain such as in woodlands, complex urban areas and near lakes, the accuracy lowering due to the limitations in the technique. However, LIDAR is generally recognised to be +/- 300mm in accuracy.

The data set covers the entire study area and was captured by the Environment Agency during April 1999 under its remit to monitor floodplain areas and is presented as Figure 6.

5.2.7 Sewer Flooding

Typically sewer systems are designed and constructed to accommodate rainfall events with a 30 year return period or less, depending on their age. Consequently rainfall events with a return period greater than 30 years would be expected to result in surcharging of some parts of the sewer system.

Records of sewer flooding have been requested from Anglian Water via a query of their DG5 registers. In order to fulfil statutory commitments set by OFWAT, water companies must maintain verifiable records of sewer flooding, which is achieved through their DG5 registers. Water companies are required to record flooding arising from public foul, combined or surface water sewers and identify where properties suffered internal or external flooding.

However as shown in email correspondence within Appendix B, Anglian Water responded stating that an investigation of sewer flooding is not a requirement of an SFRA. Anglian Water also state that as a regulated sewerage provider they are obliged to undertake capital works to remove sewers which lack hydraulic capacity, therefore any current problems would only be temporary. It is understood that Anglian Water has provided sewer flooding data to support the ongoing Haven gateway Water Cycle Study. It is therefore recommended that the Water Cycle Study is reviewed to determine areas with an increased risk of sewer flooding, and the recommendations of this study are taken into account throughout the development of Tendring DC's emerging LDF.

5.2.8 Overland Flow / Surface Water Flooding

Overland flow / surface water flooding typically arises as a result of intense rainfall, often of short duration, that is unable to soak into the ground or enter drainage systems. It can run quickly off land and result in local flooding.

In developed areas, overland flow typically tends to occur when surface water cannot enter overloaded drainage systems during significant rainfall events. There is therefore an inherent link between sewer flooding and overland flow/surface water flooding hence the conclusions of the ongoing Water Cycle Strategy should be taken into account during preparation of Tendring DC's LDF for Harwich.

The DTM has also been analysed to determine steep areas of ground which could potentially cause rapid surface water run-off during rainfall events. No additional records of surface water flooding have been provided, however topography has a major influence on run-off therefore it is a considered to be a suitable technique for a strategic study such as this.

5.2.9 Groundwater Flooding

Groundwater flooding is usually associated with chalk and limestone catchments that allow groundwater to rise to the surface through the permeable subsoil following long periods of wet weather. It is therefore unlikely that groundwater flooding will pose a significant flood risk within Harwich, the majority of which is underlain by London Clay.

The presence of the Kesgrave formation, which includes sand and gravels across the central band of Harwich indicates that this area could be more susceptible to perched groundwater i.e. situated above the London Clay, migrating to the surface. However the Kesgrave formation is present in areas of high topography where groundwater flooding is least likely to occur.

The Environment Agency do not hold any historical records of groundwater flooding within Harwich. Given the underlying geology and lack of historical data it is therefore considered that the risk of groundwater flooding throughout Harwich is generally low.

5.2.10 Artificial Sources / Infrastructure Failure

Artificial sources of flooding can include reservoirs, canals and lakes where water is retained above natural ground level. Failure of such a structure could result in rapid inundation of the surrounding area with little or no warning.

There are several ponds within Harwich as listed in Table 5-3 below, however none of these retain water above ground level through the use of bunds or embankments. The risk of flooding from these artificial sources is therefore considered to be minimal.

Location	Approximate Co-ordinates		Approximate Plan Area (m^2)
	Easting	Northing	
Boating Lake	625000	230490	6,060
Bobbit's Hole	625140	231490	2,439
Cox's Pond	626080	232310	820
Delf Pond	623740	231710	5,240
Model Yacht Pond	625000	230570	5,160

Table 5-3: Ponds/Lakes located within Harwich

None of the stakeholders contacted throughout this study hold any records of flooding arising from artificial sources and/or infrastructure failures.

6 Methodology

This section describes the data used in the production of mapping and GIS deliverables for the project. To facilitate production of the maps and GIS layers, some of the data received from the stakeholders has been standardised and/or combined.

The Level 1 SFRA assessment methodology is based on using available existing information and data where this suitable. However additional hydraulic modelling has been carried out to broadly define the functional floodplain and hydrodynamic modelling has also been undertaken to provide information on the residual risk behind defences in Harwich.

6.1 Requirements of PPS25

Planning Policy Statement 25 and its accompanying Practice Guide Companion requires Strategic Flood Risk Assessments to present sufficient information on all flood sources to enable local planning authorities to apply the Sequential Test in their administrative areas. In order to apply the Sequential Test information is required on the probability (High, Medium and Low) associated with flooding from the different flood sources. This information should be presented graphically where possible as a series of figures and/or maps.

In addition, the assessment of probability should also account for the effects of climate change on a flood source for the lifetime of any development that would be approved through the emerging Local Development Framework.

For all but tidal and fluvial flood sources the current lack of data makes definition of robust classifications of probability unreliable. For example to define high, medium and low probabilities for groundwater flooding within the study area when no information has been provided regarding previous incidents is not particularly robust. Consequently for all flood sources other than tidal and fluvial, where only anecdotal evidence of flooding is available, subjective assessments of probability have been made where the data allows.

However in some cases, definitions of probability are not practical or are unreliable; in these situations the flood risk from a particular source should be considered as ‘medium’ until proven otherwise and should be investigated through a site specific assessment of flood risk submitted as part of a planning application. Details of the requirements for site specific FRAs is presented in Section 11.

The following sections explain how the available data has been used to develop strategic flood risk mapping for use in undertaking the Sequential Test.

6.2 GIS Layers and Mapping

Geographical data such as flood extents and watercourse routes, for use in determining appropriate planning decisions, have been presented as maps (Appendix A) and published through Geographical Information System (GIS) layers.

GIS acts as an effective management tool for the coordinated capture, storage and analysis of data of a geographical nature. GIS handles data in a hierarchical manner by storing spatial features within various layers, which are allied to an underlying database. GIS is a recognised tool for the efficient collation, storage and analysis of information and is also an increasingly valuable resource for local planning authorities.

A summary of GIS layers generated for use in this SFRA is presented below including a summary to identify which GIS layers have been used in the production of the maps and figures presented with Appendix A of this Level 1 SFRA.

Name	**Details**	**Presented within Figure No.s**
EA_Flood_Warning	EA flood warning areas	8
EA_flood_zone_2_2008	EA Flood Zone 2 extents - 2008	4, 9
EA_flood_zone_3_2008	EA Flood Zone 3 extents - 2008	4
EA_main_rivers	EA designated main river centrelines	3, 4
Emergency_planning	Emergency planning rest/reception centres	9
Ew_050k_superficial	British Geological Survey drift deposits geology, 1:50,000 scale	2B
Ew_bedrock	British Geological Survey solid geology, 1:50,000 scale	2A
Flood_defences_NFCDD	EA national flood and coastal defences database	5
Historic_Flooding_1953_Outlines	EA flood extents during Jan/Feb 1953 North Sea flood event	3
Historic_Flooding_1958_Ramsey_Outline	EA flood extents during Sept 1958 Ramsey River flood event	3
LiDAR_DTM	LiDAR Topographic Data	6
Ramsey-FZ-3A-2008	Estimated flood extents based on Ramsey pumping station failure during 1 in 100 year event in 2008	C-5
Ramsey-FZ-3A-2108	Estimated flood extents based on Ramsey pumping station failure during 1 in 100 year event in 2108	C-6
Ramsey-FZ-3B-2008	Estimated flood extents based on Ramsey pumping station failure during 1 in 20 year event in 2008	4, C-5
Ramsey-FZ-3B-2108	Estimated flood extents based on Ramsey pumping station failure during 1 in 20 year event in 2108	C-6
SFRA_study_Area	Study area boundary	All
Slope_LiDAR_DTM	Slope grid calculated from LiDAR DTM	7

Table 6-1: GIS Layers

6.3 Tidal Flooding

6.3.1 Requirements

PPS25 requires definition of the following tidal Flood Zones:

Flood Zone	Definition	Probability of Flooding
Flood Zone 1	At risk from flood event greater than the 1 in 1000 year event (greater than 0.1% annual probability of flooding each year)	Low Probability
Flood Zone 2	At risk from flood event between the 1 in 200 and 1 in 1000 year event (between 0.5% and 0.1% annual probability of flooding each year)	Medium Probability
Flood Zone 3a	At risk from flood event less than or equal to the 1 in 200 year event (greater than 0.5% annual probability of flooding each year)	High Probability
Flood Zone 3b	At risk from a flood event less than or equal to the 1 in 20 year event or otherwise agreed between the Local Planning Authority and the Environment Agency (greater than 5% annual probability of flooding each year)	Functional Floodplain

Table 6-2: Tidal Flood Zone Definitions (as defined in PPS25, Table D.1)

The extent of the tidal Flood Zones within Harwich has been produced whilst ignoring the presence of the existing flood defence structures. However as shown in Figure 5 Harwich is protected from a 1 in 200 year tidal flood event under normal circumstances. Table 6-2 therefore suggests that Harwich should be designated as Flood Zone 1. However this is not the case as the presence of defences can only reduce, and not remove the risk of flooding as there is always a risk that the defences may be overtopped and/or breached.

However the extent of the functional floodplain is defined by the 1 in 20 year flood event, taking into account the presence of existing flood defences. The study area therefore does not contain any tidal functional floodplain as the defences provide a significantly higher standard of protection.

6.3.2 Climate Change

The Flood Zones should be defined considering the effects of climate change. For tidal systems PPS25 requires that sea level rise is applied when mapping climate change Flood Zones up to 2115 along the East coast of England as shown in Table 6-3. The climate change levels are shown In Table 5-1.

Table 6-3 Recommended contingency allowances for net sea level rise (from PPS25 Table B.1).

Administrative Region	Net Sea Level Rise (mm/yr) Relative to 1990			
	1990 to 2025	2025 to 2055	2055 to 2085	2085 to 2115
East of England, East Midlands, London, SE England (south of Flamborough Head)	4.0	8.5	12.0	15.0

6.3.3 Data Sources

The tidal Flood Zones have been produced from the flood outlines provided by the Environment Agency and no further adjustments have been made. The Environment Agency Flood Zones have only been defined for present day (2008) based on flood outlines generated by projecting the extreme sea levels shown in Table 5-1 onto a DTM to determine the extent of flooding

6.3.4 Mapping

The extent of the tidal Flood Zones within Harwich both for present day is presented in the Flood Zone Map 2008 (Figure 4).

6.3.5 Breach Modelling

As shown in Figure 4 the tidal Flood Zones cover a significant proportion of Harwich therefore further work has been undertaken to determine the variation in flood risk throughout the north of the study area. Hydraulic breach modelling has been undertaken at strategic locations as presented within Appendix D.

Three breach models have been constructed to cover the study area located at Harwich International Port, Harwich peninsula and Dovercourt. Each model has been used to simulate a breach in the defences occurring at the same time as a 1 in 200 year and a 1 in 1000 year tidal water level curves for present day and climate change scenarios.

The existing defences provide protection from the present day 1 in 200 year and 1 in 1000 year tidal levels, however the defences will be overtopped when extreme levels are increased to take account of rising sea levels due to climate change. The climate change scenarios therefore include simulation of a breach at the relevant location in addition to overtopping of the existing defences where appropriate.

The model outputs have been used to create flood depth and hazard mapping as shown in Figures D1 – D54. Further detail of the modelling methodology is also provided in Appendix D, including a full list of the GIS modelling outputs provided with this report.

6.4 Fluvial Flooding

6.4.1 Requirements

PPS25 requires definition of the following fluvial Flood Zones:

Flood Zone	Definition	Probability of Flooding
Flood Zone 1	At risk from flood event greater than the 1 in 1000 year event (greater than 0.1% annual probability of flooding each year)	Low Probability
Flood Zone 2	At risk from flood event between the 1 in 100 and 1 in 1000 year event (between 1% and 0.1% annual probability of flooding each year)	Medium Probability
Flood Zone 3a	At risk from flood event less than or equal to the 1 in 100 year event (greater than 1% annual probability of flooding each year)	High Probability
Flood Zone 3b	At risk from a flood event less than or equal to the 1 in 20 year event or otherwise agreed between the Local Planning Authority and the Environment Agency (greater than 5% annual probability of flooding each year)	Functional Floodplain

Table 6-4: Fluvial Flood Zone Definitions (as defined in PPS25, Table D.1)

The Practice Guide Companion to PPS25 states that all areas within Flood Zone 3 should be considered as Flood Zone 3b unless, or until, appropriate assessment shows to the satisfaction of the Environment Agency that the area falls within Flood Zone 3a. Therefore in areas where the functional floodplain has not been defined and no suitable surrogate data is available the functional floodplain (Flood Zone 3a) should be defined as the extent of Flood Zone 3a.

PPS25 states that functional floodplain should be determined considering the effects of defences and other flood risk management infrastructure. The functional floodplain relates only to river and coastal flooding, it does not include areas at risk of flooding solely from other sources of flooding (e.g., surface water, sewers).

6.4.2 Climate Change

The Flood Zones should be defined considering the effects of climate change. For fluvial systems PPS25 requires an increase of 20% in peak flows to be used when mapping climate change flood zones up to 2115.

6.4.3 Data Sources

As described in section 5.2.2 the Flood Zone mapping has been produced based on extreme tidal levels. This represents a more conservative scenario than the fluvial component alone when considering areas in the vicinity of the Ramsey River channel. However it should be noted that this statement is only correct for the lower reaches of the Ramsey River contained in the study area.

However as Harwich benefits from tidal flood defences which protect from a 1 in 200 year tidal event, there is defined no functional floodplain for the Ramsey River. Therefore the outputs of the broad brush hydraulic modelling exercise of the Ramsey River have been used to determine the extents of the functional floodplain. Full details of the modelling are included in Appendix C.

6.4.4 Mapping

The estimated flood levels for the 1 in 20 year fluvial event have been applied across the DTM to map the functional floodplain extents in the study area, as shown in Figure 4 and Figure C-5. This exercise has also been undertaken for the 1 in 20 year event with climate change to estimate the functional floodplain extents in 2108 as shown in Figure C-6.

6.5 Sewer Flooding

6.5.1 Requirements

PPS25 requires that SFRAs provide information regarding areas at risk of flooding from sewers, and data fro water companies is typically provided to allow this to be undertaken. However as discussed in section 5.2.7, Anglian Water have not provided sewer flooding data as this source of flooding is being covered by the ongoing Haven Gateway Water Cycle Strategy.

6.6 Surface Water Flooding / Overland Flow

6.6.1 Requirements

Overland flow and surface water flooding results from rainfall that fails to infiltrate the surface and travels over the ground surface. This is exacerbated by low permeable urban development or low permeability soils and geology (such as clayey soils). Overland flow is likely to occur at the base of an escarpment and low points in terrain.

Local topography and built form can have a strong influence on the direction and depth of flow. The design of development down to a micro-level can influence or exacerbate this. Overland flow paths should be taken into account in spatial planning for urban developments. In addition, surface water flooding can be exacerbated if development increases the percentage of impervious area. An assessment of overland flow must be undertaken and the risks assessed as part of a site specific FRA.

6.6.2 Data Source

GIS analysis has been carried out to determine the location of steep sloping ground, which could potentially generate significant volumes of run-off during extreme rainfall events. This has been achieved by production of a slope grid from the DTM. The slope grid has been colour coded to identify the variation in gradient across the study area.

6.6.3 Mapping

The results of this exercise are presented in Figure 7, which identifies areas that could potentially generate significant volumes of overland flow. This should also be compared with the topographic data presented in Figure 6 to determine local low points where ponding of surface water could potentially occur. The slope grid provides an indication of the overall terrain however there will be a significant variation in risk due to the absence or presence of flow barriers on the ground. Due to this reason it was not considered appropriate to attempt to classify these area further into high, medium and low risk.

6.7 Groundwater Flooding

6.7.1 Requirements

Groundwater flooding occurs when water levels in the ground rise above surface elevations. Groundwater flooding may take weeks or months to dissipate as groundwater flow is much slower than surface water flow therefore water levels take much longer to recede.

An assessment of the risk of groundwater flooding needs to be considered; however, a quantified assessment of risk from groundwater flooding is difficult to undertake, especially on a strategic scale. This is due to lack of groundwater level records and the lack of predictive tools (such as modelling) that can make assessments of the risk of groundwater flow and flooding following rainfall events.

6.7.2 Data Source

The BGS geological mapping has been used as the primary data source to determine the risk of groundwater flooding in Harwich. Groundwater flooding is usually associated with chalk and limestone catchments that allow groundwater to rise to the surface through the permeable subsoil following long periods of wet weather. Groundwater flooding can also occur in areas where Made Ground has been deposited above impermeable subsoils, typically during ground raising or levelling works. The port area therefore may contain significant areas of Made Ground above the London Clay, and an associated risk of groundwater flooding.

However despite this, it is considered unlikely that groundwater flooding will pose a significant flood risk within Harwich on a strategic scale, as the London Clay will generally prevent groundwater rising to the surface.

6.7.3 Mapping

The risk of groundwater flooding throughout Harwich is therefore considered to be low, and no mapping has been produced to demonstrate this. However site specific flood risk assessments should include full consideration of the ground conditions on site and assess the risk of groundwater flooding occurring. This is particularly important when basement areas are proposed and it must be demonstrated that the site does not lie on a key groundwater flow route such that introducing a flow barrier within the system would increase the risk of groundwater flooding elsewhere.

7 Guidance on Applying PPS25 Sequential Test

7.1 What is the PPS25 Sequential Test?

The PPS25 Sequential Test is a process by which the precautionary principle should be applied to the strategic land allocation process. PPS25 requires local planning authorities to review flood risk across their districts, steering all development towards areas of lowest risk. Development is only permissible in areas at risk of flooding in exceptional circumstances where it can be demonstrated that there are no reasonably available sites in areas of lower risk, and the benefits of that development outweigh the risks from flooding. Such development is required to include mitigation/management measures to minimise risk to life and property should flooding occur.

A Level 1 SFRA is designed to be sufficiently detailed to allow the application of the Sequential Test on the basis of Table D.1. of PPS25 (reproduced as Tables 6-1 and 6-3) and Figure 3.1 of its Practice Guide Companion and to also identify where application of the Exception Test (discussed further in Section 8) is necessary.

PPS25 acknowledges that some areas will (also) be at risk of flooding from sources other than tidal and fluvial. Consequently all sources of flooding must be considered when looking to locate new development. The other sources of flooding requiring consideration when situating new development allocations include:

- Overland Flow;
- Groundwater;
- Sewers; and
- Artificial Sources.

These sources (as sources of flooding) are typically less well understood than tidal and fluvial sources. Consequently data often only exists as point source data or through interpretation of local conditions. In addition there is conflicting guidance on suitable return periods to associate with floods arising from these sources. For example modern surface water drainage systems are constructed to a 1 in 30 year standard. Any rainfall event in excess of the 30 year return period would be expected to result in some flooding through insufficient capacities. Consequently when assessing these sources through the Sequential Test, if a location is recorded as having experienced repeated flooding from the same source this should be investigated further in a site specific flood risk assessment.

7.2 Development Vulnerability Classifications

Planning Policy Statement 25 classifies developments according to their vulnerability. Five vulnerability classifications are defined, these are:

- Essential Infrastructure;
- Highly Vulnerable;
- More Vulnerable;
- Less Vulnerable, and
- Water Compatible.

Full definitions are provided in Table D.2 of PPS25 including the types of development that fall under these classifications. PPS25 also stipulates where the differing types of vulnerable development may be appropriate based on flood risk. This is presented in Table D.3 of PPS25, which is reproduced below.

Flood Risk Vulnerability Classification		Essential Infrastructure	Water Compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Flood Zone	1	✓	✓	✓	✓	✓
Flood Zone	2	✓	✓	Exception Test Required	✓	✓
Flood Zone	3A	Exception Test Required	✓	✗	Exception Test Required	✓
Flood Zone	3B	Exception Test Required	✓	✗	✗	✗

✓ – Development is appropriate ✗ – Development should not be permitted

Table 7-1: PPS25 Table D3 Flood Risk Vulnerability and Flood Zone 'Compatibility' (DCLG, 2006)

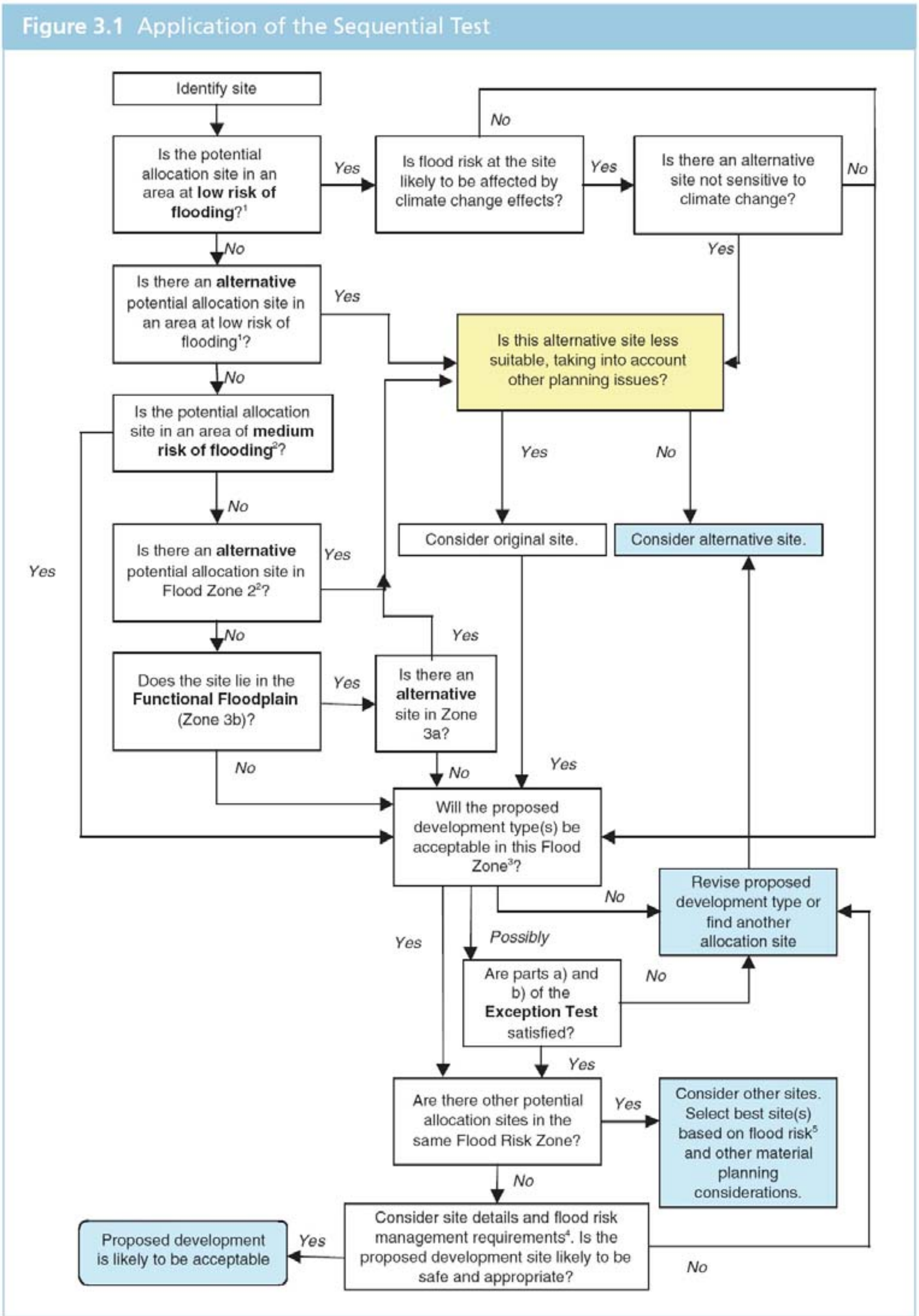
Using the information documented and mapped within this Level 1 SFRA, the Sequential Test should be undertaken by Tendring DC and accurately documented to ensure decision processes can be transparently communicated and reviewed where necessary.

The Sequential Test should be carried out on all development sites and seek to guide development to the lowest flood risk areas. Only where there are no reasonably available alternative sites to accommodate the development should sites in Flood Zones 2 or 3 be considered.

The Level 1 SFRA mapping provides the tools by which Tendring DC can undertake the Sequential Test. This is achieved by presenting information to identify the variation in flood risk across their administrative areas, allowing an area-wide comparison of future development sites with respect to flood risk considerations.

The following flow diagram (Figure 7-2), taken from the Practice Guide Companion to PPS25 illustrates how the Sequential test should be undertaken. The full process is described fully in PPS25, A Practice Guide Companion, 'Living Draft' 2007.

Figure 7-2: Application of the Sequential Test (from Figure 3.1 of PPS25: Practice Guide, A 'Living Draft')



Notes
1 Flood Zone 1 for fluvial and tidal flooding and with a low risk of flooding from other sources.
2 Flood Zone 2 for fluvial and tidal flooding and with a medium risk of flooding from other sources.
3 As defined by the Sequential Test.
4 Development to be safe and to not increase flood risk elsewhere. Required to pass part c) of the Exception Test, where applicable.
5 Including susceptibility to future climate change and residual flood risk.

7.2.1 Additional Guidance

The sequence of steps presented below in tandem with Figure 7-2 is designed to guide Tendring DC and developers through the Sequential Test. The steps are designed to ensure land allocations are primarily allocated in line with the principles of the Sequential Test or, failing this, that the requirement for application of the Exception Test is clearly identified.

Recommended stages for Tendring DC application of the Sequential Test:

1. The developments (i.e. housing, hospitals, industrial etc) that need to be accommodated should be assigned a vulnerability classification in accordance with Table D.2 "Flood Risk Vulnerability Classification" in PPS25;
2. The Flood Zone classification of all development sites should be determined based on a review of the Environment Agency Flood Zones. This should consider the effects of climate change on flood zone definition for the design life of any development that the site may be suitable for, i.e.:
   - 60 years – up to 2070 for commercial / industrial developments; and
   - 100 years – up to 2110 for residential developments
3. In the first instance the 'highly vulnerable' developments should be located in those sites identified as being within Flood Zone 1. If the 'highly vulnerable developments' cannot be located in Flood Zone 1, because the identified sites are unsuitable or there are insufficient sites in Flood Zone 1 then sites in Flood Zone 2 can be considered. According to PPS25 'highly vulnerable' uses would not be permitted in Flood Zone 3.
4. Once all 'highly vulnerable' developments have been allocated to a development site, Tendring DC can consider development types defined as 'more vulnerable'. In the first instance 'more vulnerable' development should be located in any unallocated sites in Flood Zone 1. Where these sites are unsuitable or there are insufficient sites, sites in Flood Zone 2 can be considered. If there are insufficient sites in Flood Zone 1 or 2 to accommodate the 'more vulnerable' development types, sites in Flood Zone 3a can be considered. However, any 'more vulnerable' developments in Flood Zone 3a will require application of the Exception Test. Responses to parts 'a' and 'b' of the Exception Test should be prepared and agreed through consultation with the Environment Agency before 'part c' is tackled.
5. Once all 'more vulnerable' developments have been allocated to a development site, Tendring DC can consider those development types defined as 'less vulnerable'. In the first instance 'less vulnerable' development should be located in any remaining unallocated sites in Flood Zone 1, 2 or 3a. Less vulnerable development types are not appropriate in Flood Zone 3b – Functional Floodplain.
6. 'Essential infrastructure' developments should also be preferentially located in the lowest flood risk zones, however this type of development can be located in Flood Zones 3a and 3b, where necessary, through application of the Exception Test. Where these types of development are located in Flood Zone 3a or 3b responses to parts 'a' and 'b' of the Exception Test will be required before 'part c' is tackled.
7. Water compatible development typically has the least flood risk constraints and it is therefore recommended to consider these types of development last when allocating development sites.

8. For decisions made through stages 4 to 7 it will also be necessary to consider the risks posed to the site from other flood sources and where comparable development sites in the same Flood Zone may be more suitable due to:

   - flood risk management measures,
   - the rate of flooding,
   - flood water depth, or,
   - flood water velocity.

   The breach modelling outputs can be used to provide further information on the factors listed above. As a significant proportion of Harwich lies within Flood Zone 3 it is likely that development will be required within this Flood Zone, therefore the modelling outputs provide further information regarding the variation of risk within and allow a sequential approach to be applied throughout Flood Zone 3. Sites with a lower hazard rating and/or a slower rate of flooding should therefore be considered as more suitable for development from a flood risk perspective.

   Where the development type is highly vulnerable, more vulnerable, less vulnerable or essential infrastructure and a site is found to be impacted by a recurrent flood source, the site and flood sources should be investigated further irrespective of a requirement for the Exception Test. This should be discussed with the Environment Agency to establish the appropriate time for the assessment to be undertaken, (i.e. Exception Test through a Level 2 SFRA or through a site specific flood risk assessment).

9. It is recommended that Tendring DC complete the Proforma in Table E1 (Appendix E) to assist in completion of the Sequential Test to provide a transparent framework and justification of sites that may need to be Exception Tested.

8 Guidance on Applying the PPS25 Exception Test

8.1 Why is there an Exception Test?

Application of the Sequential Test aims to steer all development towards areas of lowest risk. However, PPS25 acknowledges that in some, exceptional circumstances it may not be possible to locate development in areas of low or appropriate (considering development vulnerability) flood risk. The Sequential Test must be carried out to demonstrate that there are no reasonably available sites in lower flood risk areas. If this is the case then any additional wider sustainability benefits resulting from development can be taken into account through application of the Exception Test. In these circumstances, it is necessary to clearly demonstrate that the benefits for development of a site outweigh the flood risks to the development and its occupants.

In addition, it may be necessary to apply the Exception Test where the Sequential Test alone cannot deliver acceptable sites, and where some continuing development is necessary for wider sustainable development reasons, taking into account the need to avoid social or economic blight and the need for essential civil infrastructure to remain operational during floods.

8.2 What is the Exception Test?

The Exception Test is an additional test to be applied by decision-makers following application of the Sequential Test. The Exception Test is a series of three criteria as shown below, all of which must be satisfied for development in a flood risk area to be considered acceptable. For the Exception Test to be passed:

a) It must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk, informed by a SFRA;

b) The development should be on developable previously developed land or, if not, it must be demonstrated there is no such alternative land available; and

c) A FRA must demonstrate that the development will be safe, without increasing flood risk elsewhere, and, where possible, reducing flood risk overall.

All three parts of this test must be satisfied in order for the development to be considered appropriate in terms of flood risk. There must be robust evidence in support of every part of the test.

This report is intended as a Level 1 SFRA - should the Sequential Test identify the need for allocations to undergo the Exception Test this will be addressed in a Level 2 SFRA.

Where use of the Exception Test is required, decision-makers should apply it at the earliest stage possible in planning, to all LDD allocations for development and all planning applications other than for minor development.

A significant proportion of Harwich is located within Flood Zone 3a, therefore it is likely that the requirements of the Exception Test will need to be satisfied for 'more vulnerable' e.g. residential, development in this area.

For this reason, the breach modelling has been undertaken during this Level 1 SFRA to enable Tendring DC to take into account the variation in flood depth and hazard within Flood Zone 3a when allocating development sites. The breach modelling information should be used at this early stage to determine whether more appropriate locations area available within Flood Zone 3a, with a lower depth of flooding and associated flood hazard.

Further details of how to undertake the Exception Test will be contained within the SFRA Level 2 report.

9 Flood Risk Management

9.1 Flood Defences

The National Flood and Coastal Defence Database (NFCDD) compiled by the Environment Agency holds information on natural and man-made defences. The standard of these flood defences is only available for man-made defences. Figure 5 displays the location of NFCDD defences throughout the study area and identifies the authority which is responsible for maintenance requirements.

The Environment Agency Flood Zone maps define the extent of flooding ignoring the presence of defences. The reason for this approach is to make an allowance for residual flood risk in the event of a failure or breach/blockage/overtopping of the flood defences. This conservative approach raises the awareness of flood risk in defended areas and helps to ensure that is it not discounted as part of development but is managed appropriately.

Flood defences are typically designed and constructed to protect people and property from a given magnitude of flood. This is referred to as the design standard and may vary depending on the age of the structure, the value attributed to the people and property it is designed to serve and the scale of works necessary to construct the defence. For new defences, these issues and others are balanced through a cost benefit analysis to determine if investment in defence schemes can be justified.

9.1.1 Current

The NFCDD identifies a significant number of flood defences throughout the study area, which are classified as either tidal or fluvial defences. The tidal defences in Harwich consist of raised walls and embankments which have been designed to protect against a 1 in 200 year tidal flood event. It is understood that the original flood defences were raised to current levels by the Environment Agency following the flooding experienced in Harwich during January/February 1953.

The Ramsey River channel is also included within the NFCDD as a fluvial defence, although there is no design standard association with this information. It is understood that the Ramsey River channel is included within the database in order to identify that the Environment Agency is responsible for maintenance of the channel and pumping station, yet the design standard is unknown.

Tendring DC is responsible for maintenance of the tidal flood defences stretching from Dovercourt to Harwich Harbour. As shown in Figure 5 the Environment Agency is also responsible for defence maintenance at various locations in addition to private riparian owners such as Harwich International Port who have responsibility in other areas.

9.1.2 Future

Tendring DC's Coastal Protection Strategy states that the current policy for Dovercourt and Harwich is to maintain the existing standard of protection through continued maintenance, in line with the current SMP policies (see section 4.5). However the predicted increases in sea level will continue to reduce the standard of protection as time goes by. As shown in Figure 9-1 below, based on the current PPS25 recommended sea level rise allowances, the existing defences in Harwich will be overtopped by the 1 in 200 year tidal event in approximately 70 years time.

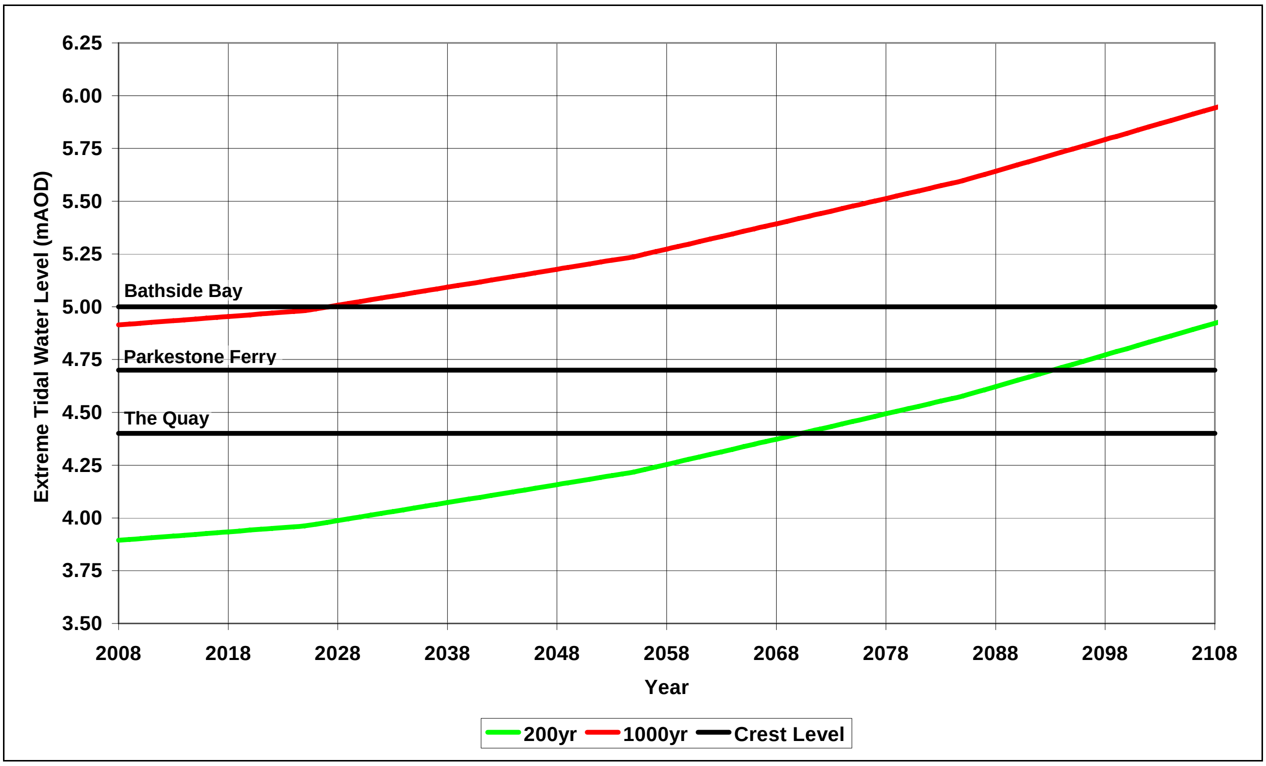


Figure 9-1: Extreme tidal water levels including climate change, based on PPS25 allowances

Given the scale and nature of existing development within Harwich, and Tendring DC's regeneration plans for the area further investment in flood risk management measures is likely to be required in the future. This will require co-ordination between the Environment Agency, Tendring DC and other riparian flood defence owners to ensure a sustainable solution is developed to ensure Harwich is defended from tidal flooding throughout this century and into the next.

9.2 Flood Warning

The Environment Agency operates a flood warning service in areas at risk of flooding. It consists of an initial Flood Warning, notifying houses and businesses within the flood warning area. This is the signal to undertake measures in preparing for a flood. When a flood event is imminent a Severe Flood Warning is issued which means there is extreme danger to properties or businesses.

The flood warnings are disseminated through a variety of mediums that include TV, radio, Automated Voice Messaging service direct to recipients' phone/fax/pager, internet and/or loudhailer. There is also an emergency Floodline number (0845 988 1188) and a quickdial number for specific areas.

Figure 8 illustrates the flood warning areas within the study area. The Flood warning system helps residents in areas of flood risk prepare for floods, through preparation of obtaining sand bags, moving valuables upstairs and where necessary evacuating the property to minimise the potential consequences of flooding.

9.3 Residual Risk

Residual risk in a generic sense can be defined as 'the remaining risk following the implementation of all risk avoidance, reduction and mitigation measures' (Communities and Local Government, 2007). In a flood risk context, this residual risk pertains to the flood risk that remains after flood avoidance and alleviation measures have been put in place.

An example of residual risk within Harwich is breaching of the flood defence walls along the Quay or failure of the Ramsey River pumping station. It is possible that the defences could be breached due to collision of shipping traffic, terrorist action and/or hydrostatic water pressure during high tides. The pumping station could be rendered inoperable by mechanical or electrical failure, although back-up measures are already in place.

Residual risk management therefore aims to prevent or mitigate the consequences of flooding that can occur despite the presence of flood alleviation measures.

Application of the Sequential Test as part of PPS25 aims to preferentially develop or relocate potential development sites into areas with low flood risk. Where this is not realistically possible, some development sites may be located in higher flood risk areas, such as PPS25 defined Flood Zones 2 and 3. As a result, such developments will require residual risk management to minimise the consequences of potential flooding, e.g. following a breach or overtopping of local defences.

Ensuring properties are defended to an appropriate design standard reduces flood risk. However, further options are also available should the residual risk to a development prove unacceptable. The two potential residual risk examples relating to Harwich are examined in more detail below, including details of potential residual risk management options.

Ramsey River

As detailed in Appendix C a broad brush hydraulic model has been developed in order to simulate the impact of failure of the Ramsey River pumping station during a 1 in 100 year fluvial event including an additional 20% flow to account for climate change. As the Ramsey River system is a pumped catchment, should the pumping station fail to operate then the flow draining from the catchment will be unable to discharge into the North Sea. The water will therefore back-up, exceed the capacity of the channel and overflow onto the surrounding floodplain.

The modelling analysis has considered a 100 year event with climate change, with a 48 hour storm duration. It is considered that this period of time would be sufficient for the pumping station to be repaired or for a temporary pumping system to be established to discharge water from the catchment.

The results of the analysis have demonstrated that the Ramsey River floodplain provides a significant volume of storage, which would be sufficient to store the volume of water generated by the 1 in 100 year event with climate change. The impacts of such a scenario occurring are flooding of commercial/retail properties and associated car parking areas in the vicinity of the pumping station. These uses are classified under PPS25 as 'less vulnerable' usage. The residual flood risk associated with failure of the Ramsey River is therefore considered to be low.

Tidal Flood Defence Breach

The breach modelling undertaken as part of this SFRA should be used to inform upon the consequences of a breach in the defences. The modelling also demonstrates the impact of overtopping during the climate change scenario. The results presented as Figures D-1 to D-54 within Appendix D should be used to consider the sustainability and appropriateness of the potential residual risk management options contained below:

9.3.1 Potential Evacuation and Rescue Routes

The Environment Agency currently consider an evacuation route safe if it can be demonstrated, through a site specific breach analysis for the 1 in 200 year probability event, that the site falls within a 'low hazard rating' as defined by Figure 3D within Appendix D. The hazard zone categories are comparable with the categories presented within the document 'FRA Guidance for new development: Phase 2 FD2320/TR2' with the debris factor removed.

The hazard associated with the 1 in 1000 year probability event should also be considered, as this will allow Emergency Services and Emergency Planners to consider the suitability of the route, in line with PPS25. If potential evacuation routes are likely to become inundated so that safe access/egress would not be possible, then the proposed development should ideally be relocated. This may also be the case should the possible evacuation routes be particularly long or across difficult terrain.

A key consideration in relation to the presence and use of evacuation routes is the vulnerability and mobility of those in danger of being inundated. Development for highly vulnerable users e.g. disabled or the elderly should be located away from high-risk areas. The Sequential Test does not however differentiate between the vulnerability of the end users of the site, only the vulnerability of the intended use 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.

9.3.2 Time to Peak of Flood Hazard

The time to peak 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 setback from the flood defence.

9.3.3 Methods of Managing Residual Flood Risk

The following sub-sections outline various methods available for the management of residual flood risk. The methods outlined will not be appropriate for all development types or all geographical areas. Therefore, they should be considered on a site-by-site basis. In addition, it is important that the use of such techniques do not exacerbate flooding elsewhere within the flood cell.

Recreation, Amenity and Ecology

There are many different ways in which 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. They range from the development of parks and open spaces through to river restoration schemes. In addition, they have wider ecological, biodiversity and sustainability benefits.

The basic function of these techniques is increased flood storage and the storage or conveyance of rainwater. Typical measures include various guises of pools, ponds, and ditches. These all can have the added benefit of improving the ecological and amenity value of an area. These features can provide a haven for local wildlife. In addition, they can contribute to a sites amenity value both aesthetically and for recreation by providing attractive areas available for activities such as walking, cycling, water sports or wildlife watching. However it is appreciated that these techniques would be very difficult to implement within substantially built up areas such as Harwich, and in particular the Harwich peninsula where a lack of space is likely to prevent such techniques from being implemented.

Secondary Defences

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.

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

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 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 within the flood cell. Level for level compensatory storage should be provided where any loss of floodplain storage has occurred as a result of land raising or developing within the undefended floodplain.

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.

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.

Finished Floor Levels

Where developing in flood risk areas is unavoidable, the most common method of mitigating flood risk to people is to ensure habitable floor levels are raised above the maximum flood water level. The Environment Agency suggest that 300mm freeboard above the 1 in 200 year flood levels including climate change are used when setting finished floor levels (600mm freeboard is required for less precisely computed levels). It is also necessary to ensure that proposed road levels are set above the 1 in 1000 year flood level including climate change where possible, to ensure that emergency access and evacuation routes are maintained. These measures can significantly reduce the risk of the proposed development becoming inundated by flooding. As with the land raising option, it is imperative that any assessment takes into consideration the volume of floodwater potentially displaced by such raising.

Flood Resilience

The Association of British Insurers in cooperation with the National Flood Forum has produced 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 DCLG's 2008 report, Improving the Flood Resilience of New Buildings and the ODPM's 2003 report, 'Preparing for Floods' (ODPM, 2003b).

Summary

The results of the breach modelling carried out for this Level 1 SFRA have confirmed that the existing defences will be overtopped when considering the effects of climate change based on PPS25 recommended allowances.

In order for Tendring DC to protect the existing development, infrastructure and associated population of Harwich, to existing standards, throughout the latter period of this century and into the next, additional flood risk management measures will be required. The measures presented throughout this report summarise options that could be implemented within Harwich, however further consideration will be required during the production of the Level 2 SFRA report as to their feasibility.

9.4 Emergency Planning

Tendring DC does not currently have a specific emergency flood plan, however a Peacetime Emergency Plan has been developed to respond to any emergency incidents that occur within the District, including flooding.

During a flood the main function of the Tendring DC would be to provide temporary accommodation to any displaced people until such time that they are in a position to return to their homes or their insurance companies can arrange temporary accommodation for them. This shelter is provided in the form of rest centres, and provides a warm dry place to sleep and basic facilities including shower, food, etc.

It is recommended that Tendring DC should prepare a specific emergency flood plan, informed by the information presented and the conclusions of this SFRA.

PPS25 classifies police stations, ambulance stations, fire stations and command centres as Highly Vulnerable buildings. Hospitals and care homes are classified as More Vulnerable establishments. In the event of an emergency, to ensure that those services vital to the rescue operation are not impacted by flood water, it is essential that all establishments related to these services are located in the lowest flood risk zones. In addition future development control polices should seek to locate more vulnerable institutes such as schools and care homes in areas of the lowest risk to minimise the potential for flood casualties.

The nominated rest and reception centres in Harwich have been identified and presented within Figure 9. This demonstrates that the nominated locations lie within Flood Zone 1and are therefore at low risk of flooding. These locations therefore appear to be appropriately situated, however further consideration of designated centres and evacuation routes should be undertaken during preparation of a specific emergency flood plan.

The following developments are typically suitable for such use as refuge and/or reception centres:

- Leisure centres;
- Churches;
- Schools; and
- Community Centres.

Table D.2 of PPS25 (Table 6-2) classifies 'Highly Vulnerable' developments, hence those that should be taken into consideration in the event of an emergency as:

- Hospitals; Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels;
- Student halls of residence; and,
- Non-residential uses for health service, nurseries and educational establishments.

Situations may arise in an emergency where the occupants of the above institutions cannot be evacuated (such as prisons). Therefore particular significance must be given to these development types when looking to allocate them. Individual flood emergency plans will be required for such developments in addition to the overall flood emergency plan produced by Tendring DC.

10 Sustainable Drainage Systems

10.1 Background

SuDS are typically softer engineering solutions such as ponds and swales which mimic natural drainage processes by managing water as close to its source as possible. Wherever possible, SuDS techniques should seek to contribute to each of the three goals identified below, with the preferred solution contributing significantly to each objective. SuDS solutions for specific sites should seek to:

- Reduce flood risk (to the site and neighbouring areas);
- Reduce pollution, and;
- Provide wildlife and landscape benefits.

The Interim Code of Practice for Sustainable Drainage Systems 2004, produced by CIRIA outlines how these goals can be achieved through implementation of a chain of techniques. Each component adds to the performance of the overall system, whereby techniques are applied right through from site management procedures through to consideration of a wider catchment as outlined below:

- **Prevention** – good site design and management to reduce run-off and pollution e.g. minimise impermeable areas, regular pavement sweeping;
- **Source control –**control of run-off at/near source e.g. rainwater harvesting, green roofs, permeable pavements;
- **Site control –** water management from several different catchments e.g. route water from roofs and impermeable areas to single infiltration/attenuation point;
- **Regional control –** integrate run-off from multiple sites e.g. use of detention pond

10.2 Why use SuDS?

Traditionally, built developments have utilised piped drainage systems to manage surface water and convey surface water run-off away from developed areas as quickly as possible. Typically these systems connect to the public sewer system for treatment and/or disposal to local watercourses. Whilst this approach rapidly transfers surface water from developed areas, the alteration of natural drainage processes can potentially impact on downstream areas by increasing flood risk and reducing water quality.

Due to the difficulties associated with upgrading sewer systems it is uncommon for sewer and drainage systems to keep pace with the rate of development/redevelopment and the increasingly stringent drainage discharge restrictions that are being placed upon them. As development continues and/or urban areas expand these systems can become inadequate to deal with the volumes of surface water that is generated, resulting in increased flood risk and/or pollution to watercourses. Allied to this are the implications of climate change and increasing rainfall intensities.

SuDS also have wider sustainability advantages by creating opportunities for landscaping and incorporation of habitats for wildlife.

10.3 SuDS Techniques

SuDS techniques can be used to reduce the rate and volume and improve the water quality of surface water discharges from sites to the receiving environment (i.e. natural watercourses or public sewers etc). Various SuDS techniques are available and operate under two main principles:

- Infiltration, and;
- Attenuation.

Due consideration should be given to appropriate SuDS techniques throughout preparation and development of the overall drainage strategy for individual development sites. A ground investigation will be required in order to determine whether infiltration techniques are feasible or whether attenuation techniques are more appropriate. The volume of on-site storage required should be calculated through hydrological analysis using industry approved procedures to ensure that a robust design storage volume is provided.

During the design process, liaison should take place with Tendring DC, the Environment Agency and if necessary, Anglian Water to establish a satisfactory design methodology and permitted rate of discharge from the site.

The application of SuDS is not limited to a single technique per site. In fact, the most successful SuDS solutions often utilise a combination of techniques, in order to provide flood risk, pollution and landscape/wildlife benefits. In addition, SuDS can be implemented on a strategic scale, for example with a number of sites contributing to large scale jointly funded and managed scheme. However it should be noted that each individual development site must provide storage to offset its own increase in runoff and attenuation cannot be 'traded' between developments.

A summary of available techniques is contained in shown overleaf in Table 10-1 below which provides a clear hierarchy reflecting the sustainability offered by each technique.

Most sustainable

SuDS Technique	Flood Reduction	Water Quality Improvements	Wildlife & Landscape Benefits
Green roofs	✓	✓	✓
Basins and ponds - constructed wetlands - balancing ponds - detention basins - retention ponds	✓	✓	✓
Filter strips and swales	✓	✓	✓
Infiltration devices - soakaways - infiltration trenches and basins	✓	✓	✓
Permeable surface and filter drains - gravelled areas - solid paving blocks - porous paving	✓	✓	
Tanked systems - over-sized pipes/tanks - storm cells	✓		

Least sustainable

Table 10-1: SuDS Hierarchy

10.4 Where can SuDS be utilised?

The underlying ground conditions of a development site will often determine the most appropriate type of SuDS solution to be used. This will need to be determined through ground investigations carried out on a site by site basis. However an initial assessment of the suitability of SuDS techniques can be carried out on a strategic scale through a review of geological mapping.

The Solid and Drift Deposits Geology throughout Harwich has been established from analysis of BGS geological mapping at 1:50,000 scale. As shown in Figure 2A, the solid geology is dominated by the presence of London Clay throughout Harwich, which typically consists of very fine grains and is therefore highly impermeable. Due to the very limited permeability of London Clay it would be appropriate to utilise attenuation systems when considering drainage design throughout Harwich.

As shown in Figure 2B there are significant areas of Harwich where the BGS mapping indicates that no drift deposits are present above the London Clay. In these areas the use of infiltration systems is highly unlikely to be feasible, as discharge directly into the impermeable London Clay would be required. However drift deposits can be found within a central band across Harwich, where the Kesgrave Formation is present above the London Clay. The Kesgrave Formation consists of sands and gravels therefore infiltration systems may prove to be feasible for sites in these areas, depending on the depth of sand and gravels present on site.

The presence of Alluvium along the fluvial and tidal floodplains within Harwich indicates low permeability therefore infiltration systems are unlikely to prove feasible in these locations. Alluvium deposits are generally created through deposition of material eroded through coastal and fluvial processes, and typically consist of clay, silt, sand and gravel. Alluvium is generally considered to be impermeable therefore it is highly unlikely that infiltration systems will prove feasible in these locations.

In general, the conclusion of the geological mapping review is that attenuation systems are likely to be the most feasible SuDS system throughout the majority of Harwich. However infiltration systems may prove feasible within the elevated central band of Harwich, where sands and gravels are present. These elevated areas also represent the key location to implement SuDS systems in order to minimise the total volume of run-off to lower lying surrounding areas through infiltration techniques.

10.5 Further Information

The above information is intended to provide an introduction to the use of SuDS and broad recommendations as to where techniques may be appropriate. The options available for provision of SuDS is not limited to those presented within this chapter and new techniques will be developed as time progresses. Chapter 13 includes a list of relevant reference material which contains further detailed information on SuDS, their benefits, limitations and how they can be utilised to maximum effect.

11 Site Specific FRA Guidance

Site specific flood risk assessments are required to assess the flood risk posed to proposed developments and to ensure that where necessary and appropriate, suitable mitigation measures are incorporated. This section presents recommendations for flood risk assessments prepared for submission with planning applications in Harwich. The guidance presented within this chapter has been based on:

- the recommendations presented within Planning Policy Statement 25 and the 'Living Draft' Practice Companion Guide to PPS25;
- a review of local policies contained within Tendring DC's Local Plan 2007, and;
- the information provided to enable preparation this Level 1 SFRA.

11.1 When is a Flood Risk Assessment Required?

When deciding if a FRA is required the piper networking site http://www.pipernetworking.com/floodrisk/ should initially be referred to determine whether or not the Environment Agency should be consulted.

When informing developers of the requirements of a flood risk assessment 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.

In the following situations a Flood Risk Assessment should always be provided with a planning application:

1. The development site is located in **Flood Zone 2 or 3**;
2. The proposed development comprises 10 or more residential dwellings and/or the site area is greater than 1 hectare **(even if the site is located 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);
3. The floor space of proposed non-residential development is **greater than 1000m^2** or the site areas is **greater than 1 hectare**;
4. The development site is located in an areas known to have experienced flooding problems from any flood source; and,
5. The development is located within 20m of top of bank of a main river watercourse regardless of Flood Zone classification.

11.2 FRA Requirements

The Practice Guide Companion to PPS25 (consultation document) advocates a staged approach to site specific flood risk assessment with the findings from each stage informing both the next level and the site masterplan, iteratively throughout the development process.

The staged approach comprises:

- Level 1 Screening Study
- Level 2 Scoping Study

- Level 3 Detailed Study

Level 1 - Screening Study

A Level 1 Screening Study is intended to identify if a development site has any flood risk issues that warrant further investigation. This should be based on existing information such as that presented in the Level 1 SFRA. Therefore this type of study can be undertaken by a development control officer in response to the developer query or by a developer where the Level 1 SFRA is available. Using the information presented in the Level 1 SFRA, and associated GIS layers, a development control officer could advise a developer of any flooding issues affecting the site. This should include a review of local structures that could potentially become blocked during a flood event. Developers can use this information to further their understanding of how the flood risk could potentially affect their development.

Level 2 - Scoping Study

A Level 2 Scoping Study is predominately a qualitative assessment designed to further understanding of how the flood sources affect the site and the options available for mitigation. The Level 2 FRA should be based on existing available information to further a developers understanding of flood risks and how they affect their development. This type of assessment should also be used to inform masterplans of the site raising a developer's awareness of the additional elements the proposed development may need to consider.

Level 3 – Detailed Study

Where the quality and/or quantity of information for any of the flood sources affecting a site is insufficient to enable a robust assessment of the flood risks, further investigation will be required. For example it is generally considered inappropriate to base a flood risk assessment for a residential care home at risk of flooding from fluvial sources on Flood Zone maps alone. In such cases the results of hydraulic modelling are preferable to ensure details of flood flow velocity, onset of flooding and depth of flood water is fully understood and that the proposed development incorporates appropriate mitigation measures.

At all stages, Tendring DC and where necessary the Environment Agency and/or Anglian Water should be consulted to ensure the FRA provides the necessary information to fulfil the requirements for Planning Applications.

11.3 FRA Guidance

The Environment Agency has developed a website http://www.pipernetworking.com/floodrisk/ to provide standing advice on FRA requirements, which includes a matrix to determine the level of assessment that is required based on Flood Zone classification and development type.

The standing advice is currently being updated and is due to be released in summer 2008. It is understood that the guidance will be available directly through the Environment Agency's website http://www.environment-agency.gov.uk which should be referred to for updated FRA guidance in the future.

Risks of Developing in Flood Risk Areas

Developing in flood risk areas can result in significant risk to a development and site users. The Environment Agency's standing advice 1 should identify the main flood risks posed to the site, additional issues to consider include:

- 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 result in redesign of the site to mitigate flood risk;
- 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-sellable if flood risk management is not adequately provided for the lifetime of the development;
- By installing SuDS without arranging for their adoption or maintenance the SuDS will eventually cease to operate as designed and may 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.

Advice from the Environment Agency's National Development Control Policy team regarding brownfield functional floodplain is that, for redevelopment of functional floodplain, the Environment Agency will consider existing building footprints to be part of the functional floodplain, unless it can be proven that they exclude flood waters. If these buildings do exclude flood waters, then solely the area around these buildings will be deemed functional. When undertaking an FRA this matter should be clarified and ideally pre-agreed with the Environment Agency.

Safe Development

Furthermore, the following items should be addressed as part of a Flood Risk Assessment in order to demonstrate that proposed developments are 'safe' in line with PPS25. The Environment Agency has specified that the following should be achieved for all development vulnerability types in order to demonstrate safe development:

- Dry access and egress should be provided for all development where possible.. Dry escape for residential dwellings should be up to the 1 in 100 year event for fluvial events and 1 in 200 year for a tidal event taking into account climate change for the lifetime of the development.
- Finished floor levels should be set at or above the 1 in 100 year plus climate change level (fluvial) and 1 in 200 year plus climate change level (tidal).
- Where floodplain compensation is undertaken the Environment Agency requires this is on a 'Level for Level, Volume for Volume Basis'.
- Flood flow routes should be preserved.

- Flood resilient constructions measures should be incorporated into new developments.

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 should consult the Environment Agency on a site by site basis to establish an appropriate definition of 'safe' development for specific sites.

12 Conclusions and Recommendations

12.1 Summary

The process of the Sequential Test outlined in PPS25 aims to steer vulnerable development to areas of lowest flood risk. The SFRA aims to facilitate this process by identifying the variation in flood risk across Harwich allowing an area-wide comparison of future development sites with respect to flood risk considerations.

The SFRA presents Flood Zone Maps that delineated the flood zones outlined in PPS25 as Flood Zone 1, low probability, Flood Zone 2, medium probability and Flood Zone 3a, high probability. In addition, Flood Zone 3b, functional floodplain, has also been mapped. Table D.1 of PPS25 provides information on which developments might be considered to be appropriate in each flood zone, subject to the application of the Sequential Test and either the Exception Test or a site-specific Flood Risk Assessment demonstrating safety.

Hydrodynamic modelling has been undertaken to produce additional outputs regarding flood hazard and depths, to provide a better understanding of the spatial variations of flood risk within the Flood Zone 3a. This information can then be used to inform the Sequential Test and inform future developers.

The results of the modelling demonstrate that when considering the predicted increase in sea level due to climate change the existing defences will be overtopped during extreme tidal events. The consequences of this scenario are significant flood depths with associated high hazards which could prevent future development based on current planning policy.

12.2 Recommendations

A Living Document

This study has been completed in accordance with PPS25 and the current guidance outlined in the draft Development and Flood Risk: A Practice Guide Companion to PPS25 ‘Living Draft’ (Feb 2007). The SFRA has been developed by building heavily upon existing knowledge with respect to flood risk within the study area.

These documents have an intended lifespan of 6-10 years, with local development documents and potential development sites typically revised within 3-6 years. Therefore it should be noted that although up-to date at the time of production, the SFRA has a finite lifespan and should potentially be upgraded or revised as required by the local authorities.

In summary, it is imperative that the SFRA is adopted as a ‘living’ document and is reviewed regularly in light of emerging policy directives and an improving understanding of flood risk within each of the Local Authority areas.

Tendring District Council Approach

As this report is a Level 1 SFRA, site-specific allocations have not been considered at this stage therefore the following recommendations are made by way of an indication of how to proceed with the SFRA process:

- Tendring DC should apply the Sequential Test to the potential development sites and identify those sites they consider will be necessary to apply the Exception Test,
- If sites require the Exception Test a Level 2 SFRA will be undertaken to provide further flood risk information in key development areas,
- Tendring DC should consider responses to parts ‘a’ and ‘b’ of the Exception Test for each of the allocation sites.

This SFRA has identified that the existing defences will be overtopped during the climate change scenarios resulting in significant flood depths and hazards. The model outputs demonstrate that future development in such areas is unlikely to be acceptable based on current planning policy.

Tendring DC has a responsibility to protect existing development and infrastructure from the impacts of climate change where technically and economically feasible. In addition to this future regeneration projects are planned for key areas, such as the Harwich peninsula, which is particularly susceptible to sea level rise due to its position.

It is therefore recommended that potential flood risk management options are investigated further within the Level 2 SFRA through consultation with the Environment Agency. This will enable a robust analysis of potential solutions to be undertaken to establish the preferred method in which to promote sustainable development.

13 References

- BRE. Digest 365 (2003) Soakaway Design. Building Research Establishment.
- British Water (2005) Technical Guidance, Guidance to Proprietary Sustainable Drainage Systems and Components – SuDS. In partnership with the Environment Agency
- BSRIA Ltd. (1997) Water Conservation: Implications of Using Recycled Greywater and Stored Rainwater in the UK. Report 13034/1. Drinking Water Inspectorate, Department of the Environment.
- CIRIA 625 (2003) Model Agreements for Sustainable Water Management Systems – Review of Existing Legislation. RP664.
- CIRIA 626 (2003) Model Agreements for Sustainable Water Management Systems – Model Agreement for Rainwater and Greywater Use Systems. P Shaffer, C Elliott, J Reed, J Holmes and M Ward.
- CIRIA C521 (2000) Sustainable Urban Drainage Systems - Design Manual for Scotland and Northern Ireland. Sustainable Urban Drainage Scottish Working Party.
- CIRIA C522 (2000) Sustainable Urban Drainage Systems - Design Manual for England and Wales. Department of Environment Transport Regions.
- CIRIA C523 (2001) Sustainable Urban Drainage Systems, Best Practice Manual for England, Scotland, Wales and Northern Ireland.
- CIRIA C539 (2001 Rainwater and Greywater Use in Buildings: Best Practice Guidance. D J Leggett, R Brown, D Brewer, G Stanfield and E Holiday. Department of Trade and Industry.
- CIRIA C609 (2004 Sustainable Drainage Systems, Hydraulic, Structural and Water Quality Advice. S Wilson, R Bray and P Cooper. Department of Trade and Industry.
- CIRIA C697 (2007) The SuDS Manual. Woods Ballard B; Kellagher R et al.
- Construction Industry Research and Information Association. 1996. Report 156 – Infiltration Drainage – Manual of Good Practice. Roger Bettess. Highways Agency and National Rivers Authority.
- National SuDS Working Group. 2004. Interim Code of Practice for Sustainable Drainage Systems. National SuDS Working Group. ISBN 0-86017-904-4.
- Eastern and Central Areas Report on Extreme Sea Levels, Environment Agency, Anglian Region. Royal Haskoning, February 2007
- Tendring District Local Plan 2007. Tendring District Council, December 2007
- Sea Defence Survey, October 2006. Tendring District Council, October 2006.
- Tendring Coast Protection Strategy 2002 to 2007. Tendring District Council, 2002.
- Preparing for Floods. ODPM, 2003b.
- Flood Performance of New Buildings, DCLG, 2008

- Flood Risk Assessment Guidance for New Development: Phase 2, R&D Technical Report FD2320/TR2, DEFRA/Environment Agency, 2005

14 Appendices

Appendix A – Figures

Appendix B – Data/Contacts Register and Correspondence

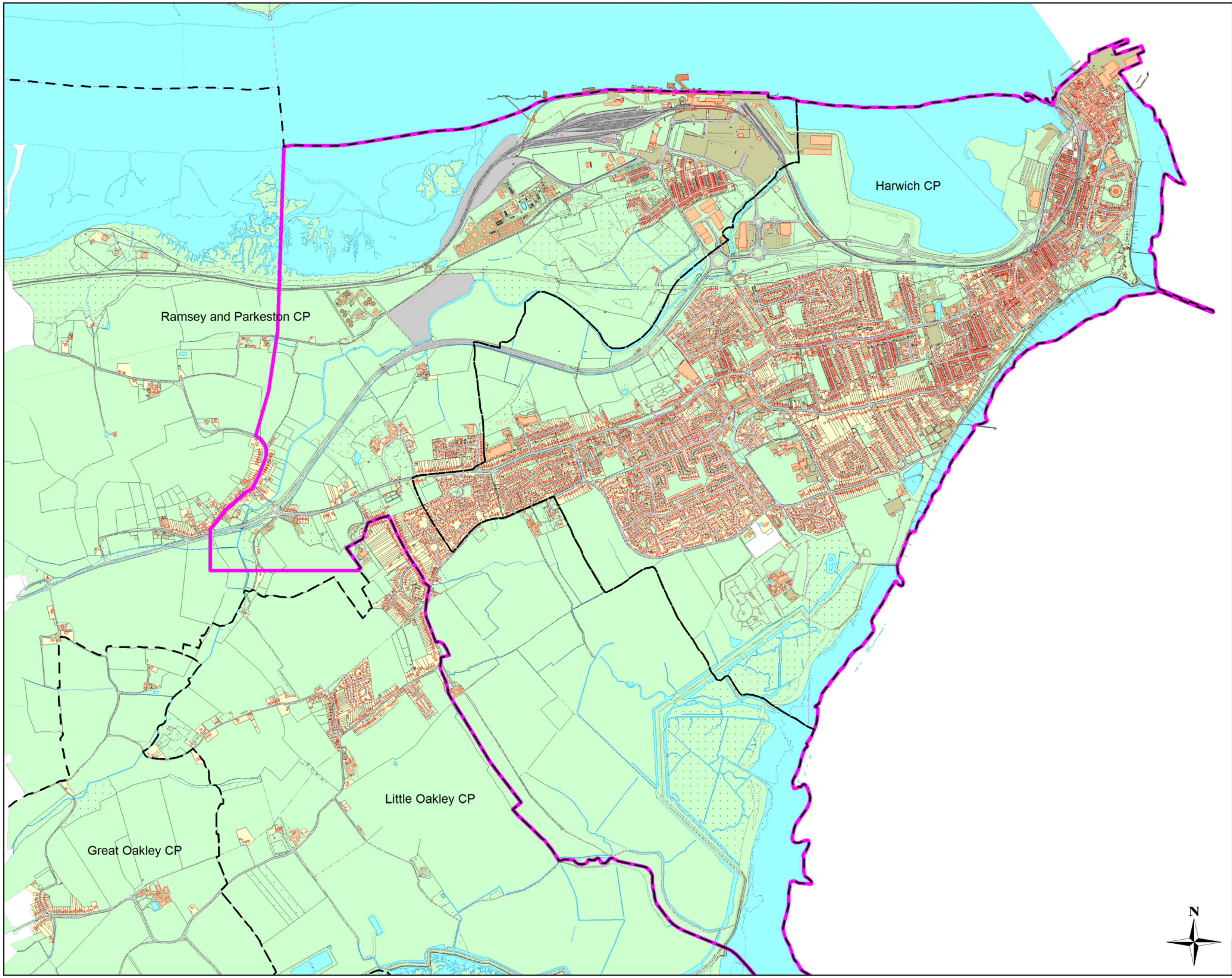
Appendix C – Ramsey River Modelling

Appendix D – Hydrodynamic Breach Modelling

Appendix E – Sequential Test Tables

Appendix F – Sustainable Drainage Systems

Appendix A – Figures



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED AND ONLY WRITTEN DIMENSIONS SHALL BE USED

Notes

Study Area

County Parish Boundaries

Revision	By / Check	Date	Suffix
Draft	TE / JR	02/08	0

Drawing Status: FINAL

Job Title: HARWICH STRATEGIC FLOOD RISK ASSESSMENT

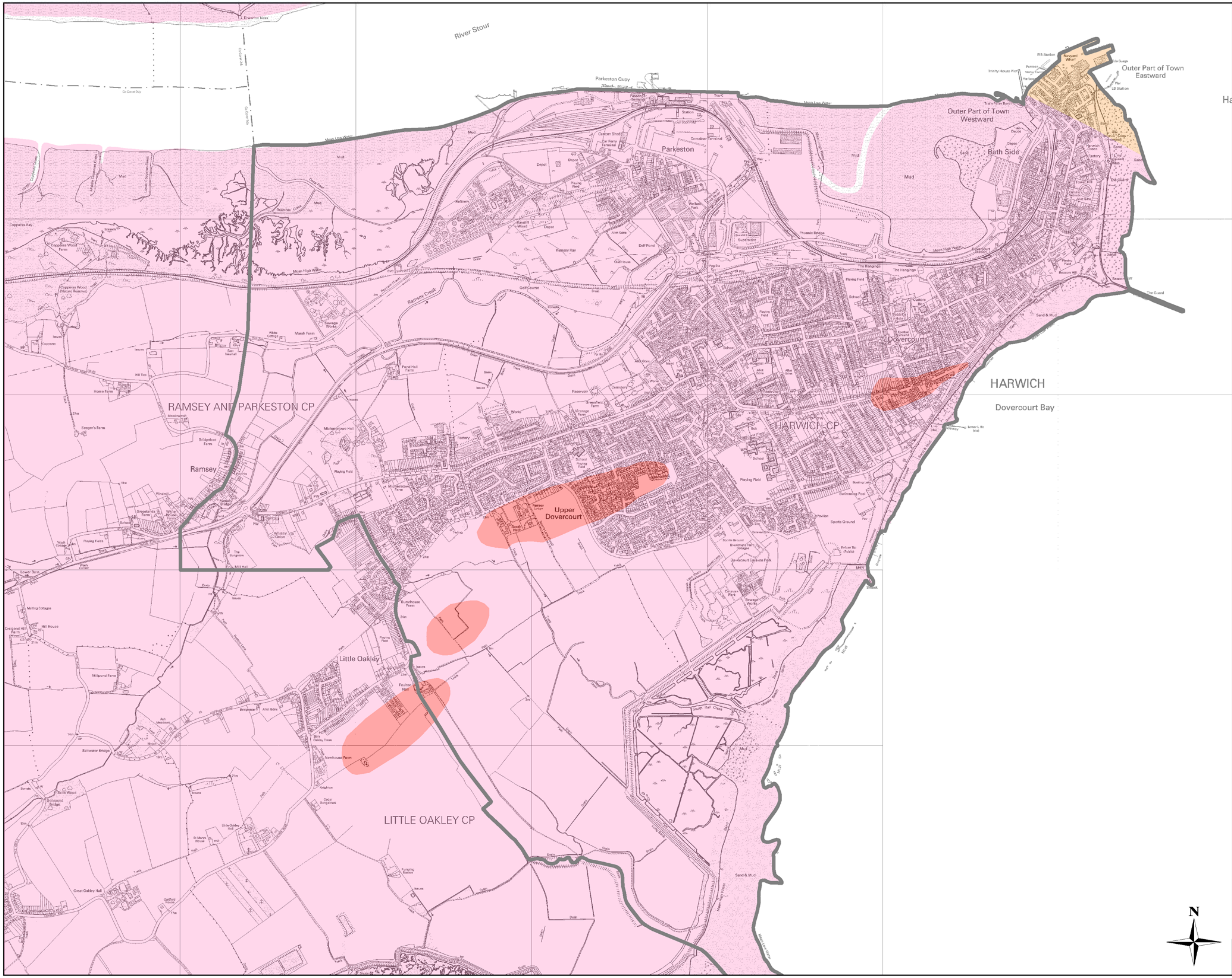
Drawing Title: STUDY AREA BOUNDARY

Scale at A3: 1:20,000

Drawn	TE	Approved	JR
Stage 1 Check: TE	Stage 2 Check: JR	Originated: TE	Date: 04/08

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Telephone +44 (0)20 7798 5000
Fax +44 (0)20 7798 5001
www.scottwilson.com

Drawing Number: **FIGURE 1**



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED AND ONLY WRITTEN DIMENSIONS SHALL BE USED

Notes

Study Area

Indicative Solid Geology

Thanet Sand & Lambeth Group

London Clay

Red Crag

Copyright:

Revision Details	By / Check	Date	Suffix
Draft	TE / JR	02/08	0

Drawing Status: FINAL

Job Title: HARWICH STRATEGIC FLOOD RISK ASSESSMENT

Drawing Title: SOLID GEOLOGY

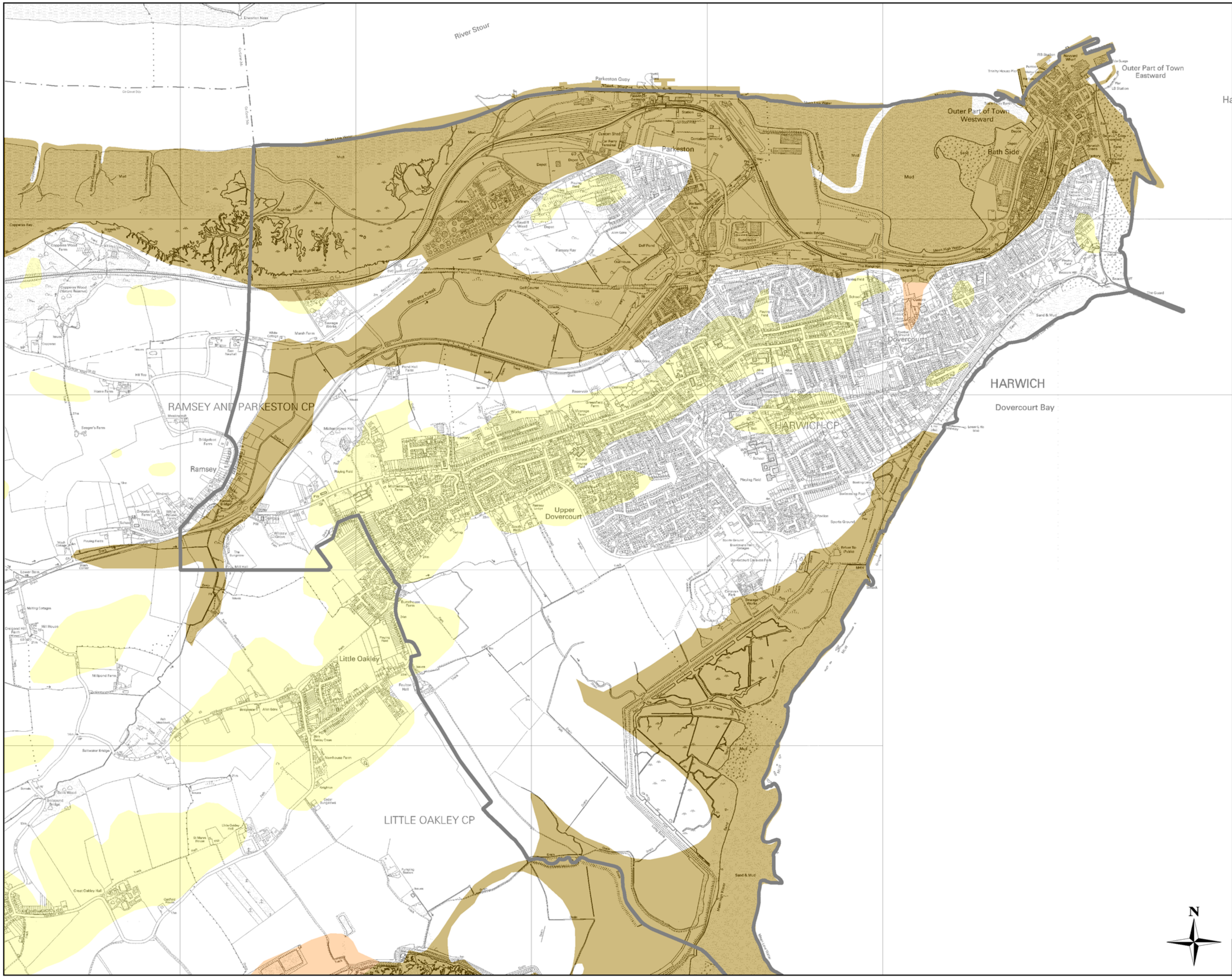
Scale at A3: 1:20,000

Drawn	Approved
TE	JR

Stage 1 Check	Stage 2 Check	Originated	Date
TE	JR	TE	04/08

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Telephone +44 (0)20 7798 5000
Fax +44 (0)20 7798 5001
www.scottwilson.com

Drawing Number: **FIGURE 2A**



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED AND ONLY WRITTEN DIMENSIONS SHALL BE USED

Notes

Study Area

Indicative Drift Deposits Geology

Alluvium

Head (Undifferentiated)

Kesgrave Formation

Revision Details	By / Check	Date	Suffix
Draft	TE / JR	02/08	0

Drawing Status: FINAL

Job Title: HARWICH STRATEGIC FLOOD RISK ASSESSMENT

Drawing Title: DRIFT DEPOSITS GEOLOGY

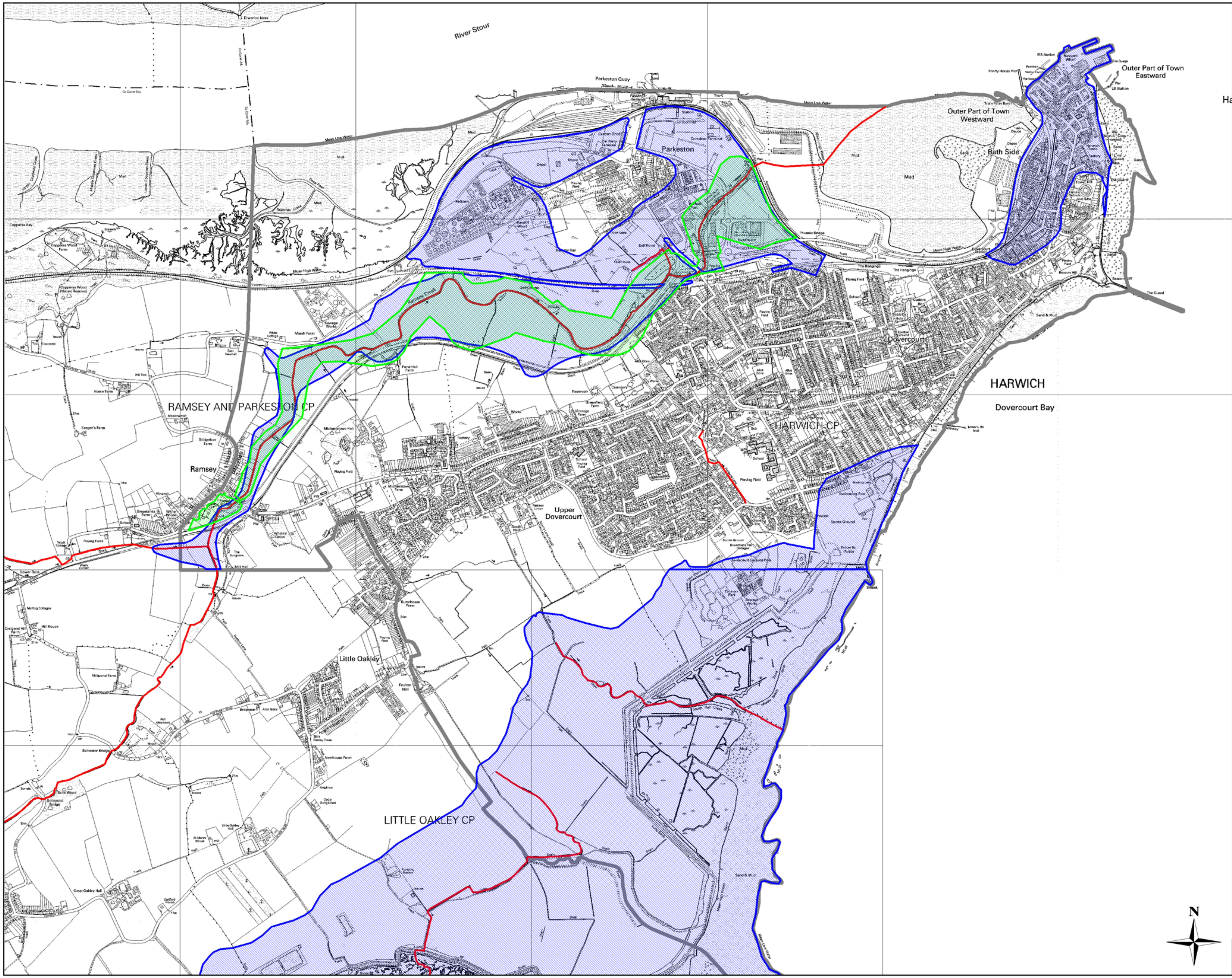
Scale at A3: 1:20,000

Drawn	Approved
TE	JR

Stage 1 Check	Stage 2 Check	Originated	Date
TE	JR	TE	04/08

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Telephone +44 (0)20 7798 5000
Fax +44 (0)20 7798 5001
www.scottwilson.com

Drawing Number: FIGURE 2B



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED AND ONLY WRITTEN DIMENSIONS SHALL BE USED

Notes

- Study Area
- Main River Centrelines
- 1953 North Sea Flood Outline
- 1958 Ramsey River Flood Outline

Revision Details	By / Check	Date	Suffix
Draft	TE / JR	02/08	0

Drawing Status: FINAL

Job Title: HARWICH STRATEGIC FLOOD RISK ASSESSMENT

Drawing Title: HISTORIC FLOODING RECORDS

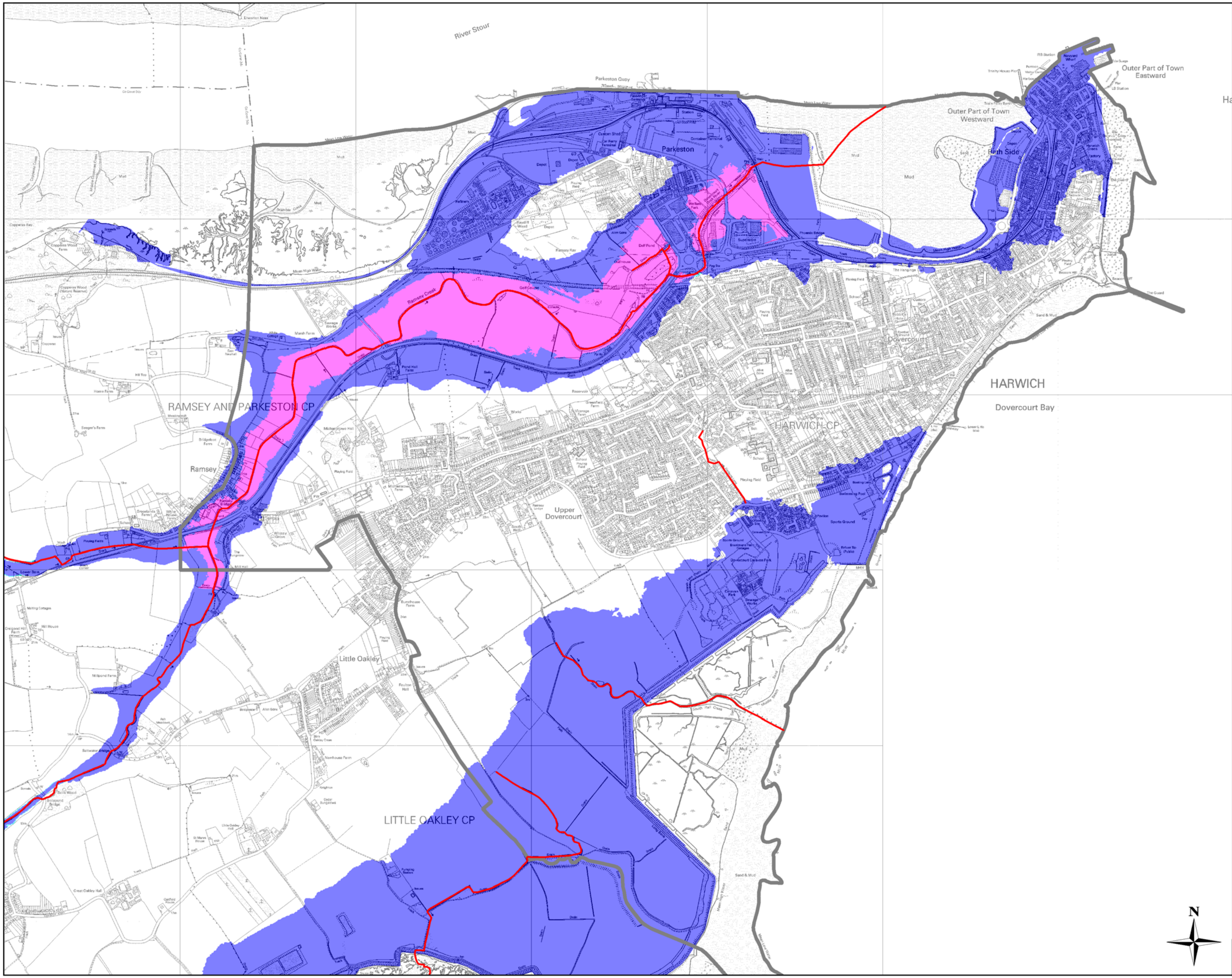
Scale at A3: 1:20,000

Drawn	Approved
TE	JR

Stage 1 Check	Stage 2 Check	Originated	Date
TE	JR	TE	04/08

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Telephone +44 (0)20 7798 5000
Fax +44 (0)20 7798 5001
www.scottwilson.com

Drawing Number: FIGURE 3



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED AND ONLY WRITTEN DIMENSIONS SHALL BE USED

Notes

- Study Area
- Main River Centrelines
- Flood Zone 3b - 2008
- Flood Zone 3a - 2008
- Flood Zone 2 - 2008

Revision Details	By / Check	Date	Suffix
Draft	TE / JR	02/08	0

Drawing Status: FINAL

Job Title: HARWICH STRATEGIC FLOOD RISK ASSESSMENT

Drawing Title: ENVIRONMENT AGENCY FLOOD ZONE MAP - 2008

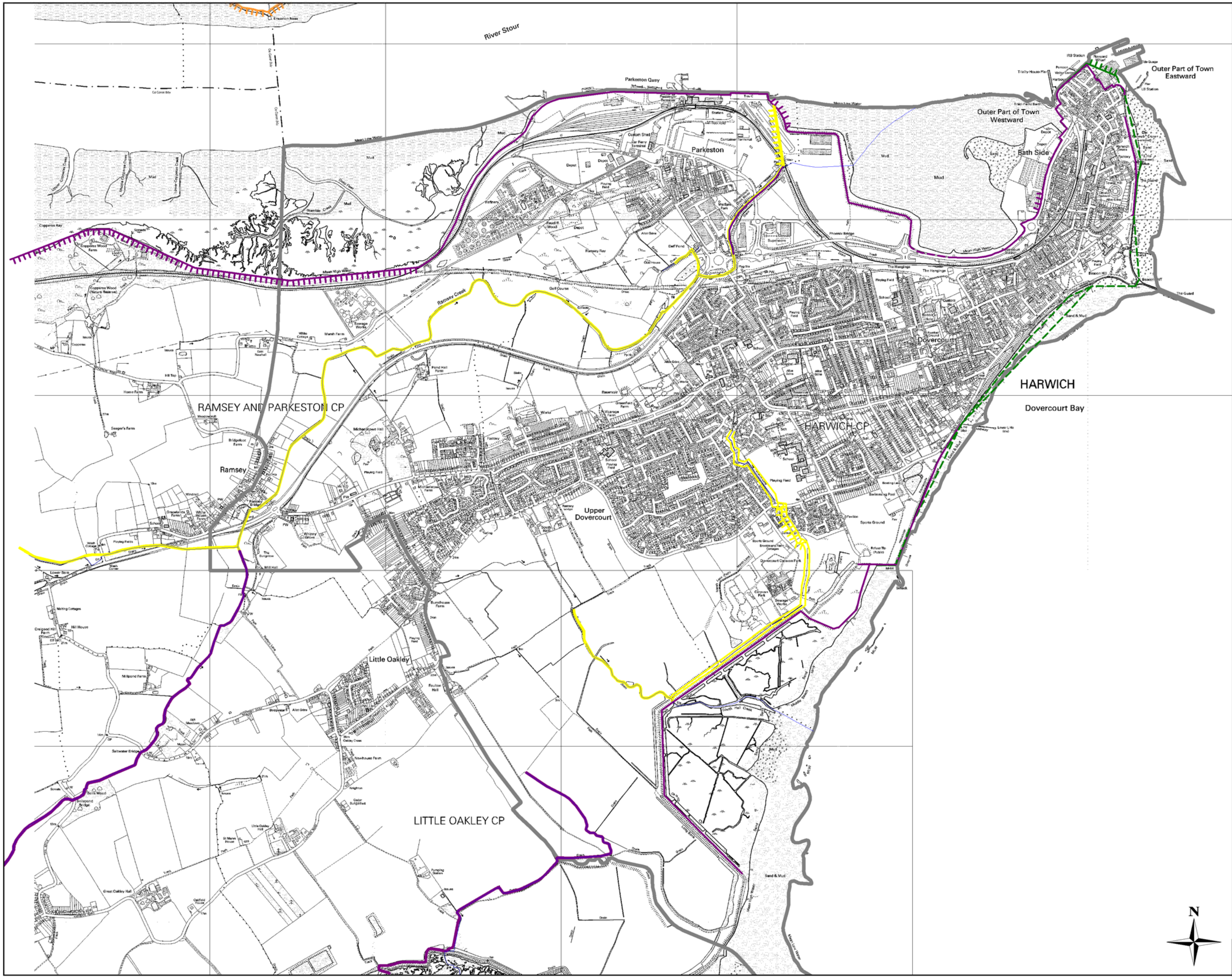
Scale at A3: 1:20,000

Drawn	Approved
TE	JR

Stage 1 Check	Stage 2 Check	Originated	Date
TE	JR	TE	04/08

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Telephone +44 (0)20 7798 5000
Fax +44 (0)20 7798 5001
www.scottwilson.com

Drawing Number: FIGURE 4



Notes

- Study Area
- Main River Centrelines

Flood Defence Design Standard

- 1 in 200 Years
- 1 in 99 Years
- Unknown

Flood Defence Maintainer

- Environment Agency
- Local Authority
- Private

Revision Details	By / Check	Date	Suffix
Draft	TE / JR	02/08	0

Drawing Status: FINAL

Job Title: HARWICH STRATEGIC FLOOD RISK ASSESSMENT

Drawing Title: FLOOD DEFENCES MAP (NFCDD)

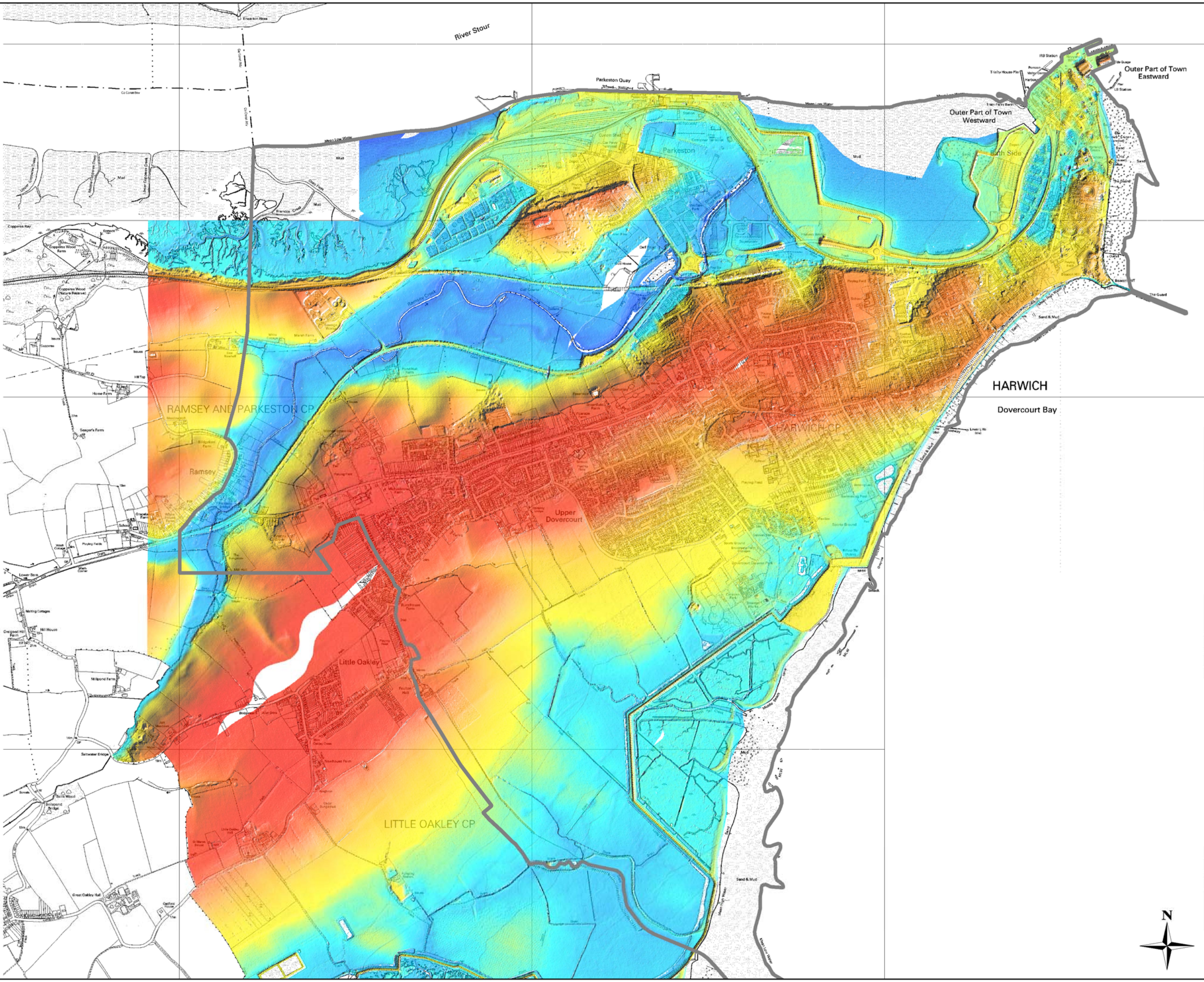
Scale at A3: 1:20,000

Drawn	Approved
TE	JR

Stage 1 Check	Stage 2 Check	Originated	Date
TE	JR	TE	04/08

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Telephone +44 (0)20 7798 5000
Fax +44 (0)20 7798 5001
www.scottwilson.com

Drawing Number: **FIGURE 5**



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED AND ONLY WRITTEN DIMENSIONS SHALL BE USED

Notes

Study Area

Ditigal Terrain Model Elevation (mAOD)

30.0
10.0
5.0
1.5
-2.0

Revision Details	By / Check	Date	Suffix
Draft	TE / JR	02/08	0

Drawing Status
FINAL

Job Title
HARWICH STRATEGIC FLOOD RISK ASSESSMENT

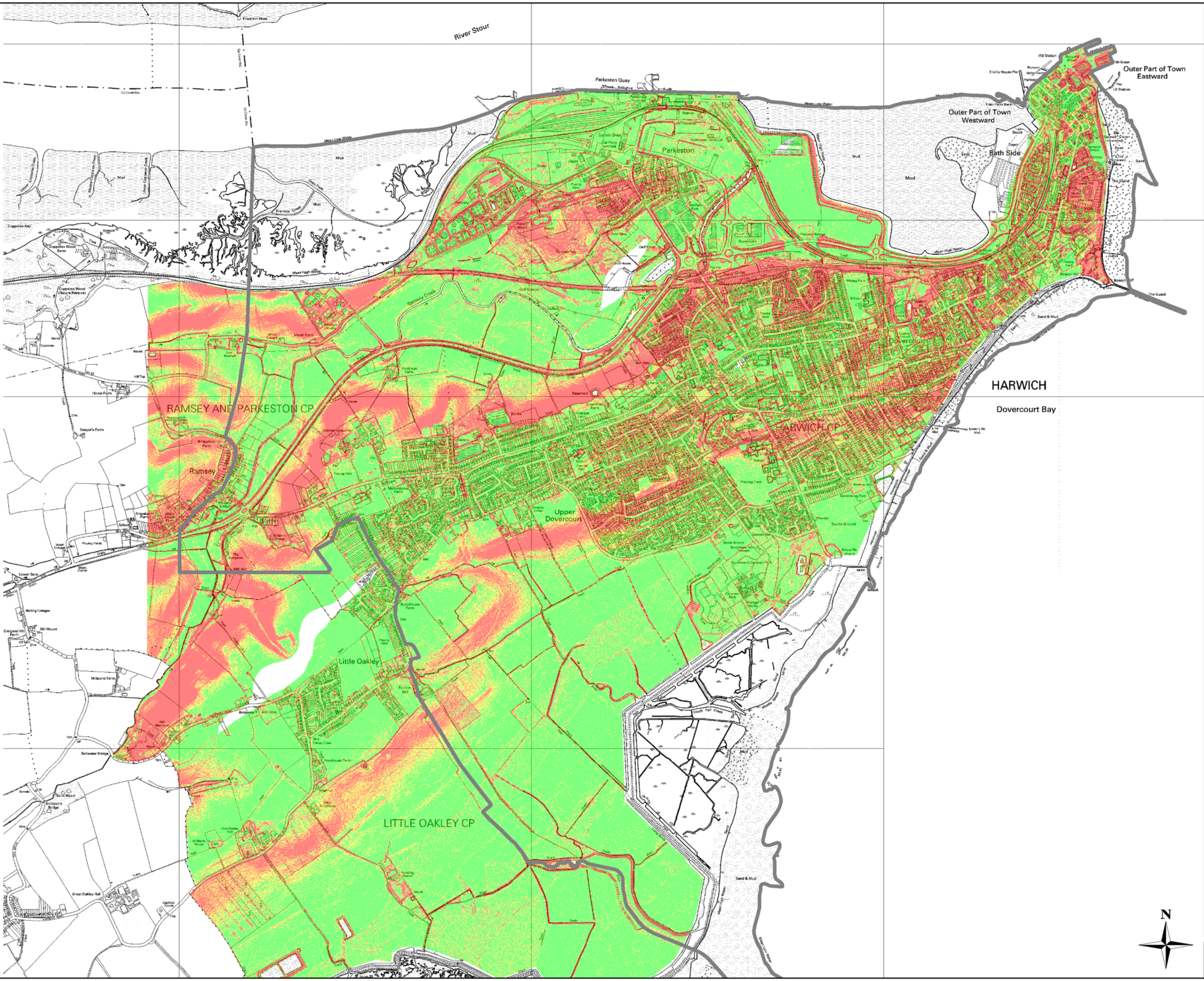
Drawing Title
AERIAL SURVEY LIDAR TOPOGRAPHIC DATA

Scale at A3: 1:20,000

Drawn	TE	Approved	JR
Stage 1 Check: TE	Stage 2 Check: JR	Originated: TE	Date: 04/08

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Telephone +44 (0)20 7798 5000
Fax +44 (0)20 7798 5001
www.scottwilson.com

Drawing Number
FIGURE 6



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED AND ONLY WRITTEN DIMENSIONS SHALL BE USED

Notes

Study Area

DTM Slope

- 0 - 2 degrees
- 2 - 3 degrees
- 3 - 4 degrees
- +4 degrees

Revision Details	By / Check	Date	Suffix
Draft	TE / JR	02/08	0

Drawing Status: FINAL

Job Title: HARWICH STRATEGIC FLOOD RISK ASSESSMENT

Drawing Title: DIGITAL TERRAIN MODEL SLOPE ANALYSIS

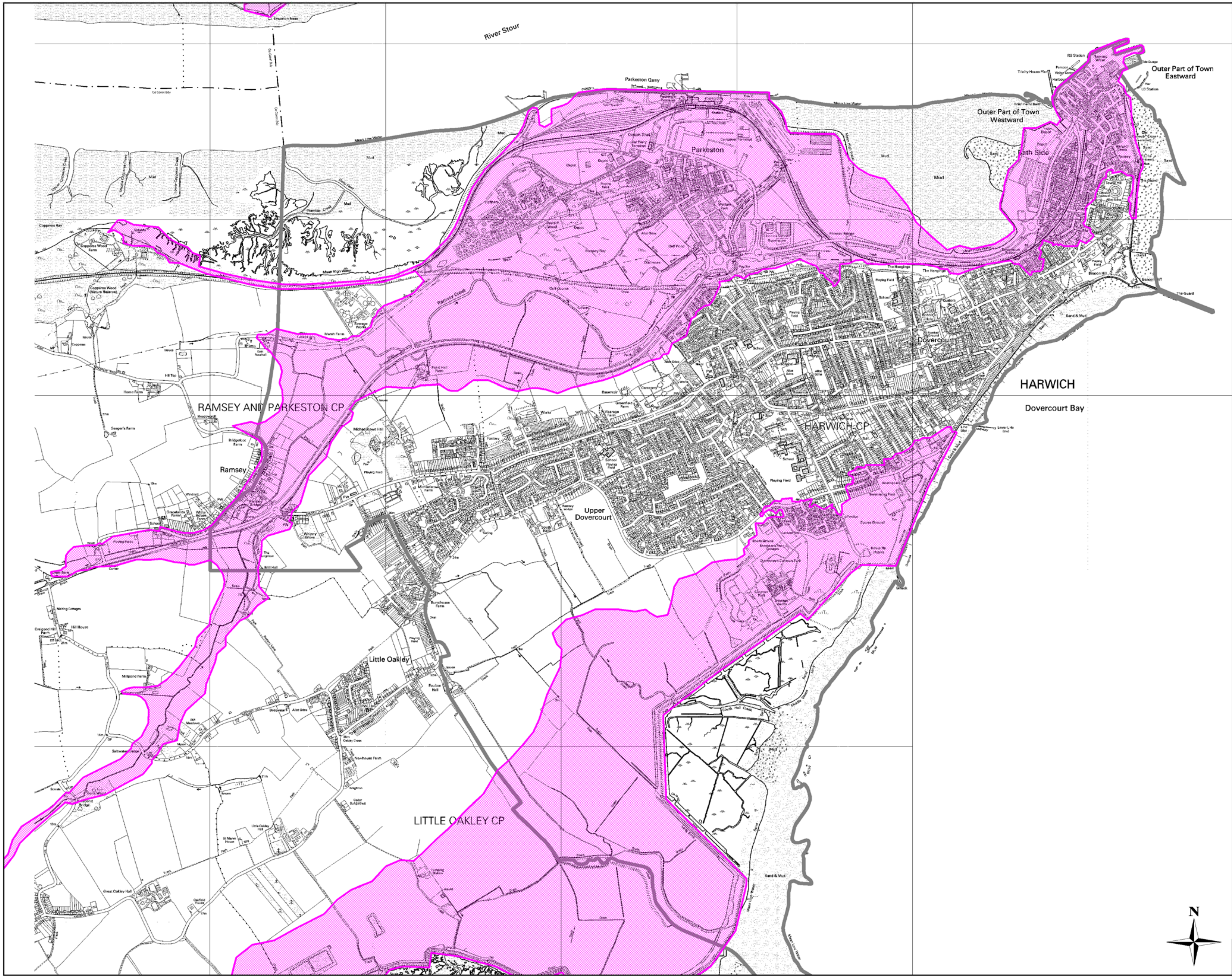
Scale at A3: 1:20,000

Drawn	Approved
TE	JR

Stage 1 Check	Stage 2 Check	Originated	Date
TE	JR	TE	04/08

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Telephone +44 (0)20 7798 5000
Fax +44 (0)20 7798 5001
www.scottwilson.com

Drawing Number: FIGURE 7



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED AND ONLY WRITTEN DIMENSIONS SHALL BE USED

Notes

Study Area

Flood Warning System Coverage

Revision Details	By / Check	Date	Suffix
Draft	TE / JR	02/08	0

Drawing Status: FINAL

Job Title: HARWICH STRATEGIC FLOOD RISK ASSESSMENT

Drawing Title: ENVIRONMENT AGENCY FLOOD WARNING AREAS

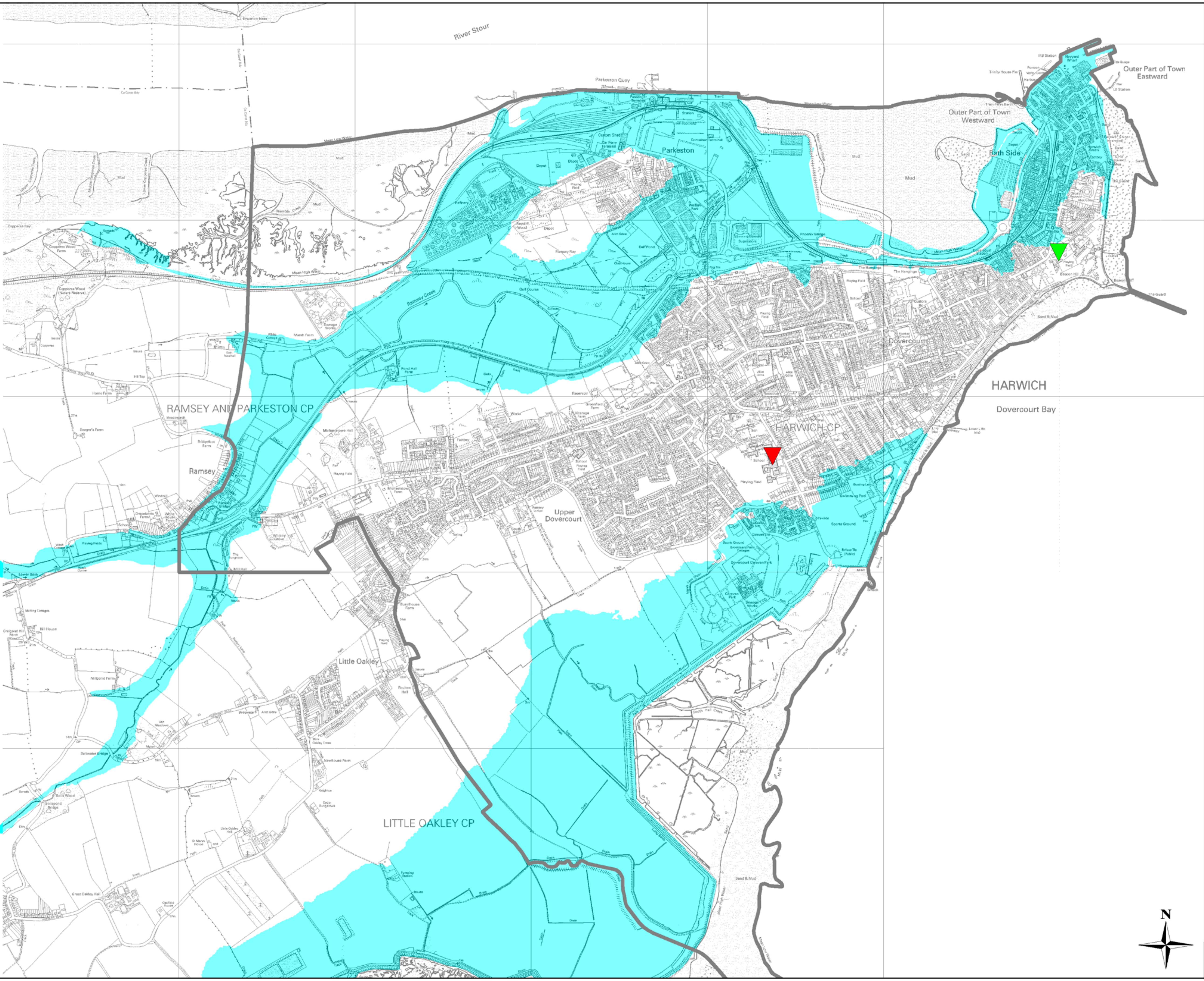
Scale at A3: 1:20,000

Drawn	Approved
TE	JR

Stage 1 Check	Stage 2 Check	Originated	Date
TE	JR	TE	04/08

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Telephone +44 (0)20 7798 5000
Fax +44 (0)20 7798 5001
www.scottwilson.com

Drawing Number: FIGURE 8



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED AND ONLY WRITTEN DIMENSIONS SHALL BE USED

Notes

Study Area

Environment Agency Flood Zone 2 - 2008

Rest Centre

Reception Centre

Revision Details	By / Check	Date	Suffix
Draft	TE / JR	02/08	0

Drawing Status: FINAL

Job Title: HARWICH STRATEGIC FLOOD RISK ASSESSMENT

Drawing Title: EMERGENCY PLANNING

Scale at A3: 1:20,000

Drawn	TE	Approved	JR
Stage 1 Check: TE	Stage 2 Check: JR	Originated: TE	Date: 04/08

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Telephone +44 (0)20 7798 5000
Fax +44 (0)20 7798 5001
www.scottwilson.com

Drawing Number: FIGURE 9

Appendix B – Data/Contacts Register and Correspondence

Data Register

Source	Description	Format
Environment Agency	LiDAR tiles outlines	GIS - Arcview shp
	Flood Zone 2	GIS - Arcview shp
	Flood Zone 3	GIS - Arcview shp
	Study Area (assumed)	GIS - Arcview shp
	LiDAR data request form	GIS - Arcview shp
	Main river centrelines	GIS - Arcview shp
	BGS superficial deposits 50k	GIS - Arcview shp
	BGS bedrock deposits	GIS - Arcview shp
	BGS drift deposits 625k	GIS - Arcview shp
	BGS solid geology 250k	GIS - Arcview shp
	Groundwater resources	GIS - Arcview shp
	Aerial photo locations (assumed)	GIS - Arcview shp
	N Essex CFMP draft report & appendices	Acrobat pdf
	N Essex CFMP final report	Acrobat pdf
	NFCDD data	GIS - Arcview shp
	NFCDD data - deleted Items (assumed)	GIS - Arcview shp
	Coastal frontage reaches	GIS - Arcview shp
	CAMS outline	GIS - Arcview shp
	COWS centreline	GIS - Arcview shp
	District council boundaries	GIS - Arcview shp
	Environmentally sensitive areas	GIS - Arcview shp
	Essex wildlife sites - draft only	GIS - Arcview shp
	Flood warning areas	GIS - Arcview shp
	Flood watch areas	GIS - Arcview shp
	Flood Zone 2	GIS - Arcview shp
	Flood Zone 3	GIS - Arcview shp
	GPS survey stations	GIS - Arcview shp
	Groundwater vulnerability areas	GIS - Arcview shp
	National areas (assumed)	GIS - Arcview shp
	Parish council boundaries	GIS - Arcview shp
	Ramsar sites	GIS - Arcview shp
	Abstraction points	GIS - Arcview shp
	Special areas of protection	GIS - Arcview shp
	Site of special scientific interest	GIS - Arcview shp
	Telemetry stations	GIS - Arcview shp
	Telemetry stations (new)	GIS - Arcview shp
	Urban areas	GIS - Arcview shp
	Nextmap SAR data	GIS - Arcview grid
	LiDAR data	GIS - Ascii grid

Source	Description	Format
	Address point data	NTF
	OS Mastermaps	GIS - gz compressed
	Extreme tidal levels	GIS – Arcview shp
Tendring DC	Trinity House FRA report - June 2007	Acrobat pdf
	Sea defences Database	various - not GIS
	Tendring District Replacement Local Plan	hard copy
	Allocation sites/growth policies/flooding polices	hard copy
	OS 10k raster mapping	Raster tiff format

Contacts Register

The following contacts have been involved with this study.

Organisation	**Name**	**Department**
Anglian Water	Gary Parsons Rob Morris	Planning Liaison Growth Planning
Environment Agency	Jeremy Bloomfield John Claydon	Flood Risk Data & Mapping
Scott Wilson	Jon Robinson Liz Williams Tom Edwards	Water
Tendring District Council	Mike Bateson Malcolm Inskster Gill Burden Karl Randall Mary Foster John Ryan	Regeneration & Community Services Technical and Procurement Services

Correspondence

Eleanor Cole

From: Parsons Gary [gParsons@anglianwater.co.uk]

Sent: 15 November 2007 13:24

To: Tom Edwards; Morris Rob C

Subject: RE: Sewer Flooding Data Request - Harwich SFRA

Tom,

It is our opinion that sewer flooding is not a requirement of the SFRA. As a regulated sewerage provider, we are obliged to undertake a capital programme of works to remove areas where sewers have insufficient hydraulic capacity, thus any current problems would be temporary. The performance of the sewer network is more a consideration of the water cycle study that has recently been commissioned for the Haven Gateway area. I apologise if this seems unhelpful, but we are becoming inundated for data requests, much of which we think is unnecessary.

If you wish to meet to discuss this in more detail, we can maybe find time here at Peterborough.

Regards

Gary

From: Tom Edwards [mailto:Tom.Edwards@scottwilson.com]
Sent: 14 November 2007 16:41
To: Parsons Gary; Morris Rob C
Subject: Sewer Flooding Data Request - Harwich SFRA

TREAT THIS MESSAGE WITH CAUTION - it has passed through one or more external networks
****

Dear Gary/Rob,

We have been commissioned by Tendring District Council to carry out a Strategic Flood Risk Assessment (SFRA) for Harwich. The study will provide a strategic review of all sources of flooding within Harwich, to ensue that TDC have sufficient flood risk information to inform their future development plans.

The SFRA will include a review of sewer flooding data and your names have been included on the project brief as the Anglian Water contacts, hence why I am contacting you. We are keen to review all available data and I would appreciate it if you could provide any historic records of flooding which you hold. Perhaps in the first instance you could get in touch to discuss what data you have, and how this will be of use to us, in order to save you retrieving unnecessary data.

We will aim to provide maps which show how the risk of sewer flooding varies throughout Harwich, therefore if data can be provided in GIS format that would be ideal. If not then we will review the existing data and determine the best way to present the information. I understand that you are required to keep updated DP5 registers which record the number of flooded properties (from foul/surface/combined sewers) within the last ten years. If this is all the information which you hold then could you please break the information down into as much detail as possible i.e. 4 or even 5 digit postcodes (if possible).

I look forward to hearing from you to discuss what data is available and the procedure for obtaining it.

Best regards

Tom

Tom Edwards
Flood Risk Consultant
Scott Wilson
6 – 8 Greencoat Place, London, SW1P 1PL
t: 020 7821 4171
e: tom.edwards@scottwilson.com
w: scottwilson.com

Appendix C – Ramsey River Modelling

Ramsey River Modelling

Background

The Ramsey River drains a catchment area of approximately 27km^2 and was historically a tidal creek. However development of the port facility including construction of the railway line created a barrier at the mouth of the river. A pumping station was therefore installed to discharge flows from the catchment into the North Sea by pumping over the railway embankment.

The pumping station consists of three individual pumps, each with a maximum pumping capacity of 1m^3/s. Two pumps are normally used to discharge flow from the catchment giving a total pumping capacity of 2 m^3/s. The additional pump remains as a back-up option should mechanical failure occur. The pumping station is also equipped with a back-up generator should the power supply fail.

The Environment Agency do not currently hold hydraulic model of the Ramey River and very limited data is available regarding the channel cross sections and pumping stations. The Environment Agency has advised that analysis is required to determine the residual risk to the surrounding area should the pumping stations fail and flows from the catchment cannot be discharged into the North Sea.

Sources of Information

The following information has been provided by the Environment Agency:

- Verbal description of the catchment
- Verbal description of the pumping station operation and capacity
- Invitation to view hard copies of proposed cross sections dating from late 1950's
- LiDAR data covering the study area

Modelling Objectives

The main objective of the modelling exercise is to determine the residual risk in the event of failure of the pumping station during the 1 in 100 year event including climate change. Despite the presence of a back-up pump and generator there is still a risk, albeit a small one, that complete failure of the pumping station could occur.

The basic theory behind this analysis a volume calculation to determine the extents flooding based on a given volume of water generated by the catchment which is unable to discharge into the North Sea. The fact that LiDAR data is available throughout the catchment is the main reason why this exercise is possible. LiDAR data provides excellent coverage and a good level of accuracy across the floodplain areas. Poor data is provided within the channel, however the volume of storage within the river channel will be insignificant compared with the volume stored on the floodplain, when considering a scenario of complete pumping station failure.

Methodology

The above information has been used to construct a broad brush hydraulic model. LiDAR topographic data has been used to construct cross sections for the model. This data set was considered more accurate and up to date than historical hard copy drawings. LiDAR data is also provided in digital format and GIS software can be used to process and extract cross sections.

However no information is available regarding bridges and culverts along the channel, several of which are located within Harwich. A survey of these structures was not possible within the scope of this study. Structures within a river channel system can typically cause an obstruction to flow during flood events and lead to localised backing up, increasing flood levels in the vicinity of the structure.

However when considering complete failure of the pumping station the water levels throughout the system will be governed by a backwater effect originating at the pumping station. The water level will therefore be relatively static throughout the system and it is not considered that the localised effects due to structures would have a significant impact on peak flood levels.

Modelling Software

Isis software has been used to model the Ramsey River. Isis is a widely used, industry standard one-dimensional modelling package used throughout the flood risk industry which is on the Environment Agency's approved list of software packages. It allows unsteady, time varying simulations to be undertaken in order to simulate the propagation of a full flood hydrograph throughout a river system. Flows and water levels are calculated throughout the flood event at small intervals, typically many times per minute, to provide details information within the river system.

Flow Estimation

Hydrological calculations have been undertaken using the Flood Estimation Handbook (FEH) to estimate the flow generated by the catchment during design rainfall events. The methods employed utilise gauged data provided by the Environment Agency's Hi-Flows UK project, which is considered to provide the best available data set of gauged flood event data from around the country. Winfap FEH software is used to create a pooling group of hydrologically similar sites in order to obtain enough gauged data to facilitate statistical analysis.

The full methodology involves a significant number of calculations and supporting evidence therefore full details have not been included within this report. However the calculations have been submitted to the Environment Agency independently, who have confirmed that the methods used provide a robust estimation of the catchment flow for the given return periods. The following flow rates were estimated for the Ramsey River:

Return Period	Flow (m^3/s)
Q2 (Qmed)	3.62
Q5	4.91
Q10	5.72
Q20*	6.31
Q25	6.63
Q50	7.73
Q100	7.93

Table C-1: FEH calculated flow rates

*It should be noted that this flow is not automatically calculated by Winfap FEH software and was therefore interpolated from the Flood Frequency Curve

Model Construction

The orientation of model cross sections has been specified based on analysis of topographic LiDAR data. A one-dimensional model such as Isis only has the ability to compute the flow in one plane therefore the orientation of cross sections is a key consideration to ensure that the volume of the floodplain is accurately represented. It is also important to ensure that the cross section data extends to high ground at the extent of the section to avoid a 'glass wall' effect. Isis will assume a vertical wall at the edge of cross section (as no further data exists) which leads to an underestimation of the cross sectional area and will artificially increase calculated flood levels. The model schematisation is shown in Figure C-1 below.

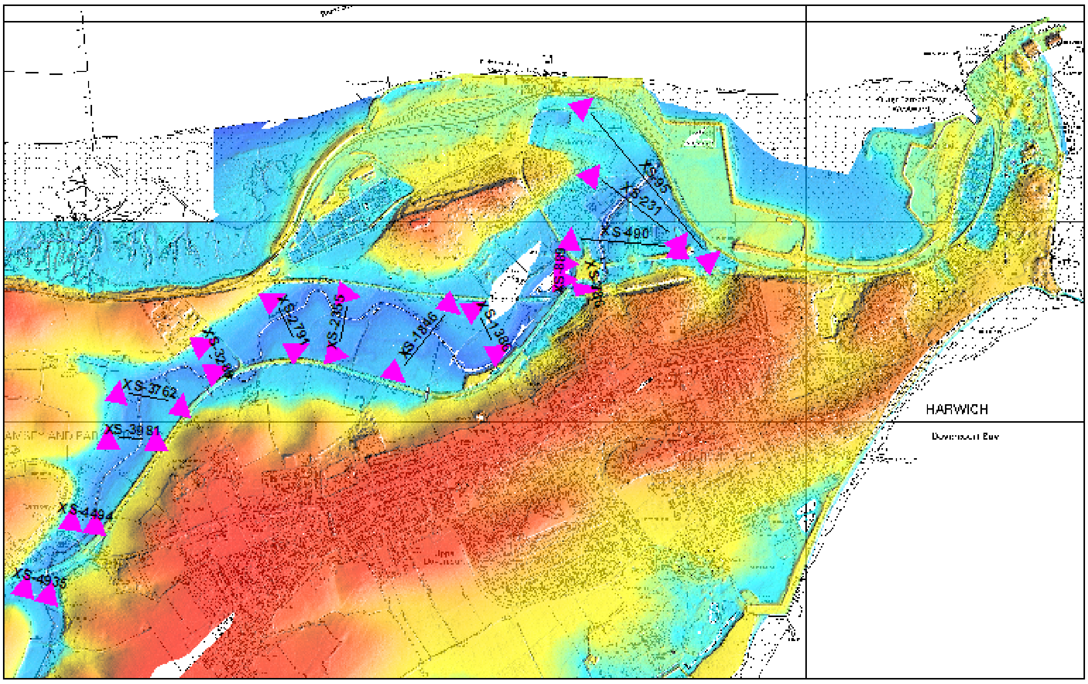


Figure C-1: Model schematic and cross section orientation

Cross sections were extracted from LiDAR data at these locations and imported into Isis software. An interpolation was used where there were gaps in the data. LiDAR data does not include accurate information for the river channel area because the laser beam is generally reflected from the water surface. Assumptions were therefore required to determine the approximate properties of the channel.

The technique employed for this purpose was to initially measure the channel width shown on OS Mastermaps and then manually 'cut' a channel into the LiDAR data cross section. The lowest LiDAR data point was assumed to represent the bed level. This is likely to represent a conservative scenario as the bed level is likely to be lower than this value. However as previously discussed the volute of water contained within the channel is considered to be insignificant when compared with the value of water on the floodplain. The resulting channel long section from the model is shown overleaf in Figure C-2.

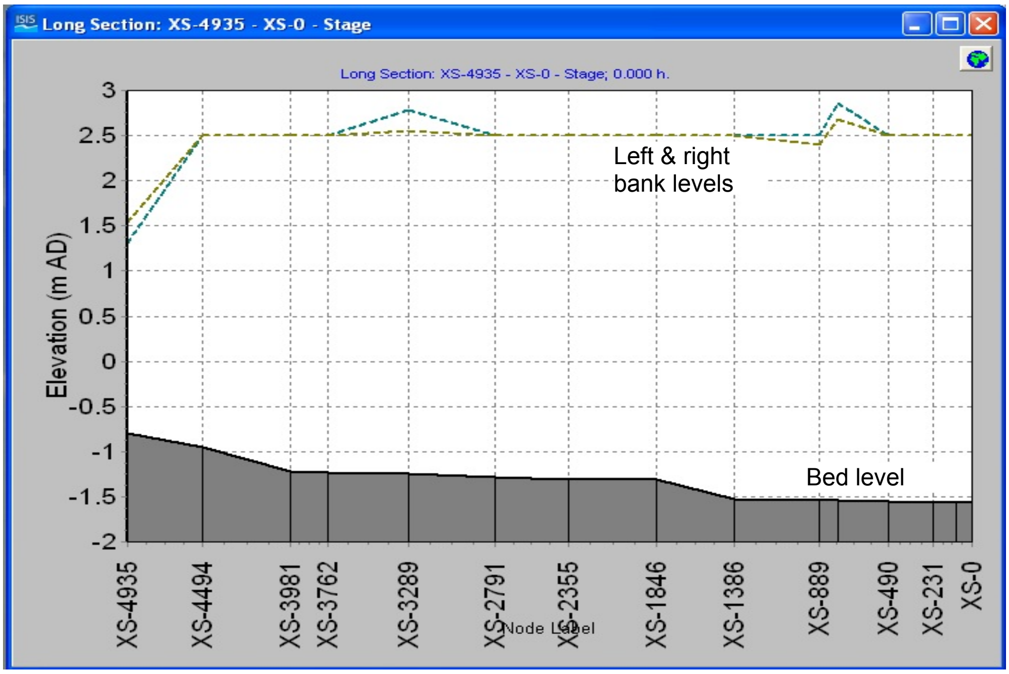


Figure C-2: Model long section

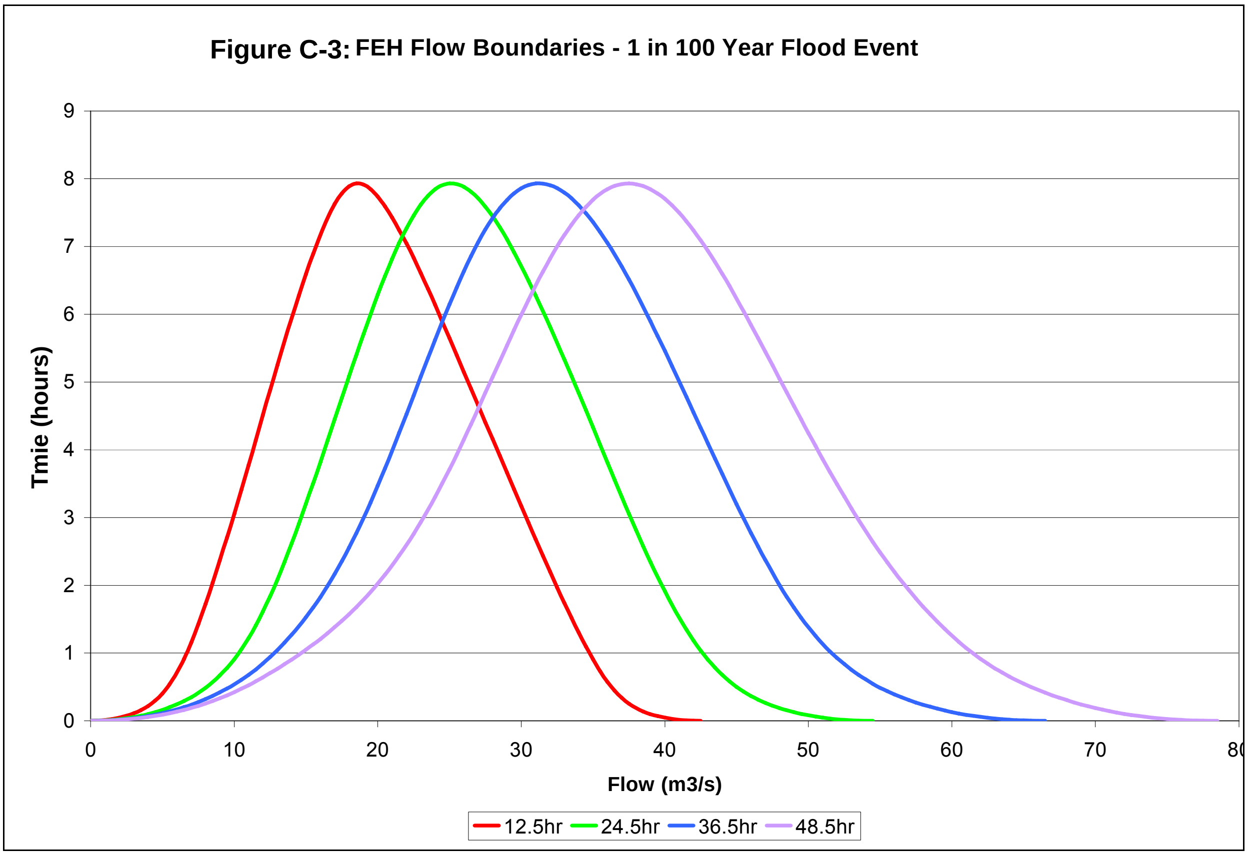
A standard Manning's roughness value of 0.045 was applied globally throughout the model. This value is based on standard Hydraulics literature (Chow, 1979 etc) and was selected to represent vegetation growth throughout the system during the summer months. This is again a conservative scenario.

Boundary Conditions

The downstream model boundary requirement was to simulate failure of the pumping station i.e. no flow should be able to leave the model. In order to represent this scenario a flapped Orifice unit with a cross sectional area of 0.001m^2 was used. A downstream water level boundary was attached to the Orifice with an artificially high water level to prevent any flow through the structure. The flap value specified on the orifice unit prevents backflow into the river system.

The upstream model boundary was specified as an FEH unit scaled to the peak flow rates calculated through hydrological calculations (see Table C-1). The storm duration is a key variable of any upstream model boundary. This is because critical flooding conditions in some catchments are caused by short duration, intense rainfall events which lead a rapid response where river levels rise and fall quickly. However in some catchments the worst case scenario is caused by longer duration events where river levels tend to rise and fall slowly.

For the pump failure scenario under consideration it is clear that the worst case scenario would be realised if pump failure occurred during an extreme rainfall event with a long duration, when the catchment would generate the greatest total volume of water. The inflow boundaries generated by various different storm durations are shown bin Figure C-3 below.



The approximate total volume of water generated during these storm durations is shown below. The table demonstrates that there is a significant difference in the total volumes of water generated during different storm durations.

Storm Duration (hours)	Total Run-off Volume (m^3)
12.5	1.99×10^6
24.5	2.31×10^6
36.5	2.71×10^6
48.5	3.14×10^6

Table C-2: Total run-off volumes for varying storm durations

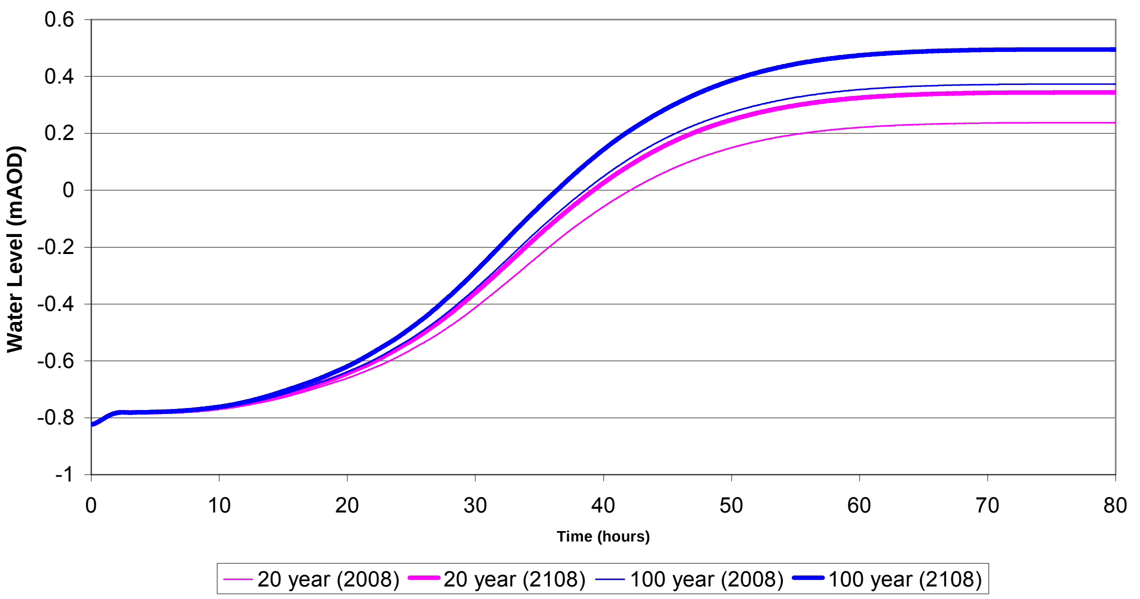
A decision had to be made regarding the duration of the design storm to simulate. In order to make this decision the overall objective of the modelling was considered further. The purpose of this exercise is to evaluate the residual risk, however it is important to ensure that a reasonably realistic scenario is considered. For example when carrying out breach modelling a short section of flood defence wall is assumed to fail and not the entire defence because this is a much more unlikely scenario.

Therefore an assumption was made that if the pumping station was to completely fail, then emergency procedures would be put in place to discharge the Ramsey River within 48 hours. This timescale is considered to be a reasonable duration for repair works and/or intermediate measures to be put in place. The design storm duration was therefore specified as 48.5 hours.

Model Simulations

The model was used to simulate the 1 in 20 year and 1 in 100 year flood events. The flow rates shown in Table C-1 below were also factored by 20% in line with PPS25 requirements in order to simulate the 1 in 20 year and 1 in 100 year events with climate change. The water level time series from all four simulations is shown below as Figure C-4, and a summary of the peak flood levels is shown in Table C-3 below.

Figure C-4: Ramsey River Modelling Results



As shown in Figure C-4 the water level within the system continues to increase until the inflow to the model ceases and from this point the water level remains static. The results are consistent with anticipated behaviour during a pump failure scenario with no discharge from the system.

Sensitivity Testing

Hydraulic models are generally tested for their sensitivity to specified variables typically including Manning's roughness. However for the purposes of this exercise this is not considered to be appropriate. The model has been classified as a broad brush model, and does not include any existing structures in the river network. The model is therefore not considered to be appropriate for sensitivity testing such as a typical hydraulic model, as for example, it will not be possible to evaluate the true sensitivity of the model to an increase in roughness because the model does not contain structures where significant energy losses typically occur. The decision has therefore been made to increase the modelled flood levels by an additional 300mm in line with the precautionary approach as detailed throughout PPS25, as shown in Table C-3 below.

Scenario	Peak Modelled Flood Level (mAOD)	Modified Flood Level i.e. +300mm (mAOD)
1 in 20 year (2008)	0.24	0.54
1in 20 year (2108)	0.34	0.64
1 in 100 year (2008)	0.37	0.67
1 in 100 year (2108)	0.50	0.80

Table C-3: Peak Flood Levels

These modified flood levels have been applied across the LiDAR DTM in order to determine the flood extents for the present day and climate change scenarios, shown in Figures C-5 and C-6 at the rear of this Appendix. The variation in flood levels and extents is minimal which is typically characteristic of a wide flat floodplain bounded by higher ground, such as the Ramsey River.

Discussion

The flood extents for the present day and climate change scenarios are generally very similar. This is because the Ramsey River valley is generally bounded by higher ground either side of the low lying floodplain, including the A120 road embankment to the south and the railway embankment to the east.

Figures C-5 and C-6 show that the area with the highest residual flood risk is the commercial development located at the downstream end of the catchment in the vicinity of the pumping station. The development located in close proximity to the channel is shown to lie within the 1 in 20 year flood extents.

Towards the upper extents of the model, the gardens of several residential properties located in the vicinity of the Ramsey Bridge are shown within the modelled flood extents. These properties could therefore be at residual risk of flooding should flood levels be locally increased by any backing up from the Ramsey Bridge.

Conclusions

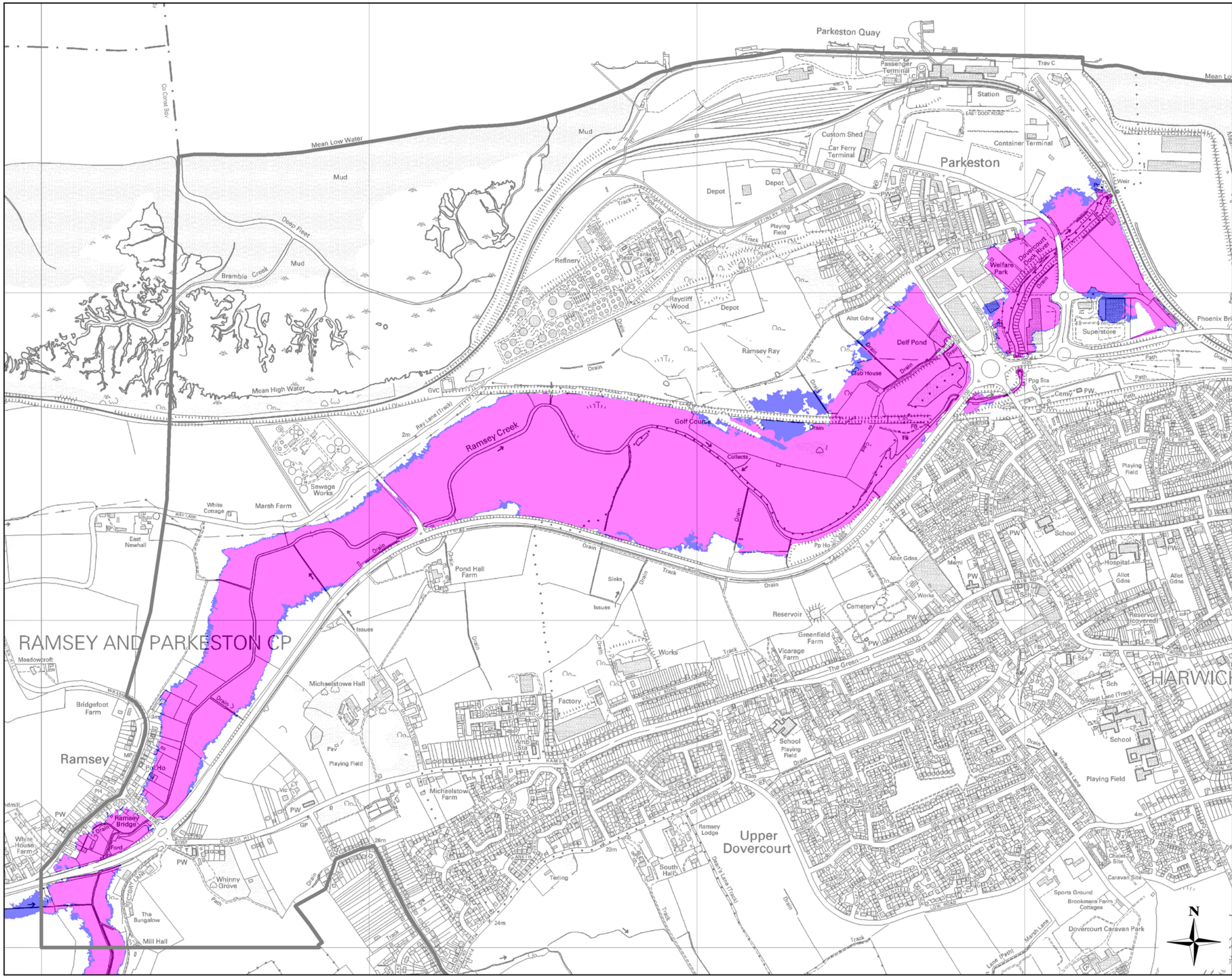
A broad brush model has been developed from the available sources of information in order to provide further information with regard to the residual flood risk in the event of complete failure of the Ramsey River pumping station during long duration flood events.

The model is considered to be suitable for the purposes of this exercise, however the modelled flood levels should not be relied upon for proposed developments in the vicinity of the Ramsey River. Further investigation will be required for site specific flood risk assessments, which should consider the effect of local channel structures such as bridges and culverts, including an assessment of the impacts of a blockage occurring.

The results of the broad brush model have been increased by 300mm in order to represent a conservative scenario and to account for the lack of information regarding local structures. The flood extents have been defined based on LiDAR topographic data for the 1 in 20 year and 1 in 100 year flood events with and without climate change. The 1 in 20 year event has been used to define the functional floodplain for the present day and climate change scenarios.

The flood extents show that the commercial developments located in the vicinity of the pumping station could be subjected to flooding during a complete pumping station failure. However commercial development is classified as a 'less vulnerable' type of development by PPS25 therefore the consequences of this would be minimal.

In summary the residual risk posed by failure of the Ramsey River pumping station is generally considered to be low. However the current back-up systems, which include a stand-by pump and independent generator should be maintained to ensure that such a scenario does not occur.



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED AND ONLY WRITTEN DIMENSIONS SHALL BE USED

Notes

- Study Area
- Flood Zone 3b - 2008
- Flood Zone 3a - 2008

Revision Details	By / Check	Date	Suffix
Draft	TE / JR	02/08	0

Drawing Status: FINAL

Job Title: HARWICH STRATEGIC FLOOD RISK ASSESSMENT

Drawing Title: RAMSEY RIVER PUMPING STATION FAILURE SCENARIO 2008

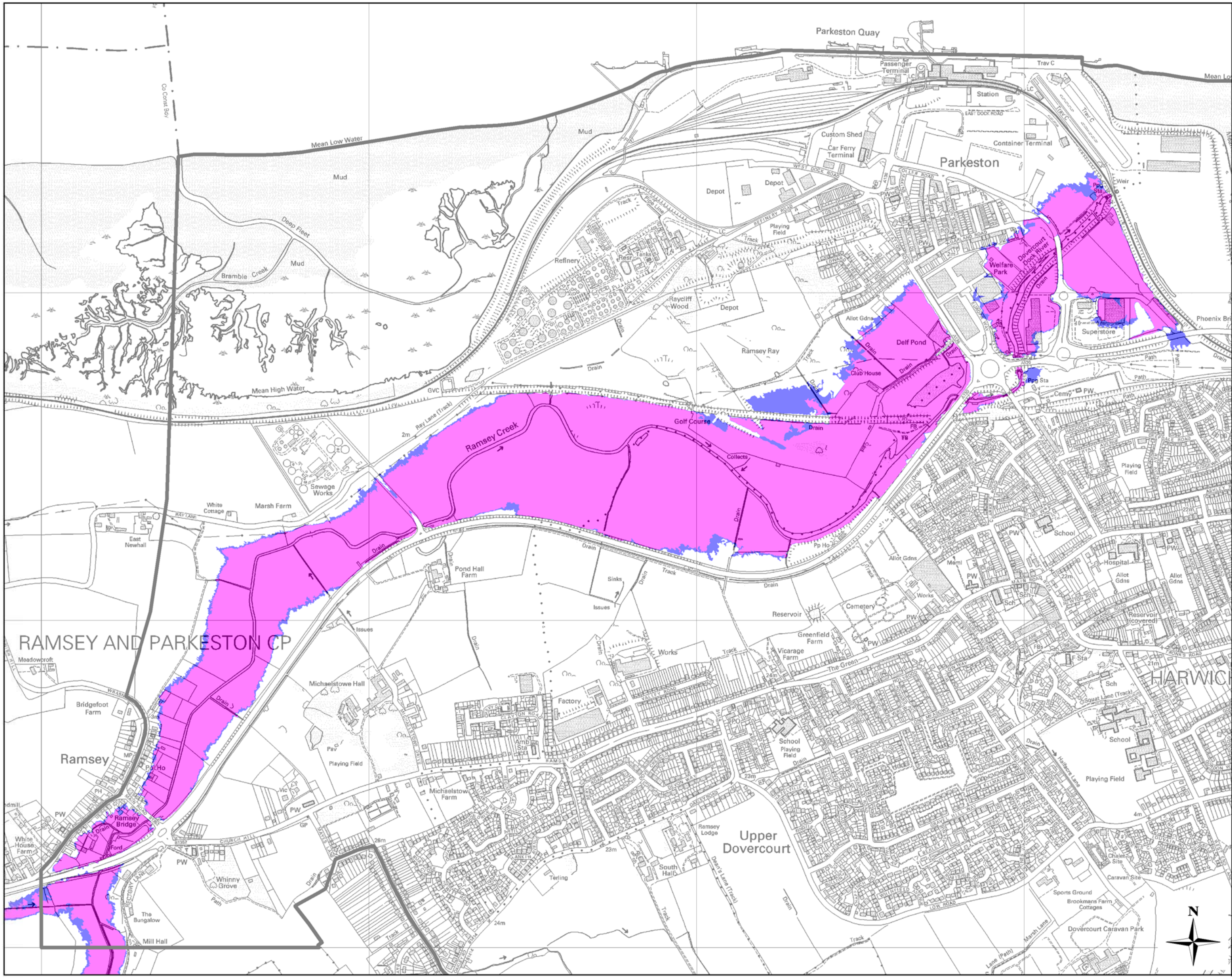
Scale at A3: NTS

Drawn	Approved
TE	JR

Stage 1 Check	Stage 2 Check	Originated	Date
TE	JR	TE	04/08

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Telephone +44 (0)20 7798 5000
Fax +44 (0)20 7798 5001
www.scottwilson.com

Drawing Number: FIGURE C-5



THIS DRAWING MAY BE USED ONLY FOR THE PURPOSE INTENDED AND ONLY WRITTEN DIMENSIONS SHALL BE USED

Notes

Study Area

Flood Zone 3b - 2108

Flood Zone 3a - 2108

Revision Details	By / Check	Date	Suffix
Draft	TE / JR	02/08	0

Drawing Status: FINAL

Job Title: HARWICH STRATEGIC FLOOD RISK ASSESSMENT

Drawing Title: RAMSEY RIVER PUMPING STATION FAILURE SCENARIO 2108

Scale at A3: NTS

Drawn	Approved
TE	JR

Stage 1 Check	Stage 2 Check	Originated	Date
TE	JR	TE	04/08

Scott Wilson
6-8 Greencoat Place
London, SW1P 1PL
Telephone +44 (0)20 7798 5000
Fax +44 (0)20 7798 5001
www.scottwilson.com

Drawing Number: FIGURE C-6

Appendix D – Hydrodynamic Breach Modelling

Hydrodynamic Breach Modelling Methodology

This chapter presents the methodologies used in developing the flood outline, maximum flood depth and hazard zone maps for this SFRA.

Digital Terrain Map (DTM) Generation

A key component in the modelling process for the SFRA is the representation of topography throughout flood prone regions of the study area. For this purpose, a Digital Terrain Map (DTM) was derived for each of the modelled areas. A DTM is a three-dimensional 'playing field' on which the model simulations are run.

The platform used for the generation of the DTM was the GIS software package MapInfo Professional (version 8.5) and its daughter package Vertical Mapper (version 3.1).

The DTM is primarily based on filtered LiDAR data provided by the Environment Agency. LiDAR (Light Detection And Ranging) is a method of optical remote sensing, similar to the more primitive RADAR (which uses radio waves instead of light). In this case, the LiDAR surveys return data at a horizontal resolution of approximately 1 metre. Filtered LiDAR data represents the "bare earth" elevation with buildings, structures and vegetation removed.

The LiDAR data was used to create a DTM grid covering the study area.

Flood Cell Definition

The breach locations were specified by the Environment Agency based on local knowledge of the condition of the defences, the location of future development sites, historical flooding events and the vulnerability of local communities. Figures D1 – D54 show the locations of the breaches modelled.

Once the DTM grids and breach locations have been obtained, the flood cell for each model must be defined. The flood cell is the geographical extent of the model, the area of the overall DTM that will be used in the model. While it would be possible to run each of the breach models using all of the derived DTM topographical data, it is far more sensible to define a smaller area on which to run each scenario.

Flood cells are typically defined by considering the topography of the area inland of the breach and the peak levels of the tidal events to be tested. MapInfo can be used to show areas of potential flooding by only displaying areas of the DTM that are below the predicted peak inundation levels in the vicinity of the breach, plus a freeboard of several hundred millimetres. Areas of the DTM that are not shown (that is, areas that are well above the tidal levels of interest) do not need to be considered in the model.

Where the local topography does not clearly define an enclosed flood cell it may be necessary to artificially enclose certain parts of the flood cell. This should only be done for areas that are not near the breach or any important areas of the model, and will typically be outlying or empty areas of the flood cell. For example, estuaries or flat, open fields at the far end of the flood cell. Since the model treats the boundaries of flood cells as 'glass walls' it is vital that any artificial boundaries do not affect levels in the important areas of the flood cell. However, this is typically not an issue in models where the inflows are based on tidal levels rather than a specific volume.

Table D-1 presents the flood cell references and a brief description of the breach located within each flood cell.

TABLE D-1 FLOOD CELLS AND THE ASSOCIATED NUMBER OF ANALYSED BREACH/OVERTOPPING EVENTS

Flood Cell	Location of Breach	Nature of Event
HAR01	Harwich International Port	Breach in existing defences
HAR02	Harwich Peninsula	Breach in existing defences
HAR03	Dovercourt	Breach in existing defences

Extreme Water Level Derivation

The extreme sea water levels associated with tidal flood events in the North Sea are common to each breach location. The extreme sea water levels for the breach locations along the coastline are based on information provided from Environment Agency from their hydraulic modelling studies.

Climate Change

PPS25 recommended contingency allowances have been applied to the extreme water levels in order to simulate climate change scenarios.

The extreme water levels for each breach location simulated in this assessment are presented in Table D-2.

TABLE D-2 MAXIMUM TIDAL WATER LEVELS

1 in 200 year event (mAOD)		1 in 1000 year event (mAOD)	
Present day (2008)	Climate change (2108)	Present day (2008)	Climate change (2108)
3.89	4.91	4.26	5.28

Tide Curve

An extreme tidal curve is required to be input to represent changes in water level during each extreme event. The extreme tidal curve for each return period scenario is created from two components; an astronomical tide and a surge residual tide. The astronomical tide is assumed to be independent of the metrological conditions.

Astronomical Tide

Mean Spring Tidal Water levels were extracted from the Admiralty Tidal Tables for Harwich and applied to a sine curve with a 12-hour cycle. Storm Surge Profile

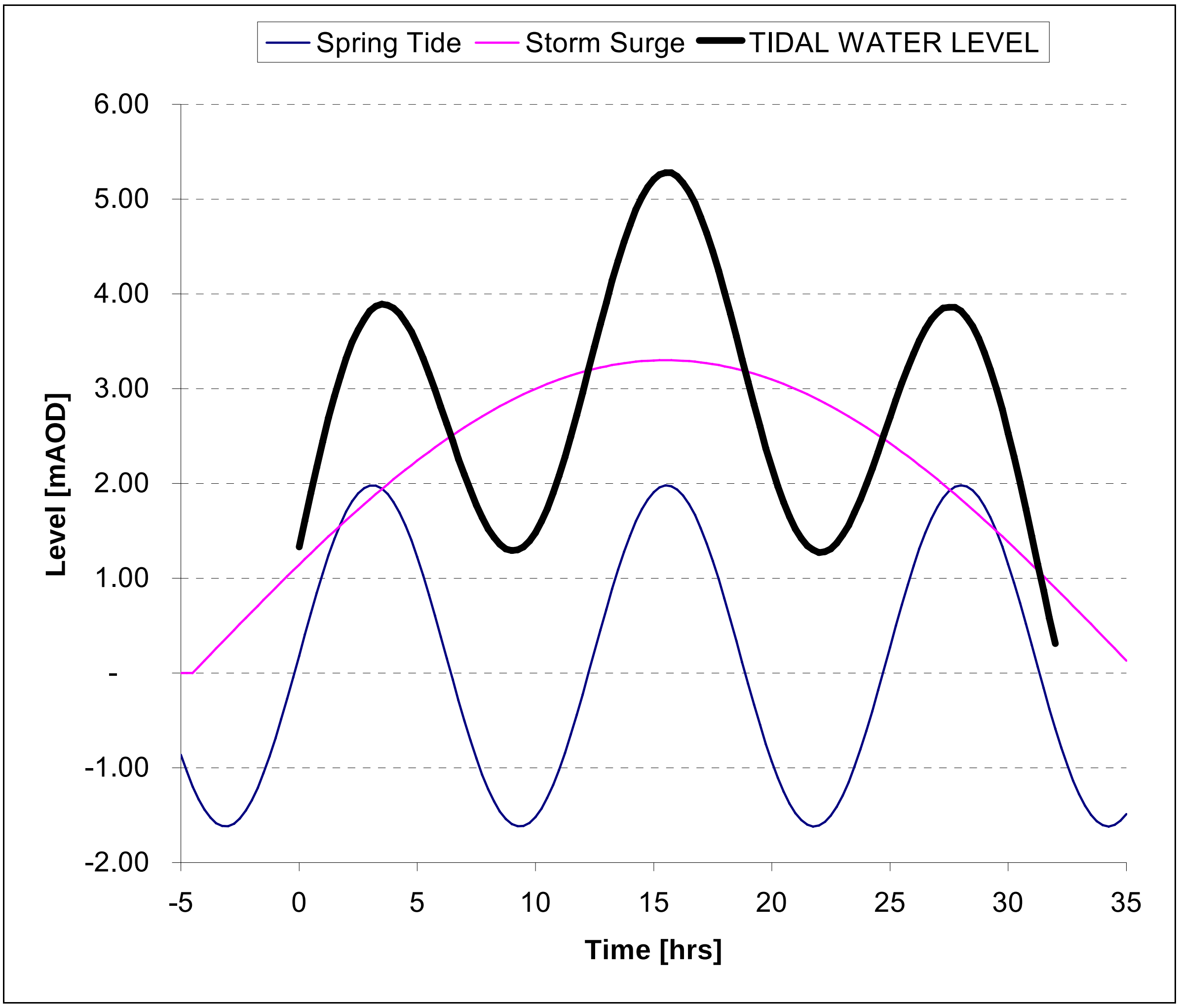
Storm Surge Profile

The surge component is simulated by a regular half-sinusoidal water level increase with assumed storm duration of 40 hours. In order to achieve the worst case scenario the storm surge peaks at the same moment as the second astronomical high tide in the simulation.

The water levels during a tidal flood event were generated by a summation of the astronomical tide levels and the storm surge residual. An example of the sea water levels used for the breach modelling analysis is shown in Figure 1D.

The repair time required to close a breach is considered to be 18 hours, or two high tides, for hard defences such as those assumed to breach in Harwich.

FIGURE 1D EXAMPLE OF MIKE 21 HD FLEXIBLE MESH



Breach Modelling

To assess flood propagation in events where the flood defences are breached, a hydraulic modelling analysis has been undertaken using the two-dimensional hydraulic modelling software MIKE21-HDFM (version 2007).

This section discusses the methodology that has been applied for the hydraulic modelling analysis of the breach events. The choice of model is discussed, the model schematisation is described and the boundary conditions used are presented.

Model and Software Selection

To achieve the study objectives, the model used to estimate the maximum flood conditions was required to:

- Accommodate the effects of a flood flow (propagation of a flood wave and continuous change of water level);

- Simulate the hydraulics of the flow that breach the flood defences; and
- Generate detailed information on the localised hydraulic conditions over the flooded area in order to evaluate flood hazard.

To investigate the flood conditions resulting from every breach location over the study domain, the two-dimensional (2D) hydraulic modelling software MIKE21-HDFM (MIKE21-Hydrodynamic Flexible Mesh Model, 2007 version) has been used.

MIKE21-HDFM simulates water level variations and flows for depth-averaged unsteady two-dimensional free-surface flows. MIKE21 is specifically oriented towards establishing flow patterns in complex water systems, such as coastal waters, estuaries and floodplains. The MIKE21 hydraulic modelling software is developed by the Danish Hydraulic Institute (DHI) Water and Environment.

MIKE21-HDFM is a new modelling system based on a flexible mesh (FM) approach. The flexible mesh model has the advantage that the resolution of the model can be varied across the model area. The model utilises the numerical solution of two-dimensional shallow water equations.

Model Extent and Resolution

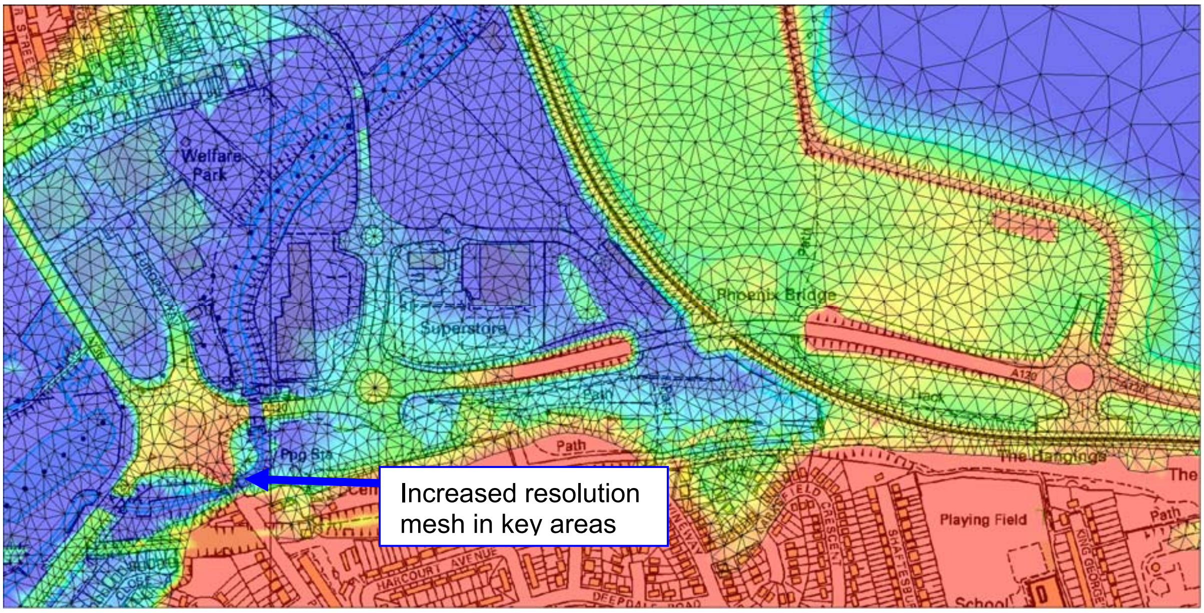
For each flood cell, a MIKE21 flexible mesh model has been developed using the MIKE21 program Mesh Generator. The mesh generator creates a mesh over the flood cell DTM using triangular elements. The element size varies throughout the model domain and depends upon the complexity of floodplain topographic features and/or areas of interest.

Using the flexible mesh module it is possible to generate a highly resolved mesh in areas of particular interest or in areas that are important from a hydrodynamic viewpoint and have a lower resolution in areas that have a lower priority reducing demands on computational resources.

To represent the hydraulics around the breach with a relatively high level of accuracy, a comparatively small element size has been applied in the vicinity of breaches. The breach has been represented by a minimum of four elements. Urban areas and structures within the floodplain have the potential to affect the free flow of floodwater. Embankments, flood defences, significant water courses and other linear features have been incorporated into the flexible mesh by creating break-lines parallel to the feature.

By adding break lines, the mesh orientation is forced to follow the alignment of the features and the localised elevations of structures are used by the mesh generator. The break lines of linear man-made features were schematised by reference to the DTM, OS Mastermaps and 1:25000 OS maps. The crest levels of linear features, such as secondary flood embankments, road embankments and railway embankments, have been established by interrogation of the DTM. It should be noted that the majority of the features described above have been identified through a desktop analysis only, and have not been verified on the ground. Results from the breach modelling which show strong dependence on barriers should therefore be used with caution.

FIGURE 2D EXAMPLE OF MIKE 21 HD FLEXIBLE MESH



Breach Specifications

The flood conditions (i.e. inundation rate, flood extent, depth of flooding) that may be experienced if a flood defence were to breach are a function of the breach dimensions, time required to repair the breach (exposure duration) and tidal conditions. Since it is not possible to set repair time in the modelling software, the breach and tidal details are the two major factors that determine the extent of inundation due to breaching.

Suitable breach dimensions were determined using the Environment Agency Strategic Flood Risk Assessment (SFRA) Guidance. The breach width is determined on the location and type of embankment as tabulated in Table D-3.

TABLE D-3 BREACH WIDTH CATEGORIES

Location type	Defence type	Breach width (m)
Open coast	Earth bank	200
	Dunes	100
	Hard	50
	Sluice	Sluice width
Estuary	Earth bank	50
	Hard	20
Tidal river	Earth bank	50
	Hard	20
Fluvial river	Earth bank	40
	Hard	20

At Harwich International Port and Harwich Peninsula the flood defences consist of walls and/or raised ground, classified as 'hard' defences. A 20m breach width was specified at these locations as required for estuaries. The defences at Dovercourt consist of raised earth embankments topped with a concrete splash wall. The Environment Agency has specified that a 200m breach width should be simulated at this location to ensure a precautionary approach is followed, taking into account the presence of the earth embankments at this open coastal location.

The base level of the breaches have been set to the lowest elevation of the land directly behind (landward) the flood defence.

In the hydraulic modelling undertaken for this study, the breach in the flood defence was present during the whole flood event (i.e. it is deemed to have occurred prior to the onset of the extreme tidal event) as it is not possible to vary the DTM during the simulation period. This is a conservative assumption.

It is important to note that the current condition of the defences has not been used as a criterion on which to base the breach dimensions. Instead, it has been assumed that over time all defences will be maintained to the required standard, that is the standard they are currently built to. That is, no assessment has been made of the probability of failure.

Boundary Conditions

The MIKE21 breach models require one boundary condition to be defined. This is a time dependent head boundary (HT) at the seaward side of the breach location, which replicates the extreme tide levels/cycle during a tidal flood event.

Four tidal flood events were analysed for each breach location. The tidal flood events analysed were:

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

Hydraulic Roughness

Hydraulic roughness represents the conveyance capacity of the vegetative growth, bed and bank material, channel, sinuosity and structures of the floodplain. Within the MIKE21 model, hydraulic roughness is defined by the dimensionless Manning Number 'N'.

The assigned hydraulic roughness coefficient is based on engineering judgement and available literature (e.g. Chow, 1979).

The applied Manning Number, N, for the study area was set at 35. This represents a common roughness coefficient for sea bed and non-urban areas, which forms the majority of each study area.

While it is possible to define individual roughness coefficients to various areas within a MIKE21 model, in this case it was deemed appropriate to simply apply a single roughness to the entire study area.

Model Simulations Undertaken

To investigate the breach flood conditions throughout Harwich, several model simulations were undertaken. A total of 12 model simulations were undertaken for three breach locations (four simulations per breach, as previously defined).

The model results of the individual model simulations have been processed to create flood depth and hazard maps presented in Figures D1 – D54.

Definition of Hazard Categories

Breach analysis presents data to identify the residual risk of flooding from a failure of local defences. The mapping of flood hazard zone maps within the study area represents an appreciation of the residual risk to provide an additional level of information to local planning authorities allowing them to make more detailed consideration of the sequential test and PPS25 vulnerability classifications within Flood Zone 3a.

Flood hazard is a function of both the flood depth and flow velocity. Therefore, to create flood hazard maps, the modelled flood water depth and flow velocities resulting from each model scenario have been assessed.

In most flood events the maximum hazard of a flood at a certain location is not experienced at the peak of the flood but before the maximum floodwater level occurs. This is the point at which the greatest flood depths and velocities typically occur. Thus, in order to determine the maximum flood hazard, the hazard level was assessed by using an in-house tool (HazardIndex) which assigns one of three hazard categories (low, medium or high) to each element in the mesh at every time step of the model simulation, then determines the maximum for that element.

The HazardIndex is based on a very similar approach presented within the 'Flood Risks to People' produced by DEFRA (FD2321) however excludes the presence of a debris factor. When undertaking breach modelling for a strategic study of this nature it is not considered to be appropriate to apply a global debris factor. The presence of debris would vary significantly in both source and scale across the study area therefore assuming a global debris factor could provide ambiguous results for the SFRA.

The relationship between flood depth and flow velocity and the definition of hazard zones and presented in Figure 3D.

FIGURE 3D: DEFINITIONS OF HAZARD CATEGORIES

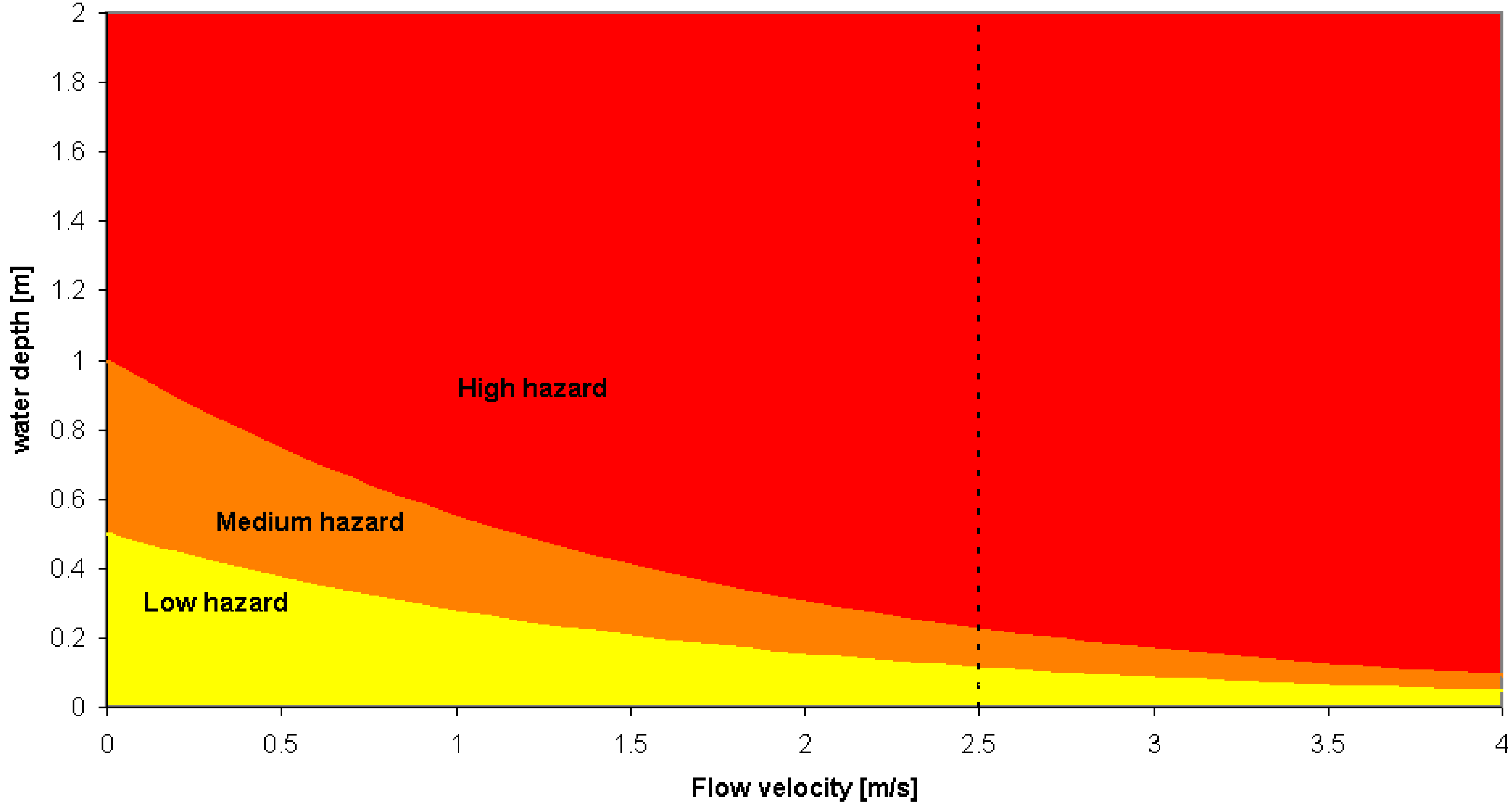


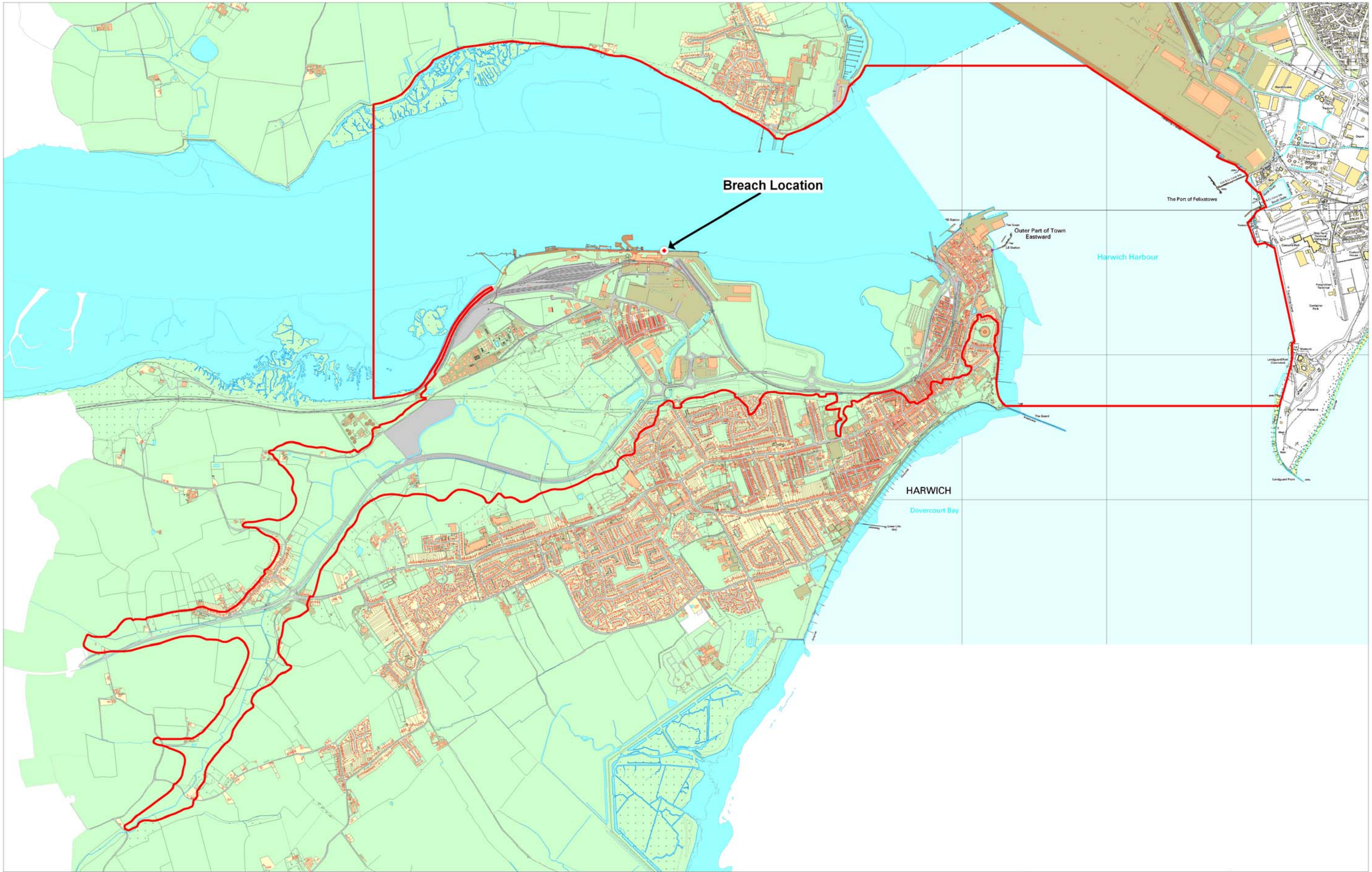
TABLE D-4 HYDRODYNAMIC MODELLING FIGURES

Figure Number	Area	Description
D1	HAR01 - Port	Floodcell
D2	HAR01 - Port	Hazard 200yr - Near Breach
D3	HAR01 - Port	Depth 200yr - Near Breach
D4	HAR01 - Port	Hazard 1000yr - Near Breach
D5	HAR01 - Port	Depth 1000yr - Near Breach
D6	HAR01 - Port	Hazard 200CC - Near Breach
D7	HAR01 - Port	Depth 200CC - Near Breach
D8	HAR01 - Port	Hazard 1000CC - Near Breach
D9	HAR01 - Port	Depth 1000CC - Near Breach
D10	HAR01 - Port	Hazard 200CC - Full Extent
D11	HAR01 - Port	Depth 200CC - Full Extent
D12	HAR01 - Port	Hazard 1000CC - Full Extent
D13	HAR01 - Port	Depth 1000CC - Full Extent
D14	HAR01 - Port	Outlines 2007 - Near Breach
D15	HAR01 - Port	Outlines 2107 - Near Breach
D16	HAR01 - Port	Outlines 2107 - Full Extent
D17	HAR02 - Peninsula	Floodcell
D18	HAR02 - Peninsula	Hazard 200yr - Near Breach
D19	HAR02 - Peninsula	Depth 200yr - Near Breach
D20	HAR02 - Peninsula	Hazard 1000yr - Near Breach
D21	HAR02 - Peninsula	Depth 1000yr - Near Breach
D22	HAR02 - Peninsula	Hazard 200CC - Near Breach
D23	HAR02 - Peninsula	Depth 200CC - Near Breach
D24	HAR02 - Peninsula	Hazard 1000CC - Near Breach
D25	HAR02 - Peninsula	Depth 1000CC - Near Breach
D26	HAR02 - Peninsula	Hazard 200CC - Full Extent
D27	HAR02 - Peninsula	Depth 200CC - Full Extent
D28	HAR02 - Peninsula	Hazard 1000CC - Full Extent
D29	HAR02 - Peninsula	Depth 1000CC - Full Extent
D30	HAR02 - Peninsula	Outlines 2007 - Near Breach
D31	HAR02 - Peninsula	Outlines 2107 - Near Breach
D32	HAR02 - Peninsula	Outlines 2107 - Full Extent
D33	HAR03 - Dovercourt	Present Floodcell
D34	HAR03 - Dovercourt	CC Floodcell
D35	HAR03 - Dovercourt	Hazard 200yr - Near Breach
D36	HAR03 - Dovercourt	Depth 200yr - Near Breach
D37	HAR03 - Dovercourt	Hazard 1000yr - Near Breach
D38	HAR03 - Dovercourt	Depth 1000yr - Near Breach
D39	HAR03 - Dovercourt	Hazard 200CC - Near Breach
D40	HAR03 - Dovercourt	Depth 200CC - Near Breach
D41	HAR03 - Dovercourt	Hazard 1000CC - Near Breach
D42	HAR03 - Dovercourt	Depth 1000CC - Near Breach
D43	HAR03 - Dovercourt	Hazard 200yr - Full Extent
D44	HAR03 - Dovercourt	Depth 200yr - Full Extent
D45	HAR03 - Dovercourt	Hazard 1000yr - Full Extent

D46	HAR03 - Dovercourt	Depth 1000yr - Full Extent
D47	HAR03 - Dovercourt	Hazard 200CC - Full Extent
D48	HAR03 - Dovercourt	Depth 200CC - Full Extent
D49	HAR03 - Dovercourt	Hazard 1000CC - Full Extent
D50	HAR03 - Dovercourt	Depth 1000CC - Full Extent
D51	HAR03 - Dovercourt	Outlines 2007 - Near Breach
D52	HAR03 - Dovercourt	Outlines 2107 - Near Breach
D53	HAR03 - Dovercourt	Outlines 2007 - Full Extent
D54	HAR03 - Dovercourt	Outlines 2107 - Full Extent

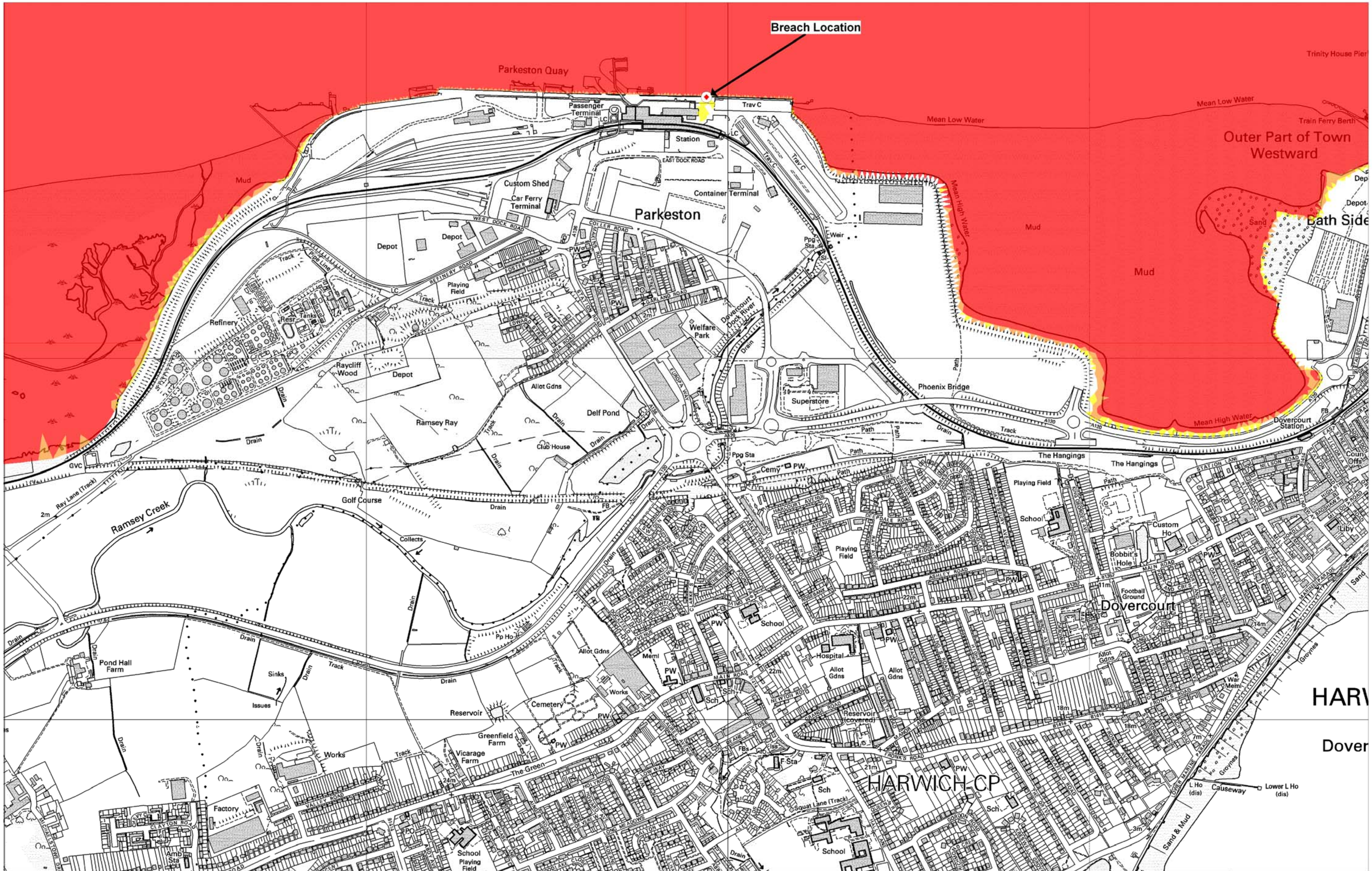
TABLE D-5 HYDRODYNAMIC MODELLING GIS LAYERS

Area	Type	Event	Year
HAR01 - Port	Depth	1 in 200 Year	2008
HAR01 - Port	Hazard	1 in 200 Year	2008
HAR01 - Port	Outline	1 in 200 Year	2008
HAR01 - Port	Depth	1 in 1000 Year	2008
HAR01 - Port	Hazard	1 in 1000 Year	2008
HAR01 - Port	Outline	1 in 1000 Year	2008
HAR01 - Port	Depth	1 in 200 Year	2108
HAR01 - Port	Hazard	1 in 200 Year	2108
HAR01 - Port	Outline	1 in 200 Year	2108
HAR01 - Port	Depth	1 in 1000 Year	2108
HAR01 - Port	Hazard	1 in 1000 Year	2108
HAR01 - Port	Outline	1 in 1000 Year	2108
HAR02 - Peninsula	Depth	1 in 200 Year	2008
HAR02 - Peninsula	Hazard	1 in 200 Year	2008
HAR02 - Peninsula	Outline	1 in 200 Year	2008
HAR02 - Peninsula	Depth	1 in 1000 Year	2008
HAR02 - Peninsula	Hazard	1 in 1000 Year	2008
HAR02 - Peninsula	Outline	1 in 1000 Year	2008
HAR02 - Peninsula	Depth	1 in 200 Year	2108
HAR02 - Peninsula	Hazard	1 in 200 Year	2108
HAR02 - Peninsula	Outline	1 in 200 Year	2108
HAR02 - Peninsula	Depth	1 in 1000 Year	2108
HAR02 - Peninsula	Hazard	1 in 1000 Year	2108
HAR02 - Peninsula	Outline	1 in 1000 Year	2108
HAR03 - Dovercourt	Depth	1 in 200 Year	2008
HAR03 - Dovercourt	Hazard	1 in 200 Year	2008
HAR03 - Dovercourt	Outline	1 in 200 Year	2008
HAR03 - Dovercourt	Depth	1 in 1000 Year	2008
HAR03 - Dovercourt	Hazard	1 in 1000 Year	2008
HAR03 - Dovercourt	Outline	1 in 1000 Year	2008
HAR03 - Dovercourt	Depth	1 in 200 Year	2108
HAR03 - Dovercourt	Hazard	1 in 200 Year	2108
HAR03 - Dovercourt	Outline	1 in 200 Year	2108
HAR03 - Dovercourt	Depth	1 in 1000 Year	2108
HAR03 - Dovercourt	Hazard	1 in 1000 Year	2108
HAR03 - Dovercourt	Outline	1 in 1000 Year	2108



Project:	Title:		FIGURE D1
Harwich SFRA **Tendring District Council**	**HAR01 - Harwich International Port Model Flood Cell Location**	Flood Cell Outline	Scale: 1:25000 @ A3
			Drw NM Date 21/02/08 Rev 1

Scott Wilson
www.scottwilson.com



Project:	Title:
Harwich SFRA **Tendring District Council**	**HAR01 - Harwich Int'l Port - Near Breach** **1 in 200 Year - 2008** **Flood Hazard**

High Hazard **Medium Hazard** **Low Hazard**

FIGURE D2

Scale: 1:10000 @ A3

Drw NM | Date 21/02/08 | Rev 1

Scott Wilson
www.scottwilson.com

Project:
Harwich SFRA
Tendring District Council

Title:
HAR01 - Harwich Int'l Port - Near Breach
1 in 200 Year - 2008
Flood Depth

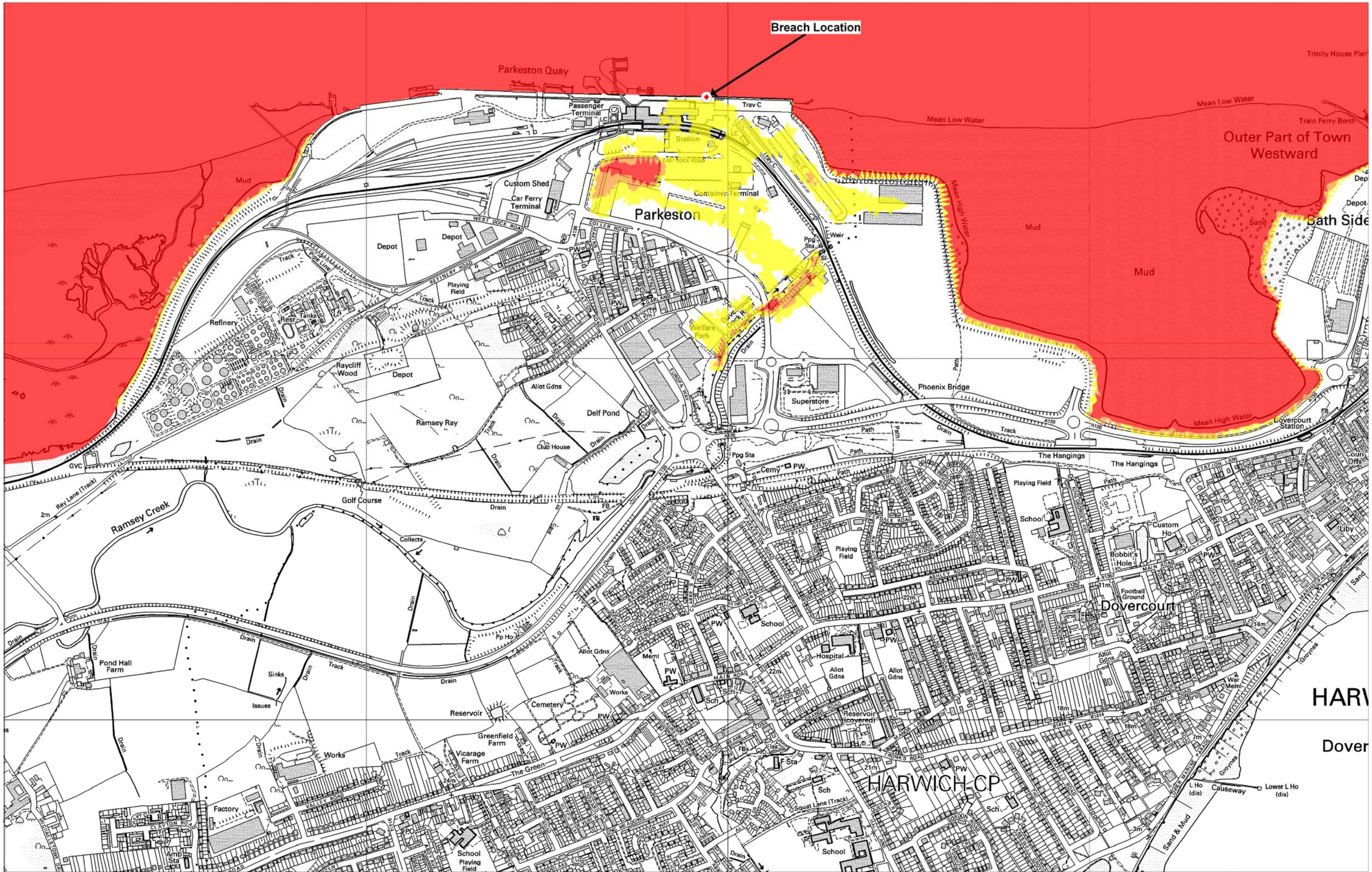
Maximum Flood Depth [m]:
0.05 0.50 1.00 1.50 2.00 3.00

FIGURE D3

Scale: 1:10000 @ A3

Drw NM | Date 21/02/08 | Rev 1

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR01 - Harwich Int'l Port - Near Breach
1 in 1000 Year - 2008
Flood Hazard

High Hazard
Medium Hazard
Low Hazard

FIGURE D4

Scale: 1:10000 @ A3

Drw NM | Date 21/02/08 | Rev 1

Scott Wilson
www.scottwilson.com

Project:
Harwich SFRA
Tendring District Council

Title:
HAR01 - Harwich Int'l Port - Near Breach
1 in 1000 Year - 2008
Flood Depth

Maximum Flood Depth [m]:

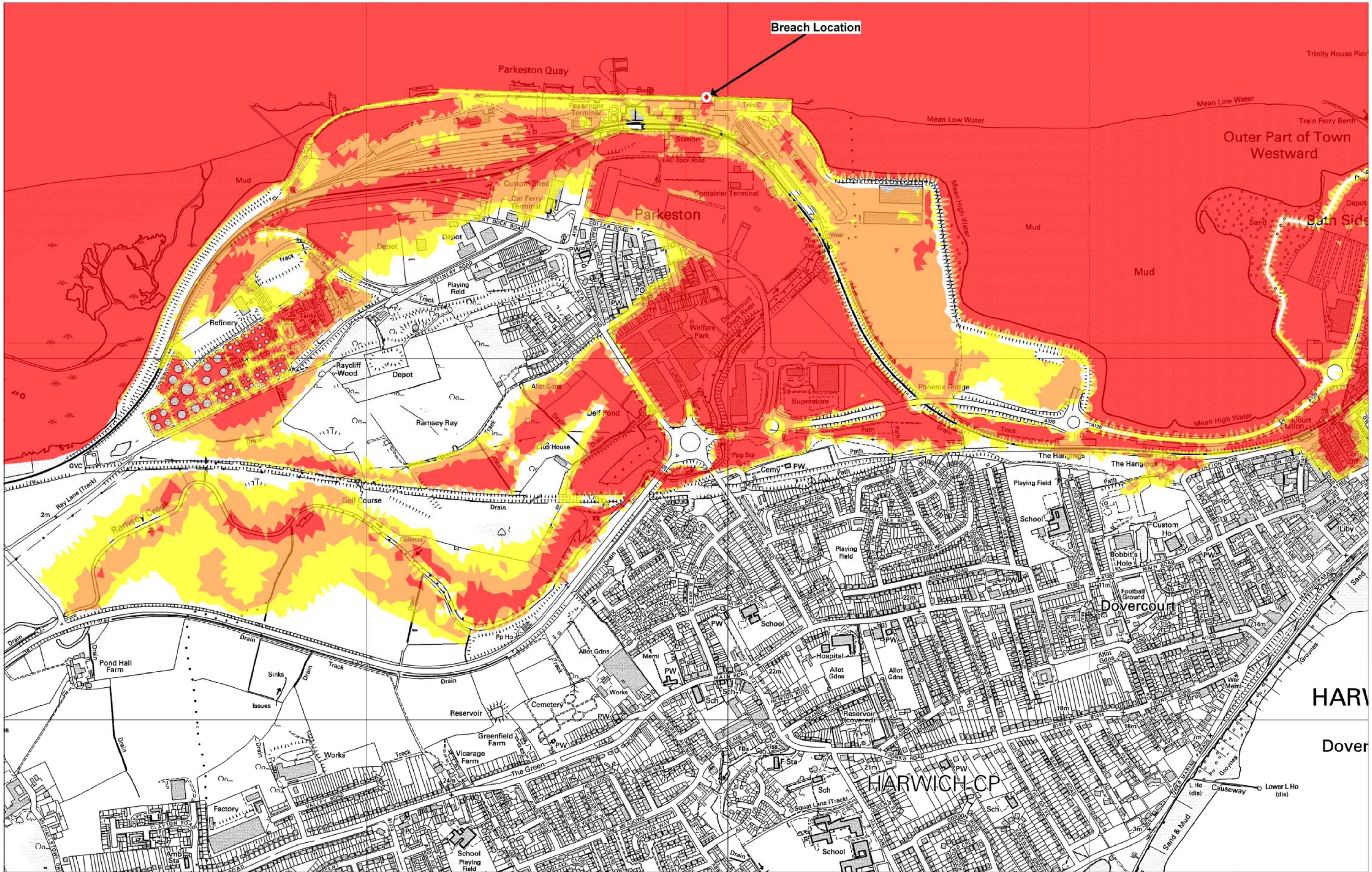
0.05 0.50 1.00 1.50 2.00 3.00

FIGURE D5

Scale: 1:10000 @ A3

Drw NM Date 21/02/08 Rev 1

www.scottwilson.com



High Hazard
Medium Hazard
Low Hazard

Project:
Harwich SFRA
Tendring District Council

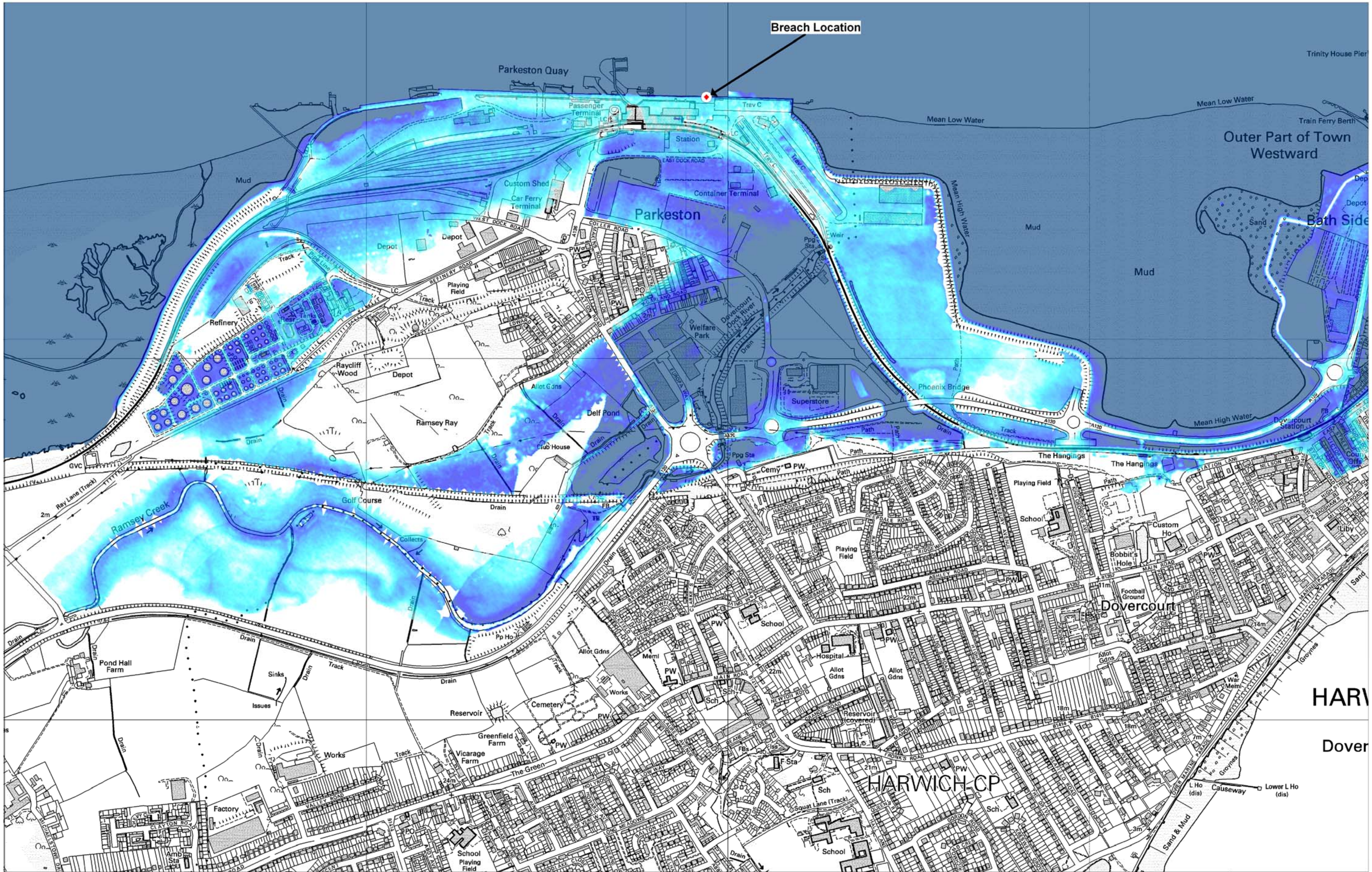
Title:
HAR01 - Harwich Int'l Port - Near Breach
1 in 200 Year - 2108
Flood Hazard

FIGURE D6

Scale: 1:10000 @ A3

Drw	NM	Date	21/02/08	Rev	2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

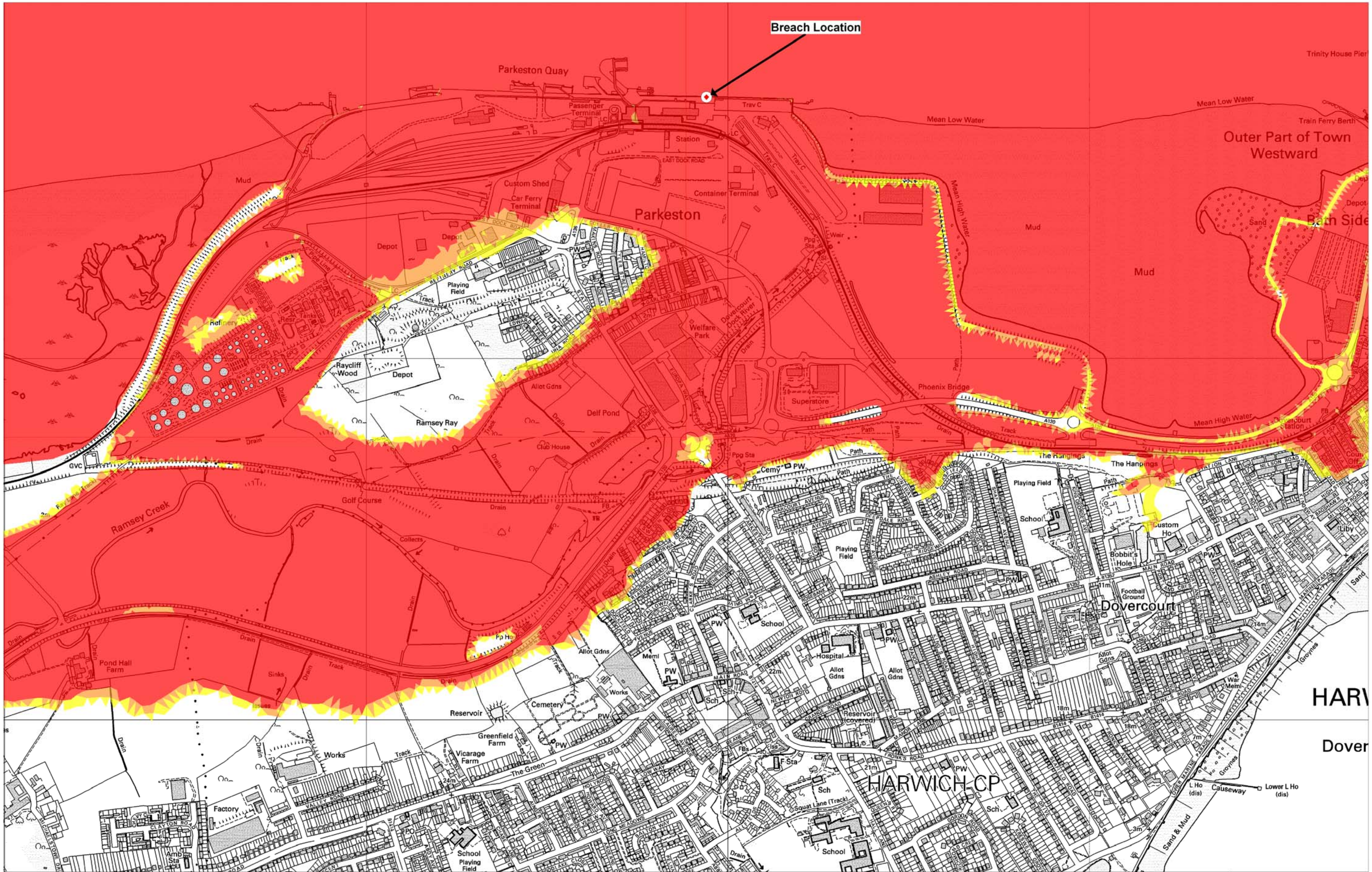
Title:
HAR01 - Harwich Int'l Port - Near Breach
1 in 200 Year - 2108
Flood Depth

FIGURE D7

Scale: 1:10000 @ A3

Drw	NM	Date	21/02/08	Rev	2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR01 - Harwich Int'l Port - Near Breach
1 in 1000 Year - 2108
Flood Hazard

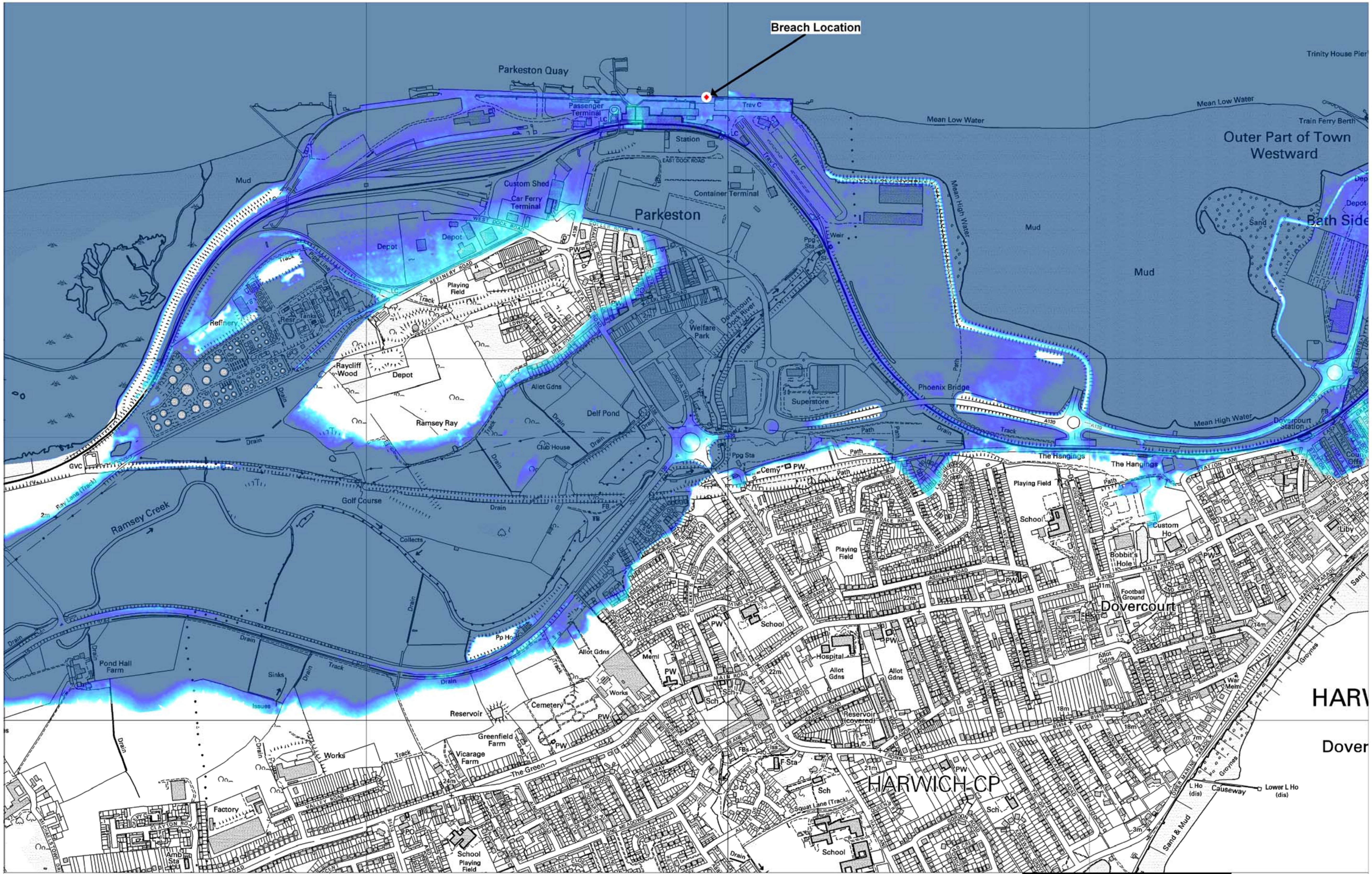
High Hazard
Medium Hazard
Low Hazard

FIGURE D8

Scale: 1:10000 @ A3

Drw NM Date 21/02/08 Rev 2

www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR01 - Harwich Int'l Port - Near Breach
1 in 1000 Year - 2108
Flood Depth

FIGURE D9

Scale: 1:10000 @ A3

Drw	NM	Date	21/02/08	Rev	2

Scott Wilson
www.scottwilson.com

Project:

Harwich SFRA
Tendring District Council

Title:

HAR01 - Harwich Int'l Port - Full Extent
1 in 200 Year - 2108
Flood Hazard

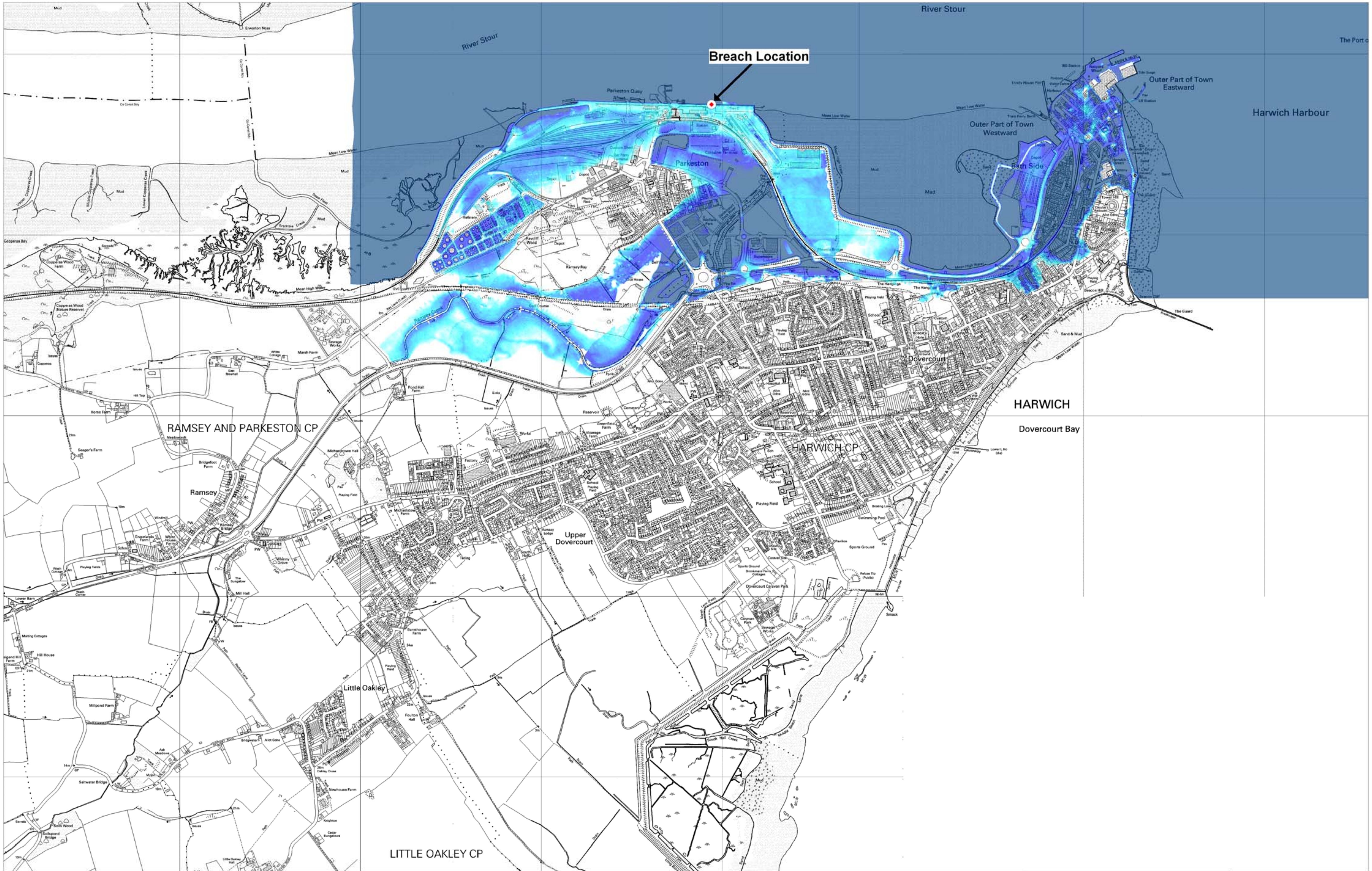
High Hazard | Medium Hazard | Low Hazard

FIGURE D10

Scale: 1:20000 @ A3

Drw NM Date 21/02/08 Rev 2

www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR01 - Harwich Int'l Port - Full Extent
1 in 200 Year - 2108
Flood Depth

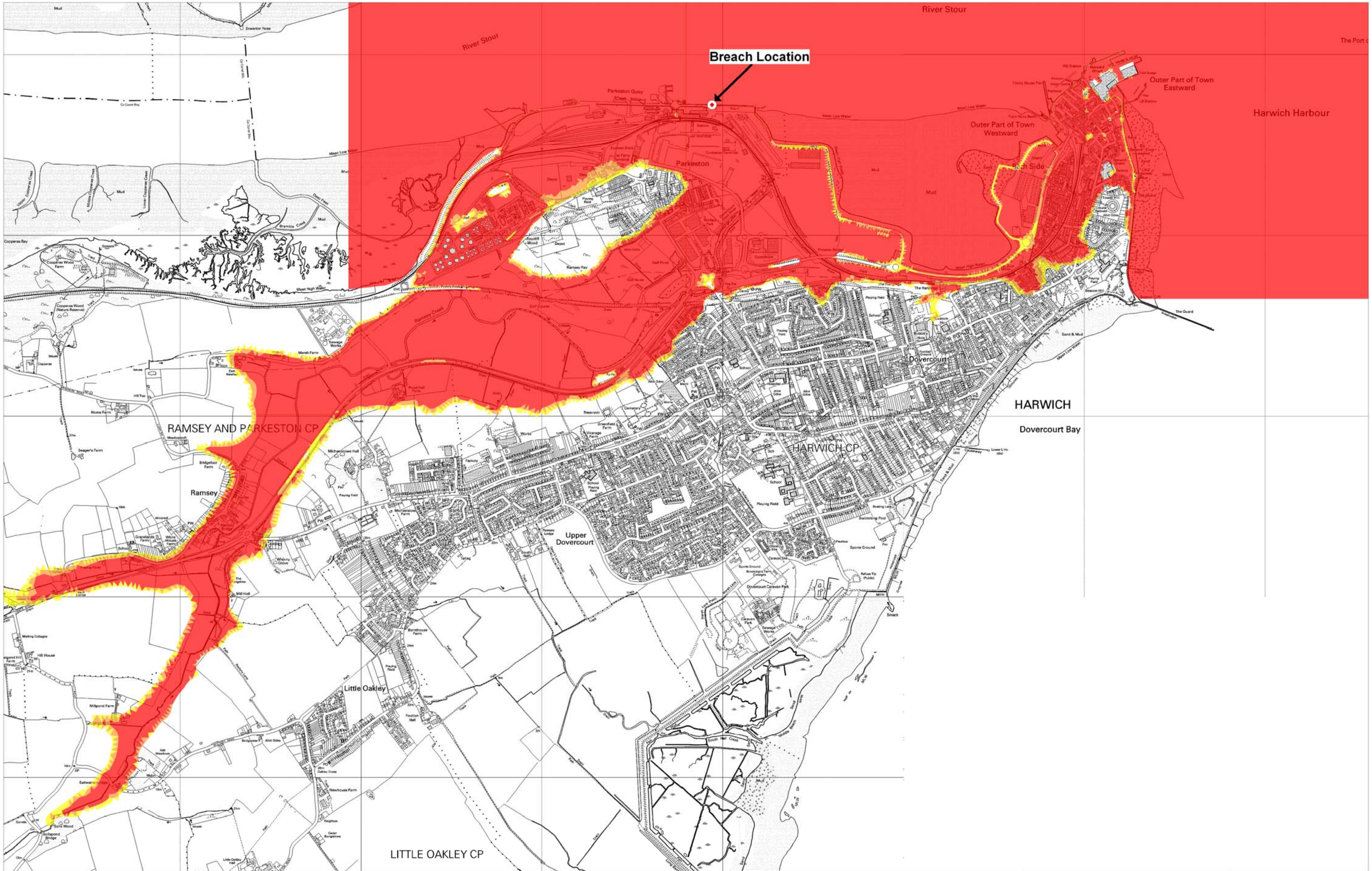
Maximum Flood Depth [m]:
0.05 0.50 1.00 1.50 2.00 3.00

FIGURE D11

Scale: 1:20000 @ A3

Drw	NM	Date	21/02/08	Rev	2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR01 - Harwich Int'l Port - Full Extent
1 in 1000 Year - 2108
Flood Hazard

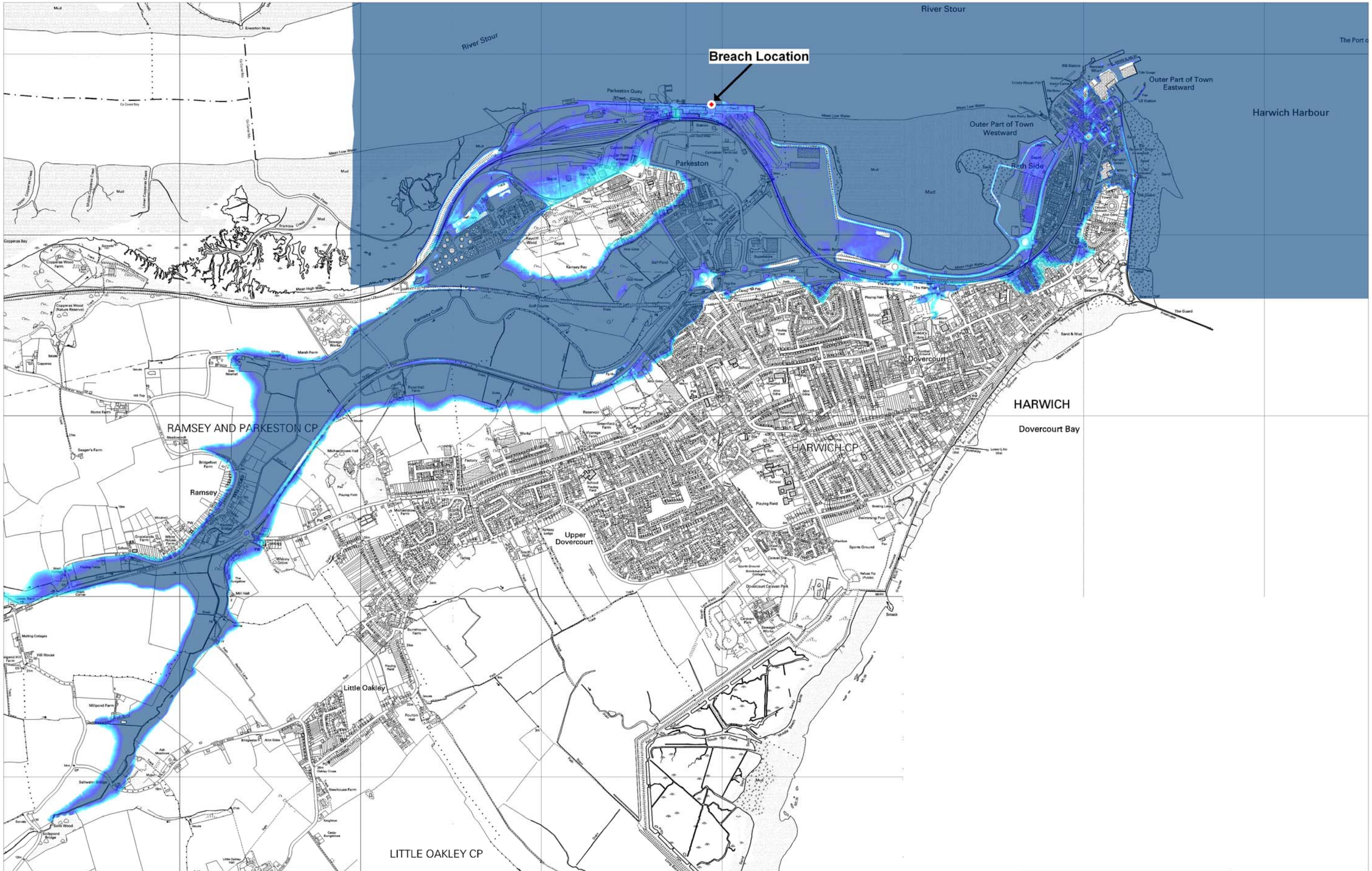
High Hazard
Medium Hazard
Low Hazard

FIGURE D12

Scale: 1:20000 @ A3

Drw NM | Date 21/02/08 | Rev 2

www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR01 - Harwich Int'l Port - Full Extent
1 in 1000 Year - 2108
Flood Depth

Maximum Flood Depth [m]:
0.05 0.50 1.00 1.50 2.00 3.00

FIGURE D13

Scale: 1:20000 @ A3

Drw NM Date 21/02/08 Rev 2

Scott Wilson
www.scottwilson.com

Project:

Harwich SFRA
Tendring District Council

Title:

HAR01 - Harwich Int'l Port - Near Breach Flood Outlines - 2008

1 in 200 Year **1 in 1000 Year**

FIGURE D14

Scale: 1:10000 @ A3

Drw	NM	Date	21/02/08	Rev	2

Scott Wilson
www.scottwilson.com

Project:
Harwich SFRA
Tendring District Council

Title:
HAR01 - Harwich Int'l Port - Near Breach Flood Outlines - 2108

1 in 200 Year | 1 in 1000 Year

FIGURE D15

Scale: 1:10000 @ A3

Drw	NM	Date	21/02/08	Rev	2

Scott Wilson
www.scottwilson.com

Project:
Harwich SFRA
Tendring District Council

Title:
HAR01 - Harwich Int'l Port - Full Extent Flood Outlines - 2108

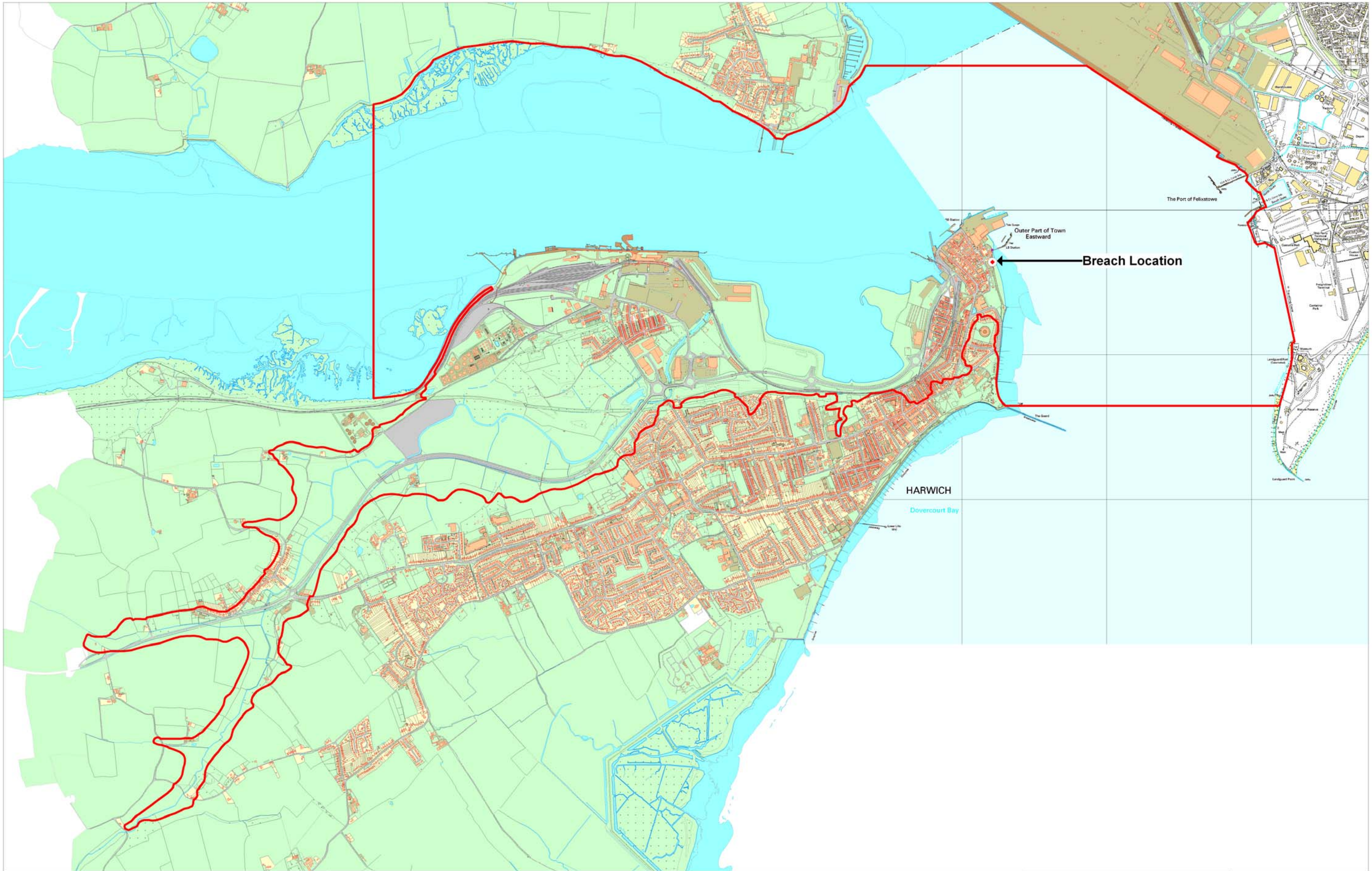
1 in 200 Year **1 in 1000 Year**

FIGURE D16

Scale: 1:20000 @ A3

Drw NM Date 21/02/08 Rev 2

www.scottwilson.com



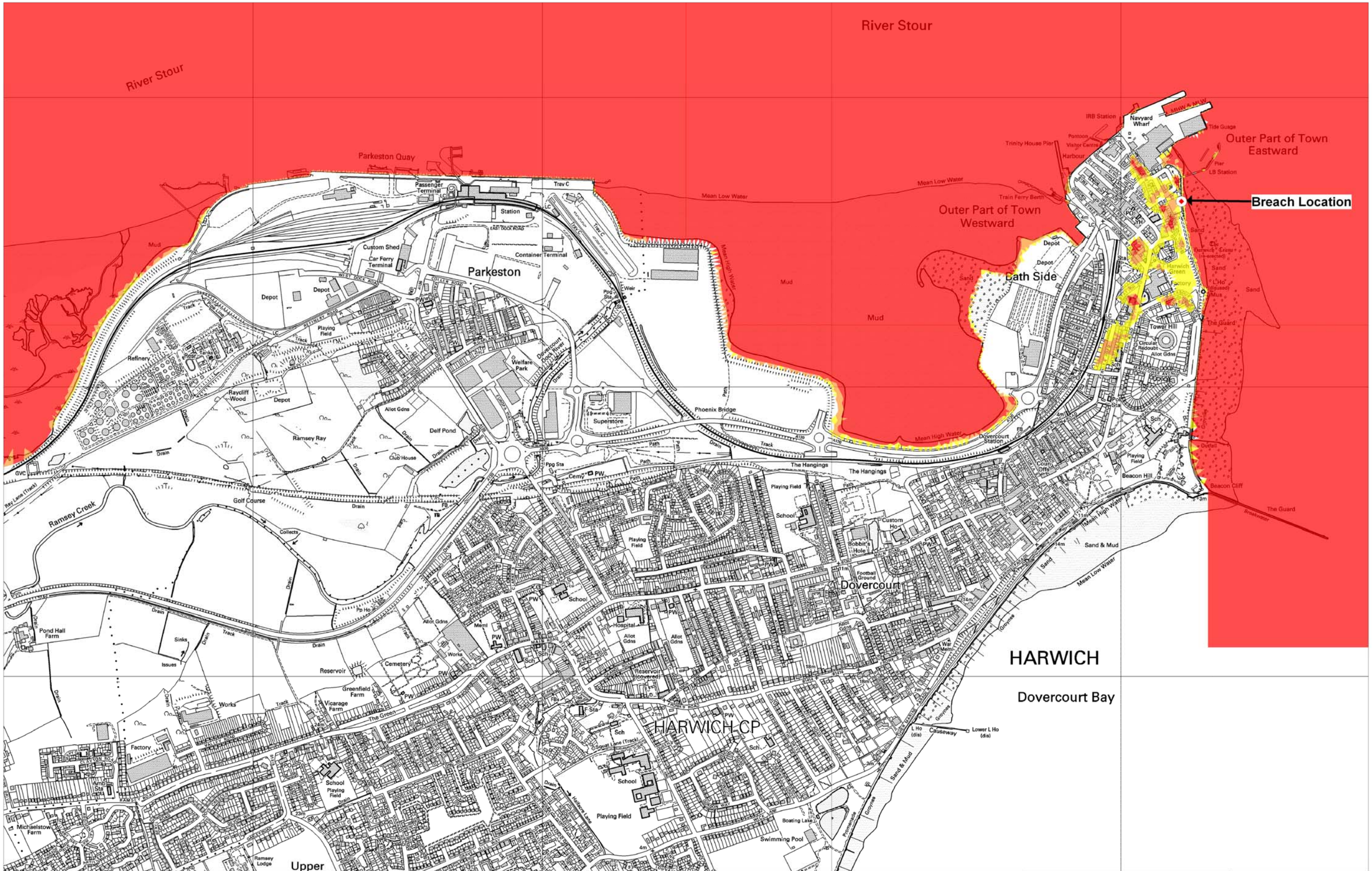
Flood Cell Outline

Project: **Harwich SFRA Tendring District Council**	Title: **HAR02 - Harwich Peninsula Model Flood Cell Location**	**FIGURE D17**

Scale: 1:25000 @ A3

Drw NM Date 21/02/08 Rev 1

www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR02 - Harwich Peninsula - Near Breach
1 in 200 Year - 2008
Flood Hazard

High Hazard
Medium Hazard
Low Hazard

FIGURE D18

Scale: 1:12500 @ A3

Drw	NM	Date	21/02/08	Rev	2

Scott Wilson
www.scottwilson.com

Project:
Harwich SFRA
Tendring District Council

Title:
HAR02 - Harwich Peninsula - Near Breach
1 in 200 Year - 2008
Flood Depth

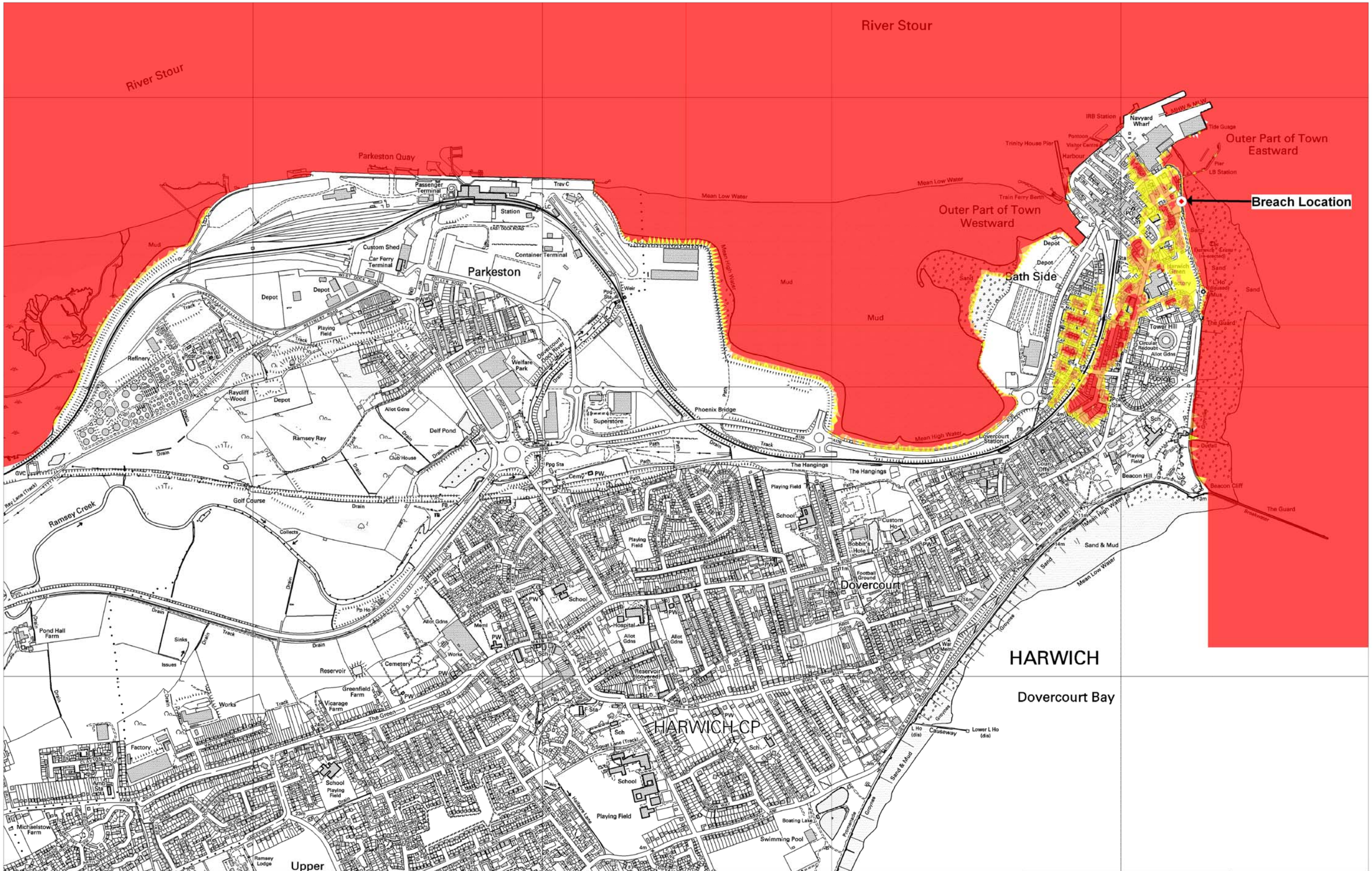
Maximum Flood Depth [m]:
0.05 0.50 1.00 1.50 2.00 3.00

FIGURE D19

Scale: 1:12500 @ A3

Drw	NM	Date	21/02/08	Rev	2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR02 - Harwich Peninsula - Near Breach
1 in 1000 Year - 2008
Flood Hazard

High Hazard **Medium Hazard**
Low Hazard

FIGURE D20

Scale: 1:12500 @ A3

Drw	NM	Date	21/02/08	Rev	2

Scott Wilson
www.scottwilson.com

Project:
Harwich SFRA
Tendring District Council

Title:
HAR02 - Harwich Peninsula - Near Breach
1 in 1000 Year - 2008
Flood Depth

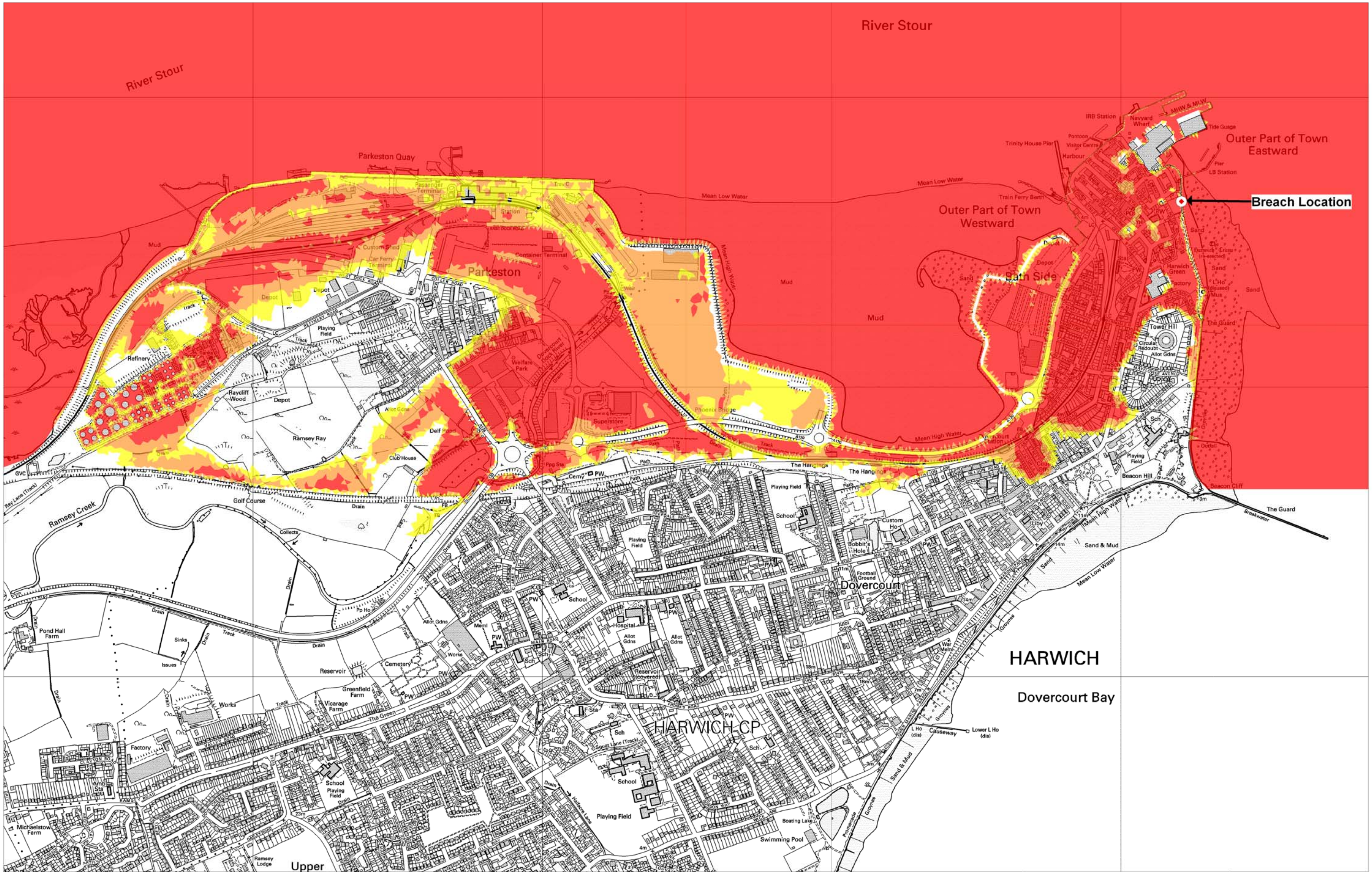
Maximum Flood Depth [m]:
0.05 0.50 1.00 1.50 2.00 3.00

FIGURE D21

Scale: 1:12500 @ A3

Drw NM Date 21/02/08 Rev 2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR02 - Harwich Peninsula - Near Breach
1 in 200 Year - 2108
Flood Hazard

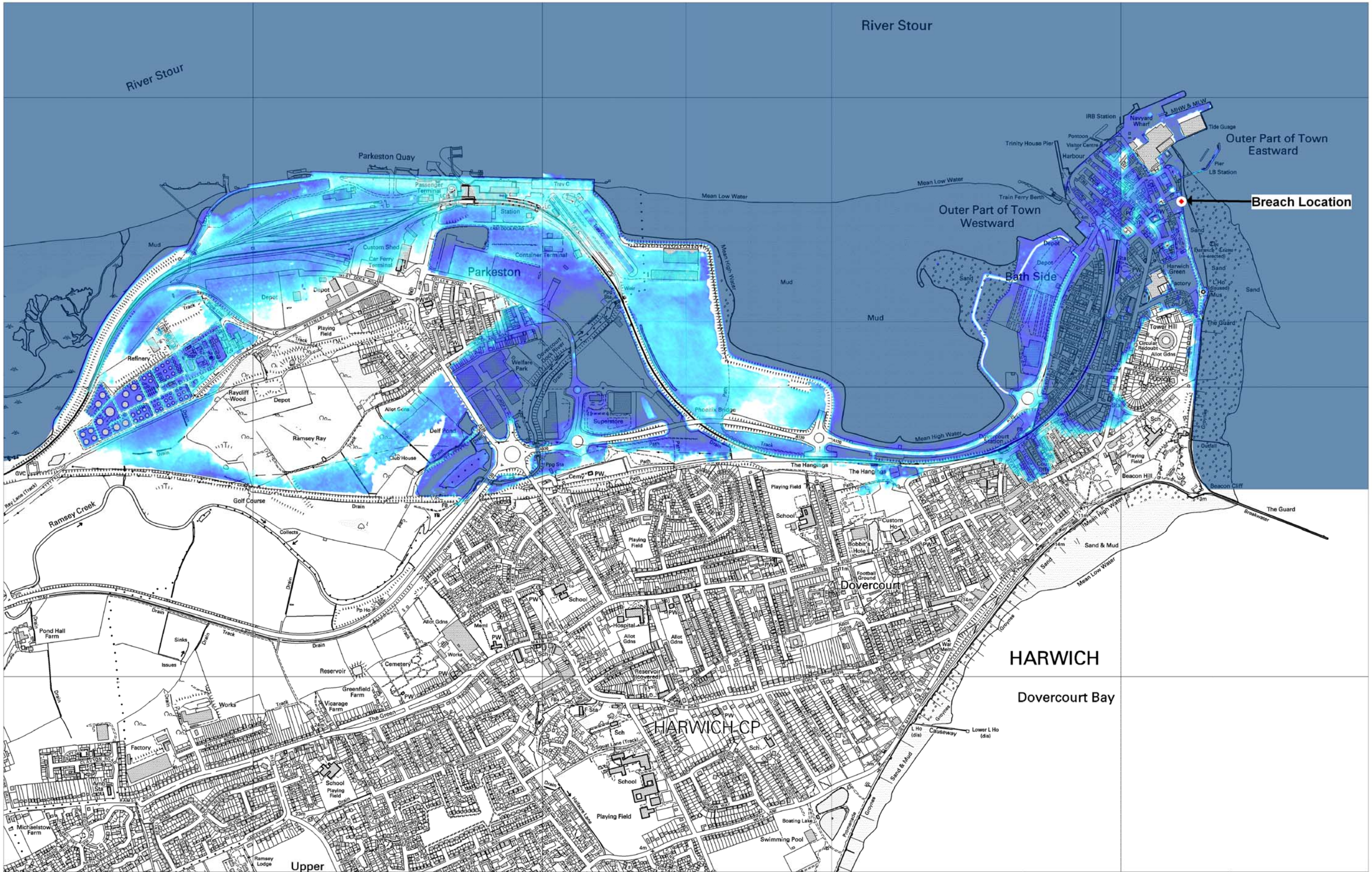
High Hazard
Medium Hazard
Low Hazard

FIGURE D22

Scale: 1:12500 @ A3

Drw NM | Date 21/02/08 | Rev 2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

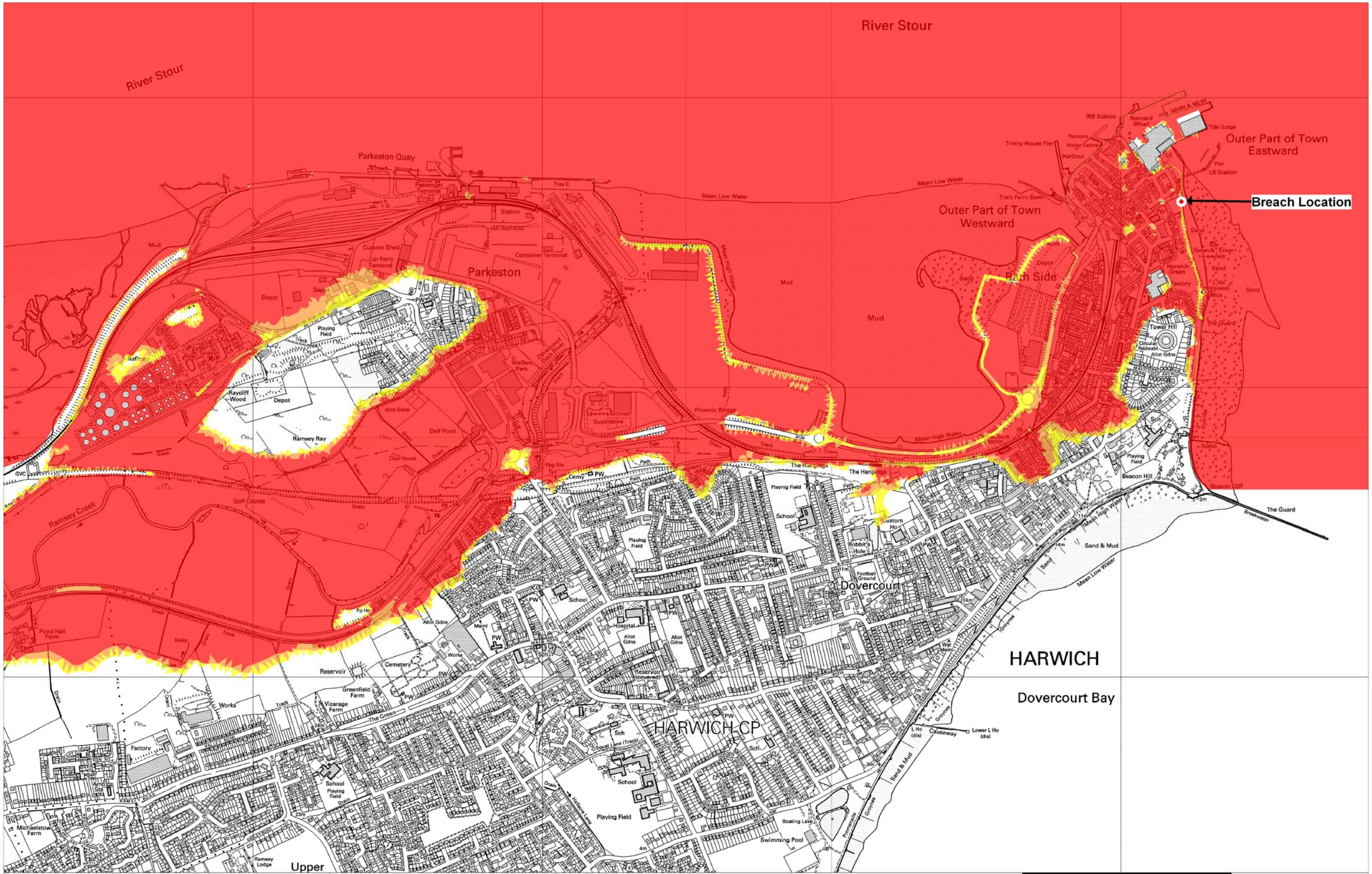
Title:
HAR02 - Harwich Peninsula - Near Breach
1 in 200 Year - 2108
Flood Depth

FIGURE D23

Scale: 1:12500 @ A3

Drw	NM	Date	21/02/08	Rev	2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR02 - Harwich Peninsula - Near Breach
1 in 1000 Year - 2108
Flood Hazard

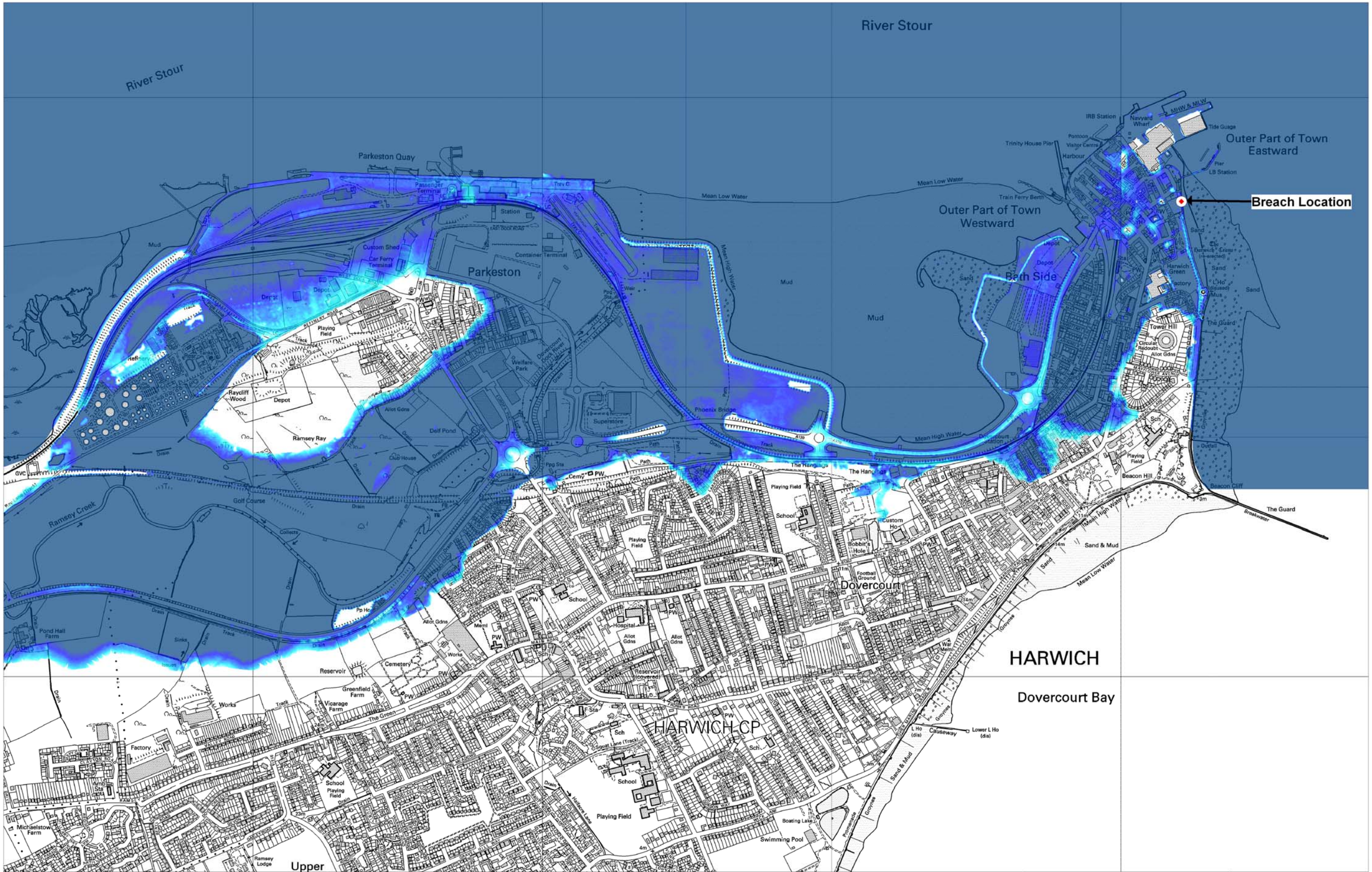
High Hazard
Medium Hazard
Low Hazard

FIGURE D24

Scale: 1:12500 @ A3

Drw	NM	Date	21/02/08	Rev	2

Scott Wilson
www.scottwilson.com



Project:

Harwich SFRA
Tendring District Council

Title:

HAR02 - Harwich Peninsula - Near Breach
1 in 1000 Year - 2108
Flood Depth

Maximum Flood Depth [m]:

0.05 0.50 1.00 1.50 2.00 3.00

FIGURE D25

Scale: 1:12500 @ A3

Drw NM Date 21/02/08 Rev 2

Scott Wilson

www.scottwilson.com

Project:
Harwich SFRA
Tendring District Council

Title:
HAR02 - Harwich Peninsula - Full Extent
1 in 200 Year - 2108
Flood Hazard

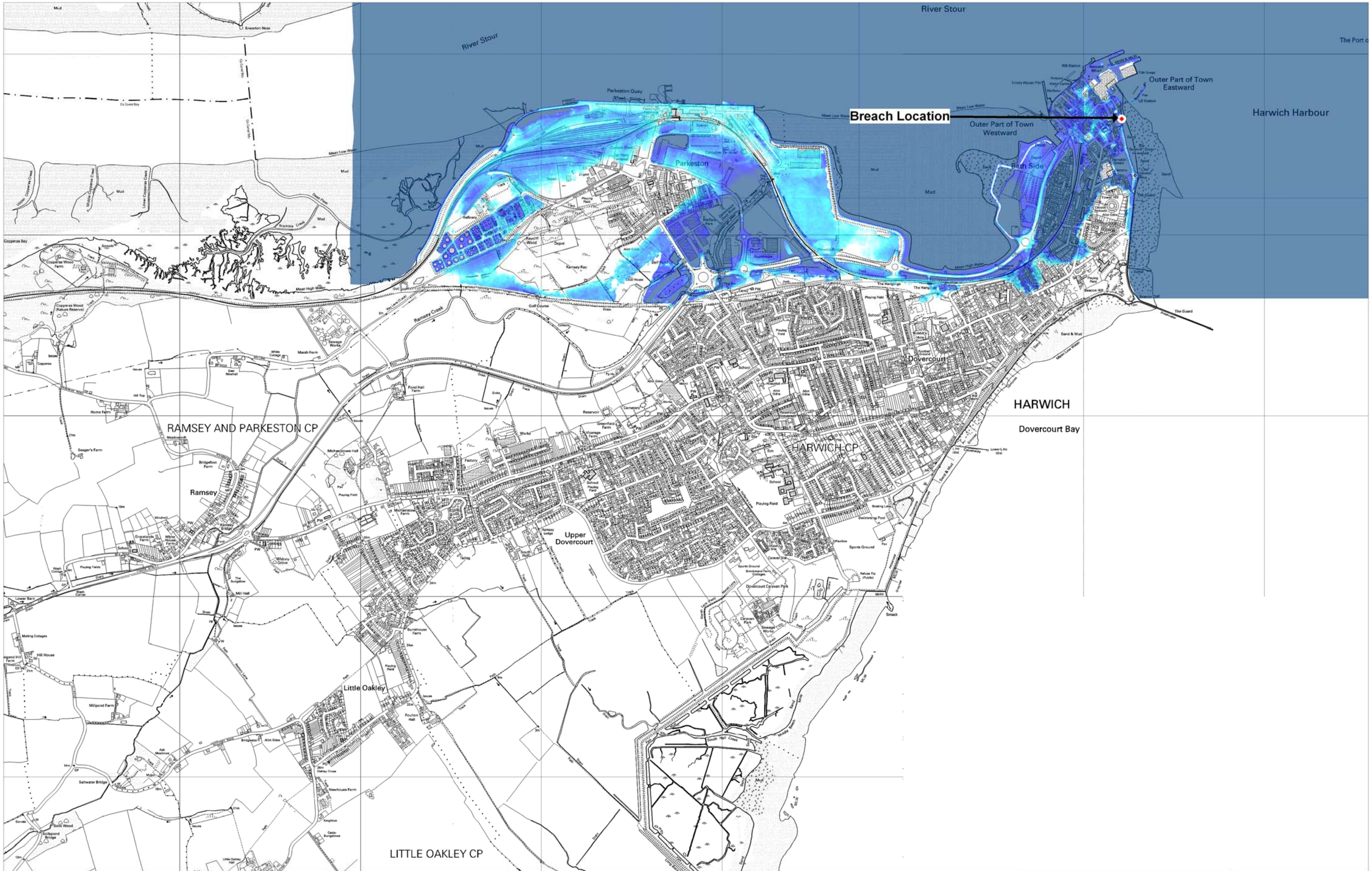
High Hazard
Medium Hazard
Low Hazard

FIGURE D26

Scale: 1:20000 @ A3

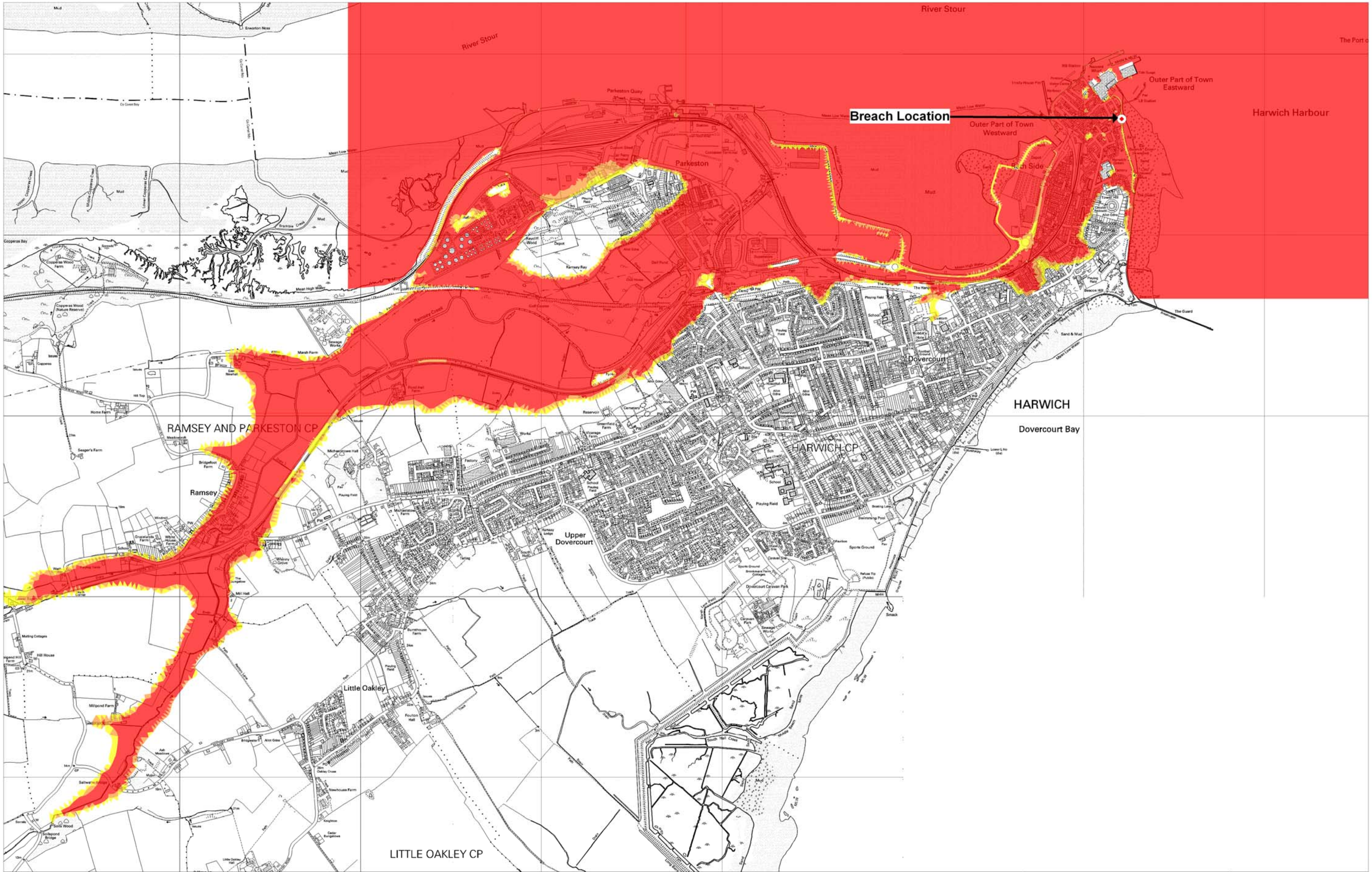
Drw NM | Date 21/02/08 | Rev 2

Scott Wilson
www.scottwilson.com



Project: **Harwich SFRA** **Tendring District Council**	Title: **HAR02 - Harwich Peninsula - Full Extent** **1 in 200 Year - 2108** **Flood Depth**	Maximum Flood Depth [m]: 0.05 0.50 1.00 1.50 2.00 3.00	**FIGURE D27** Scale: 1:20000 @ A3 Drw NM Date 21/02/08 Rev 2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR02 - Harwich Peninsula - Full Extent
1 in 1000 Year - 2108
Flood Hazard

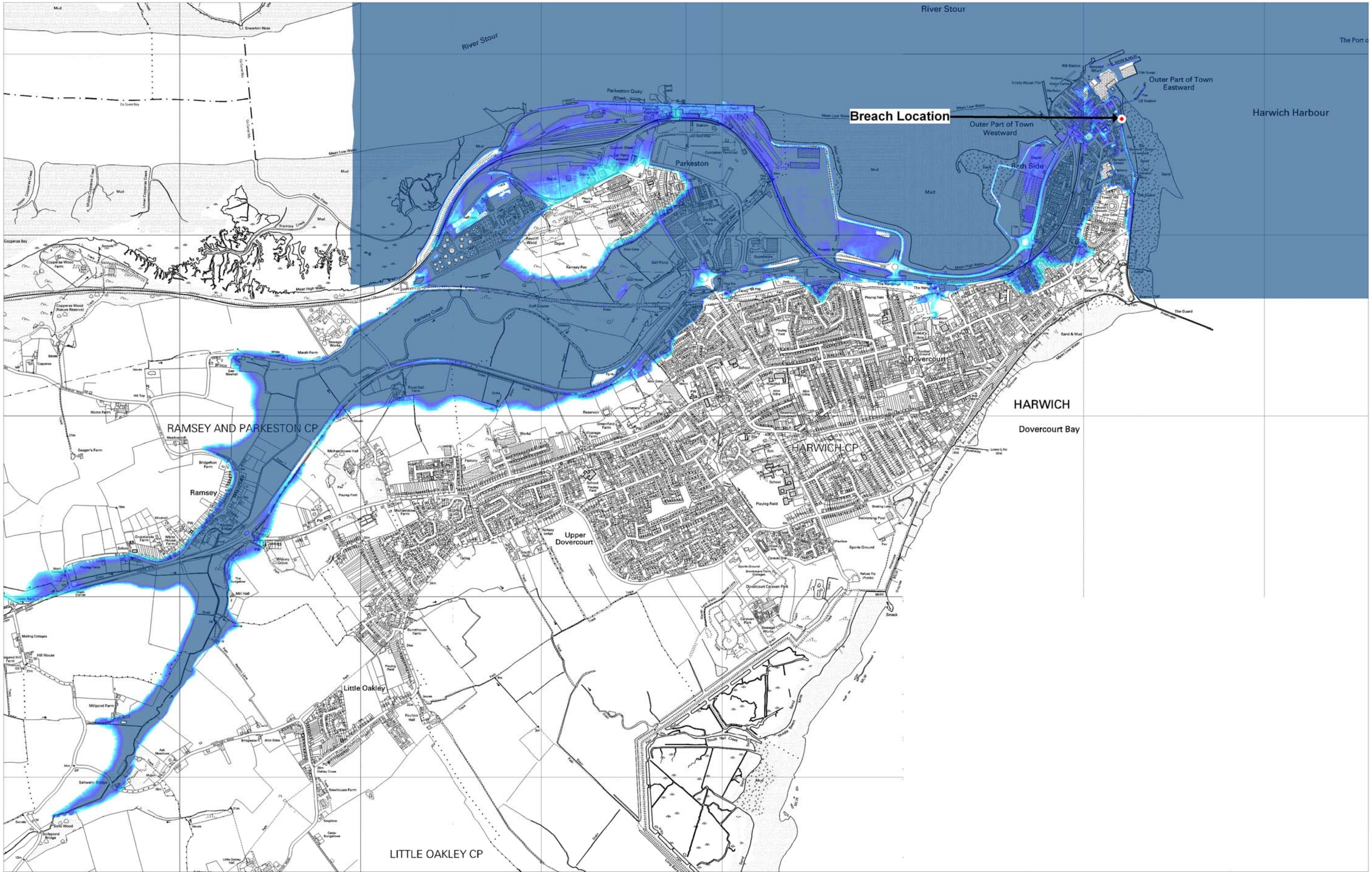
High Hazard
Medium Hazard
Low Hazard

FIGURE D28

Scale: 1:20000 @ A3

Drw NM Date 21/02/08 Rev 2

Scott Wilson
www.scottwilson.com



Project:	Title:	Maximum Flood Depth [m]:	FIGURE D29
Harwich SFRA **Tendring District Council**	**HAR02 - Harwich Peninsula - Full Extent** **1 in 1000 Year - 2108** **Flood Depth**	0.05 0.50 1.00 1.50 2.00 3.00	Scale: 1:20000 @ A3
			Drw NM Date 21/02/08 Rev 2

www.scottwilson.com

Project:
Harwich SFRA
Tendring District Council

Title:
HAR02 - Harwich Peninsula - Near Breach Flood Outlines - 2008

1 in 200 Year **1 in 1000 Year**

FIGURE D30

Scale: 1:12500 @ A3

Drw	NM	Date	21/02/08	Rev	2

Scott Wilson
www.scottwilson.com

Project:
Harwich SFRA
Tendring District Council

Title:
HAR02 - Harwich Peninsula - Near Breach Flood Outlines - 2108

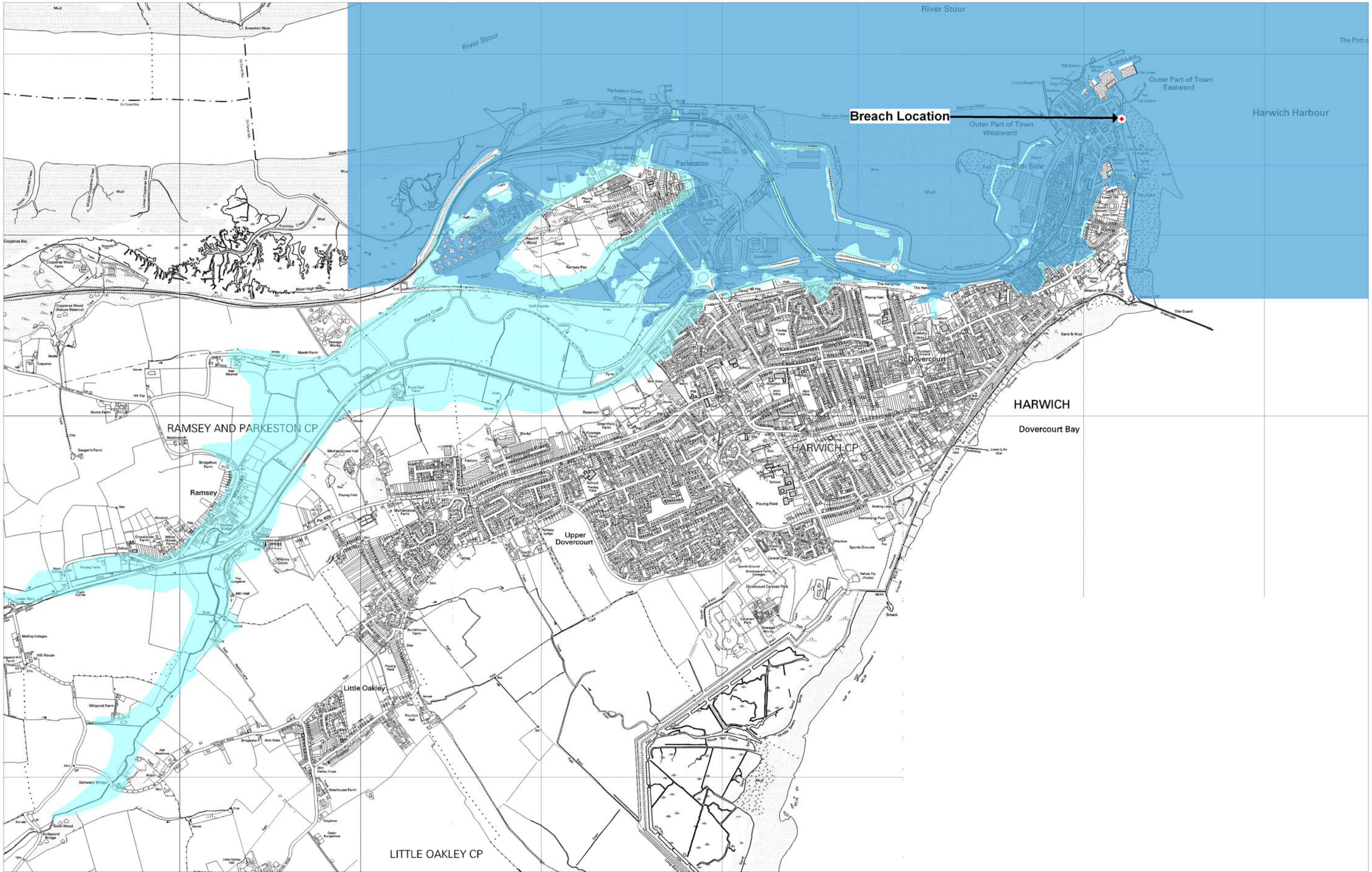
1 in 200 Year **1 in 1000 Year**

FIGURE D31

Scale: 1:12500 @ A3

Drw NM Date 21/02/08 Rev 2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR02 - Harwich Peninsula - Full Extent Flood Outlines - 2108

1 in 200 Year **1 in 1000 Year**

FIGURE D32

Scale: 1:20000 @ A3

Drw NM Date 21/02/08 Rev 2

Scott Wilson
www.scottwilson.com

Project:
Harwich SFRA
Tendring District Council

Title:
HAR03 - Dovercourt
Model Flood Cell Location - 2008

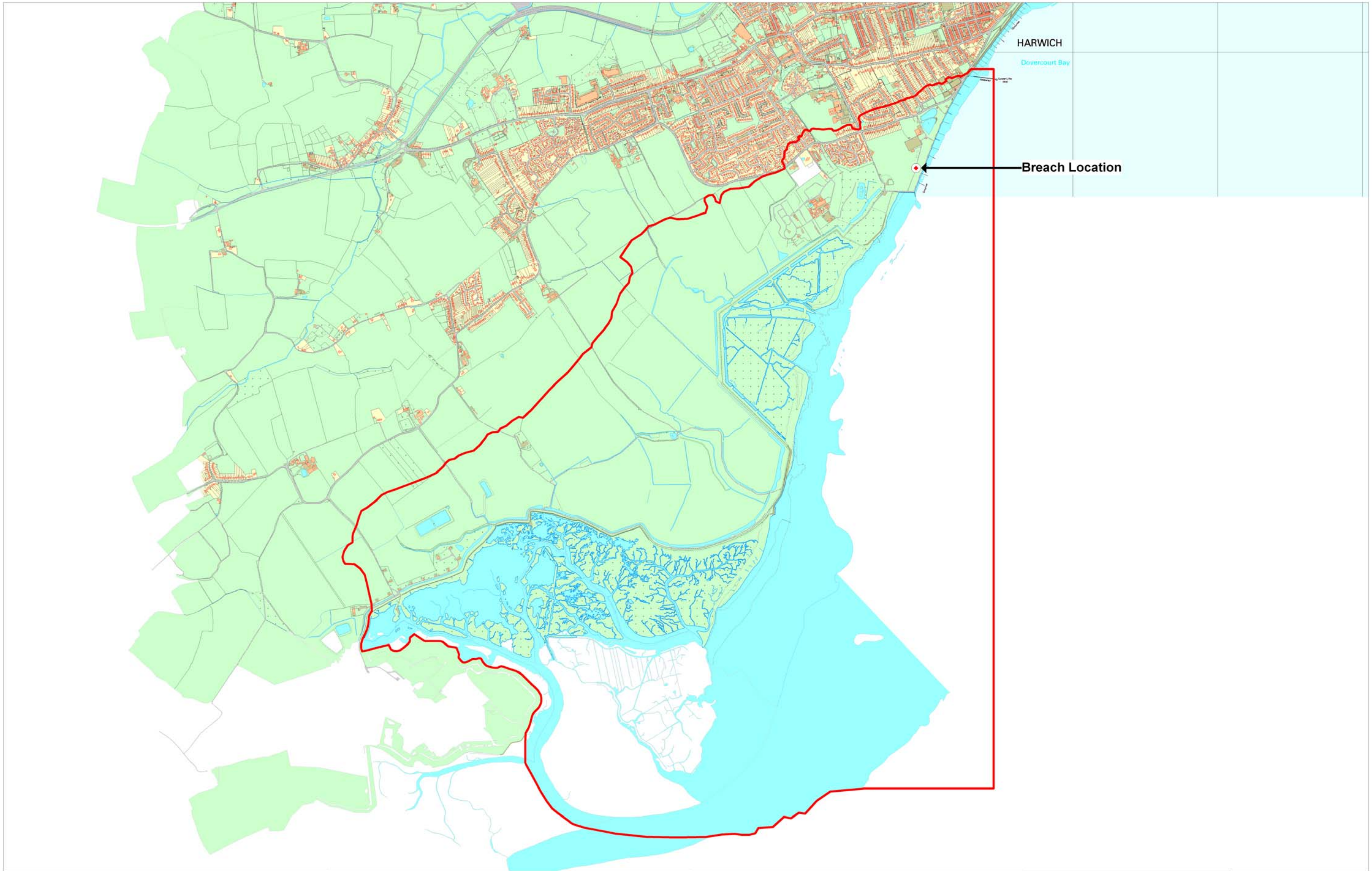
Flood Cell Outline

FIGURE D33

Scale: 1:25000 @ A3

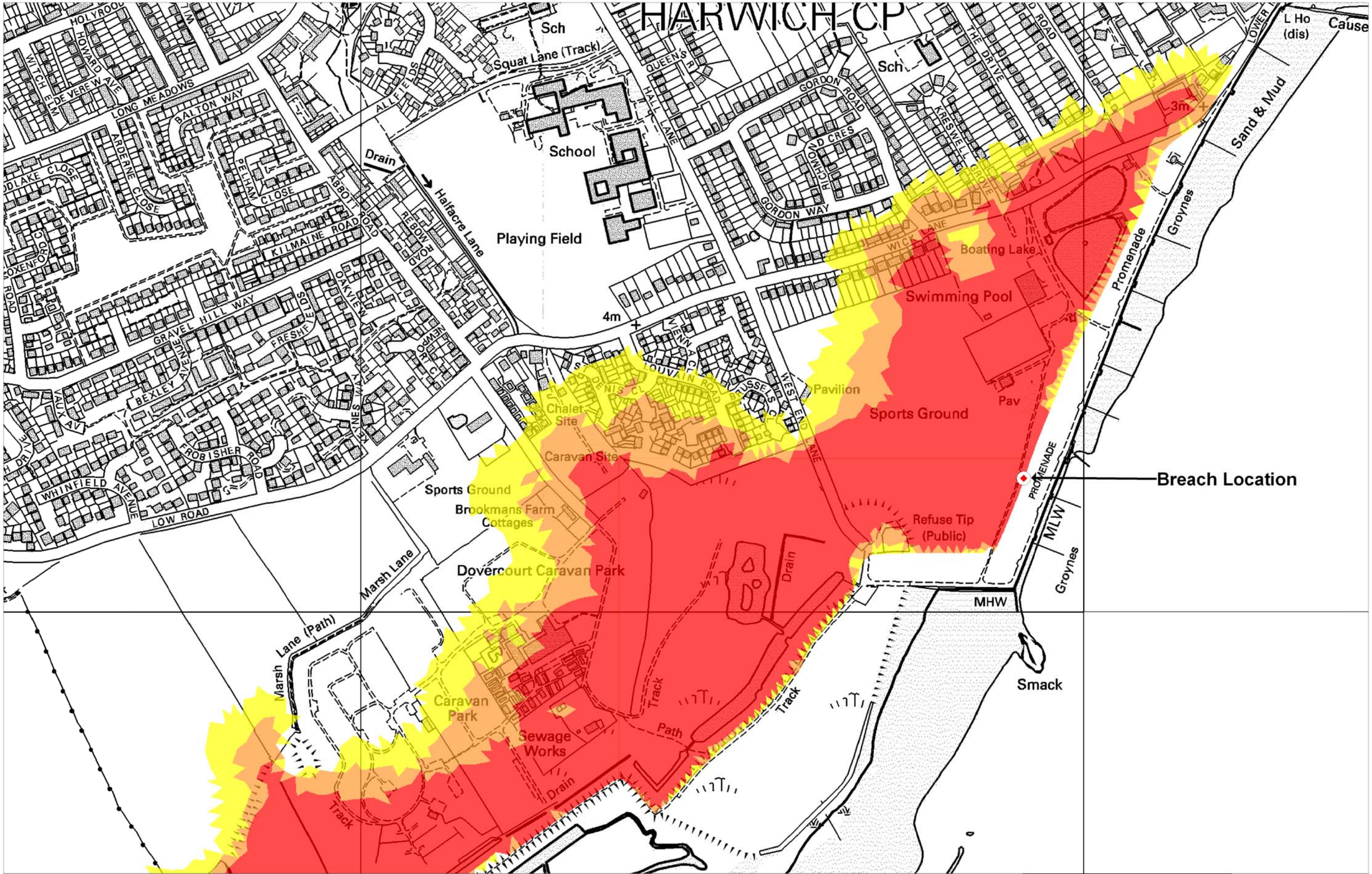
Drw NM | Date 21/02/08 | Rev 1

www.scottwilson.com



Project:	Title:		FIGURE D34
Harwich SFRA **Tendring District Council**	**HAR03 - Dovercourt** **Model Flood Cell Location - 2108**	**Flood Cell Outline**	Scale: 1:25000 @ A3 Drw NM Date 21/02/08 Rev 1

www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR03 - Dovercourt - Near Breach
1 in 200 Year - 2008
Flood Hazard

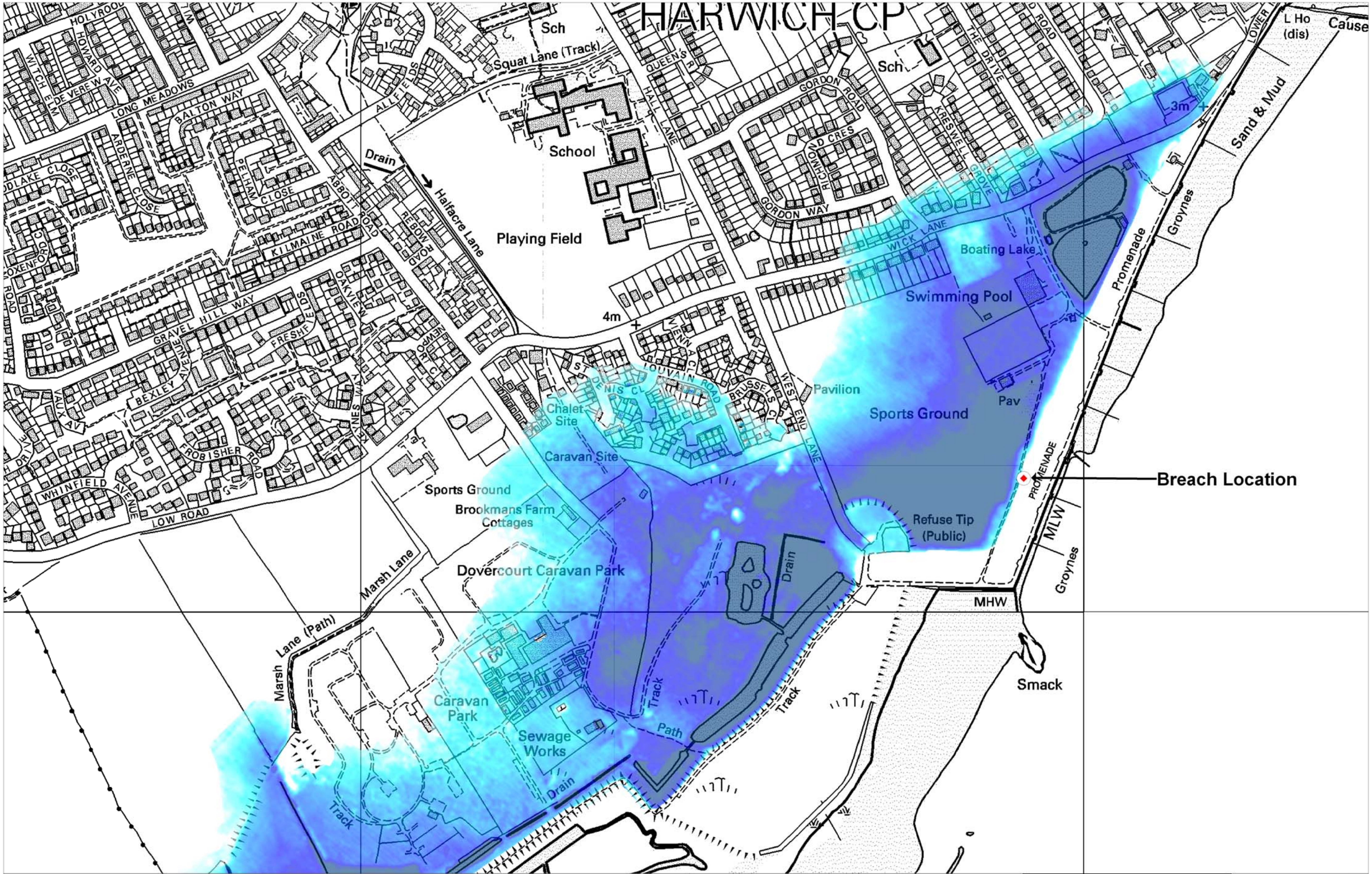
High Hazard
Medium Hazard
Low Hazard

FIGURE D35

Scale: 1:5000 @ A3

Drw	NM	Date	10/04/08	Rev	2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR03 - Dovercourt - Near Breach
1 in 200 Year - 2008
Flood Depth

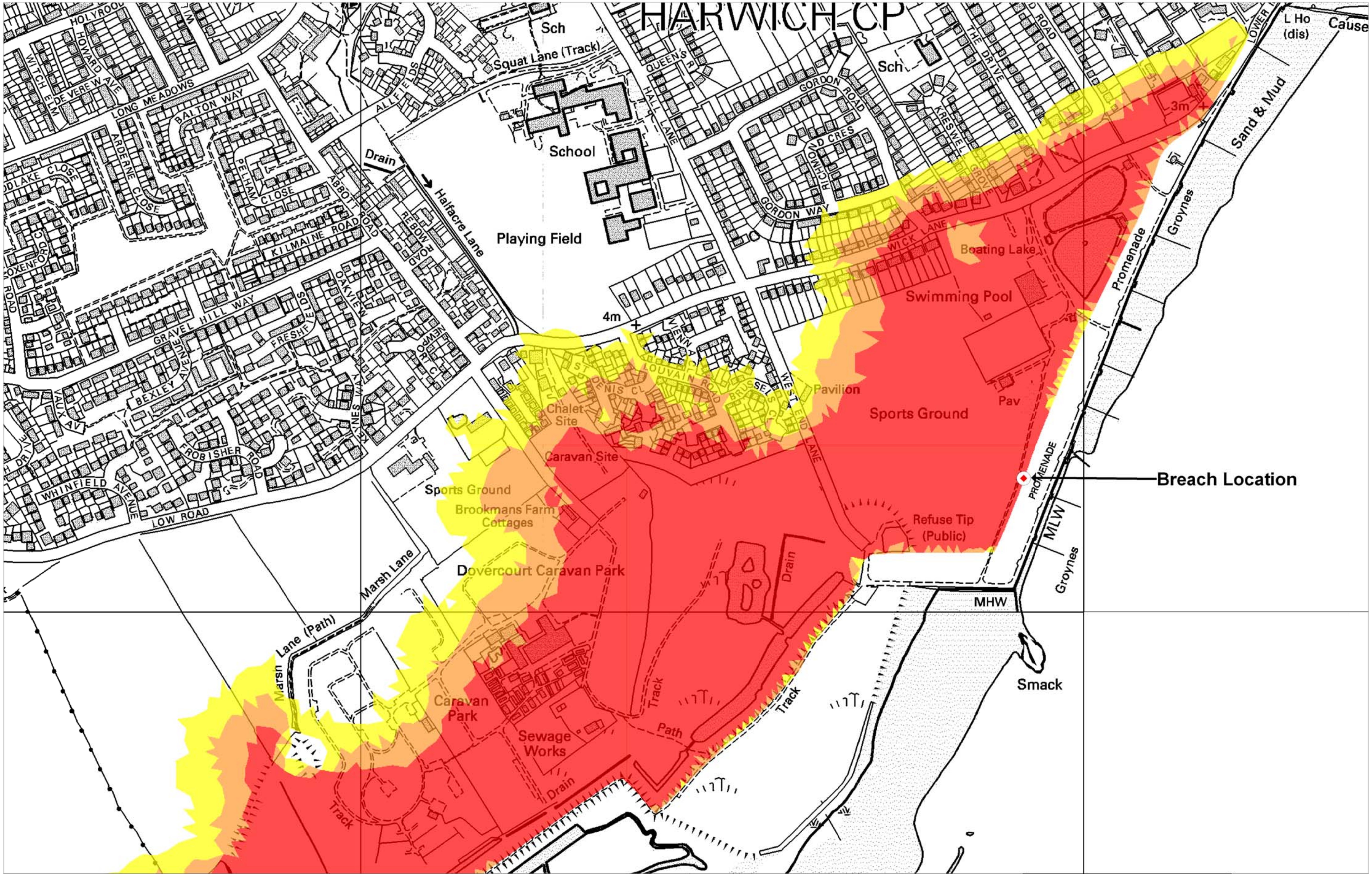
Maximum Flood Depth [m]:
0.05 0.50 1.00 1.50 2.00 3.00

FIGURE D36

Scale: 1:5000 @ A3

Drw NM Date 10/04/08 Rev 2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR03 - Dovercourt - Near Breach
1 in 1000 Year - 2008
Flood Hazard

High Hazard
Medium Hazard
Low Hazard

FIGURE D37

Scale: 1:5000 @ A3

Drw	NM	Date	10/04/08	Rev	2

Scott Wilson
www.scottwilson.com

Project:
Harwich SFRA
Tendring District Council

Title:
HAR03 - Dovercourt - Near Breach
1 in 1000 Year - 2008
Flood Depth

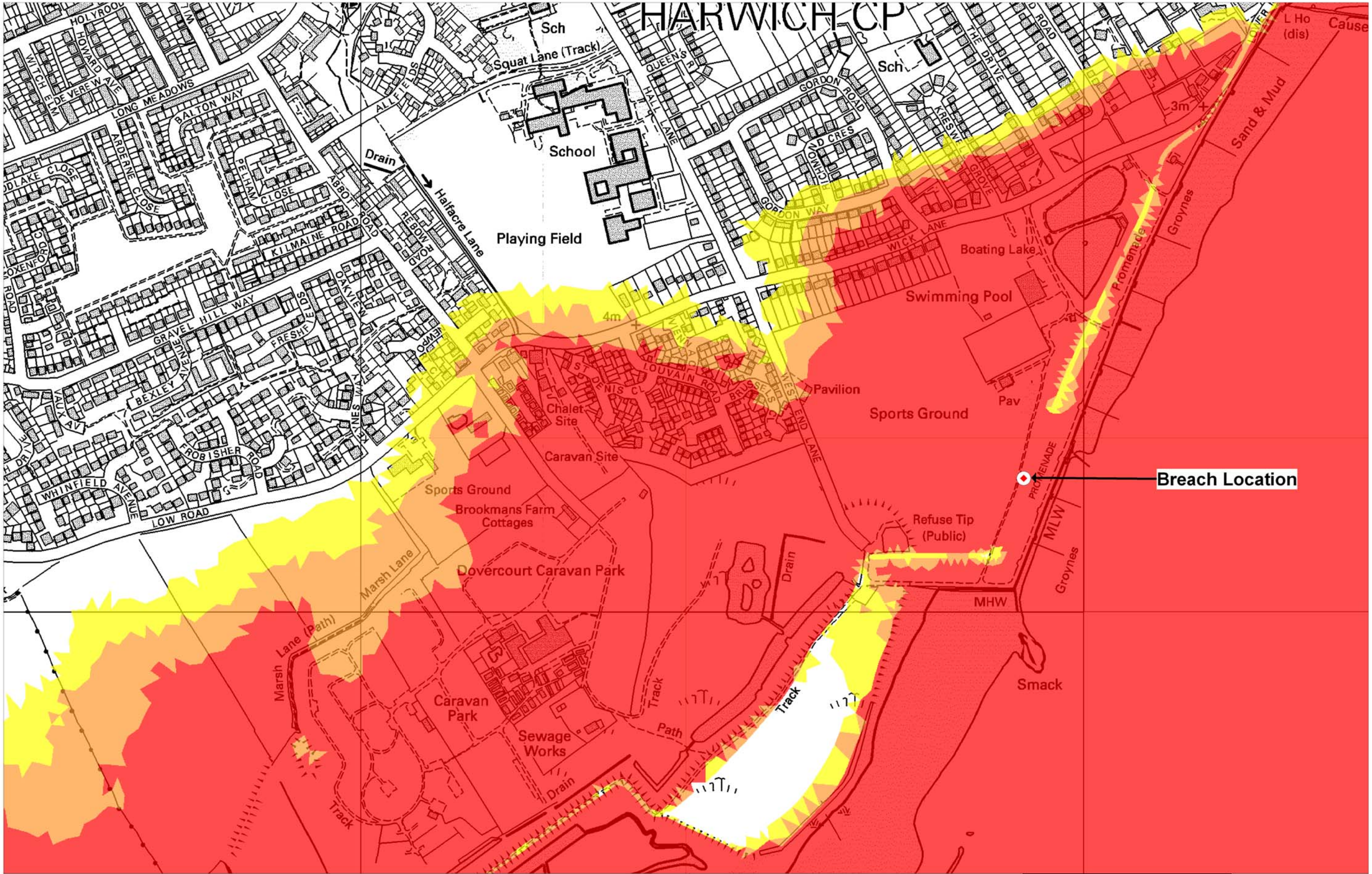
Maximum Flood Depth [m]:
0.05 0.50 1.00 1.50 2.00 3.00

FIGURE D38

Scale: 1:5000 @ A3

Drw NM Date 10/04/08 Rev 2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

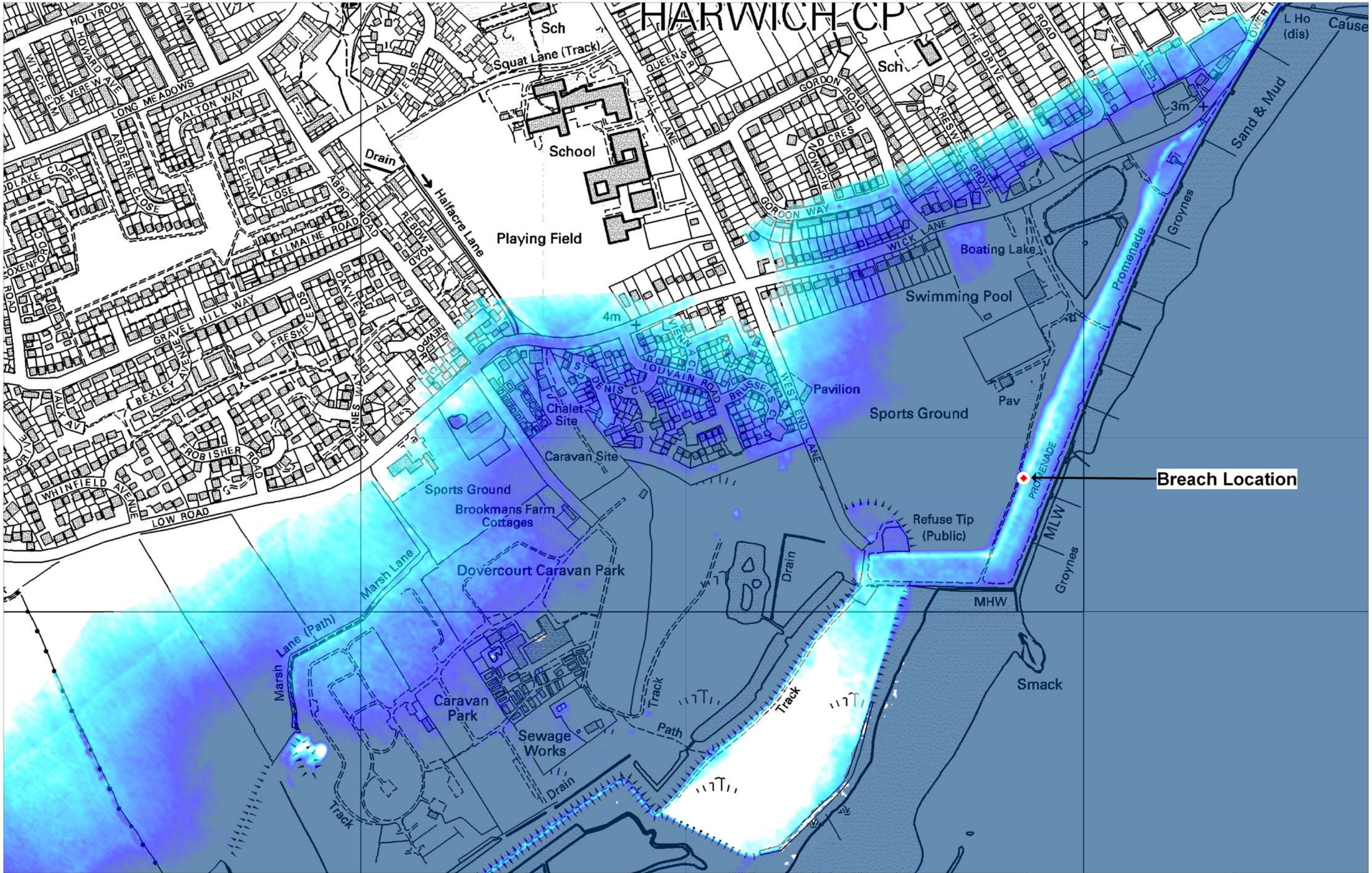
Title:
HAR03 - Dovercourt - Near Breach
1 in 200 Year - 2108
Flood Hazard

FIGURE D39

Scale: 1:5000 @ A3

Drw NM | Date 10/04/08 | Rev 2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR03 - Dovercourt - Near Breach
1 in 200 Year - 2108
Flood Depth

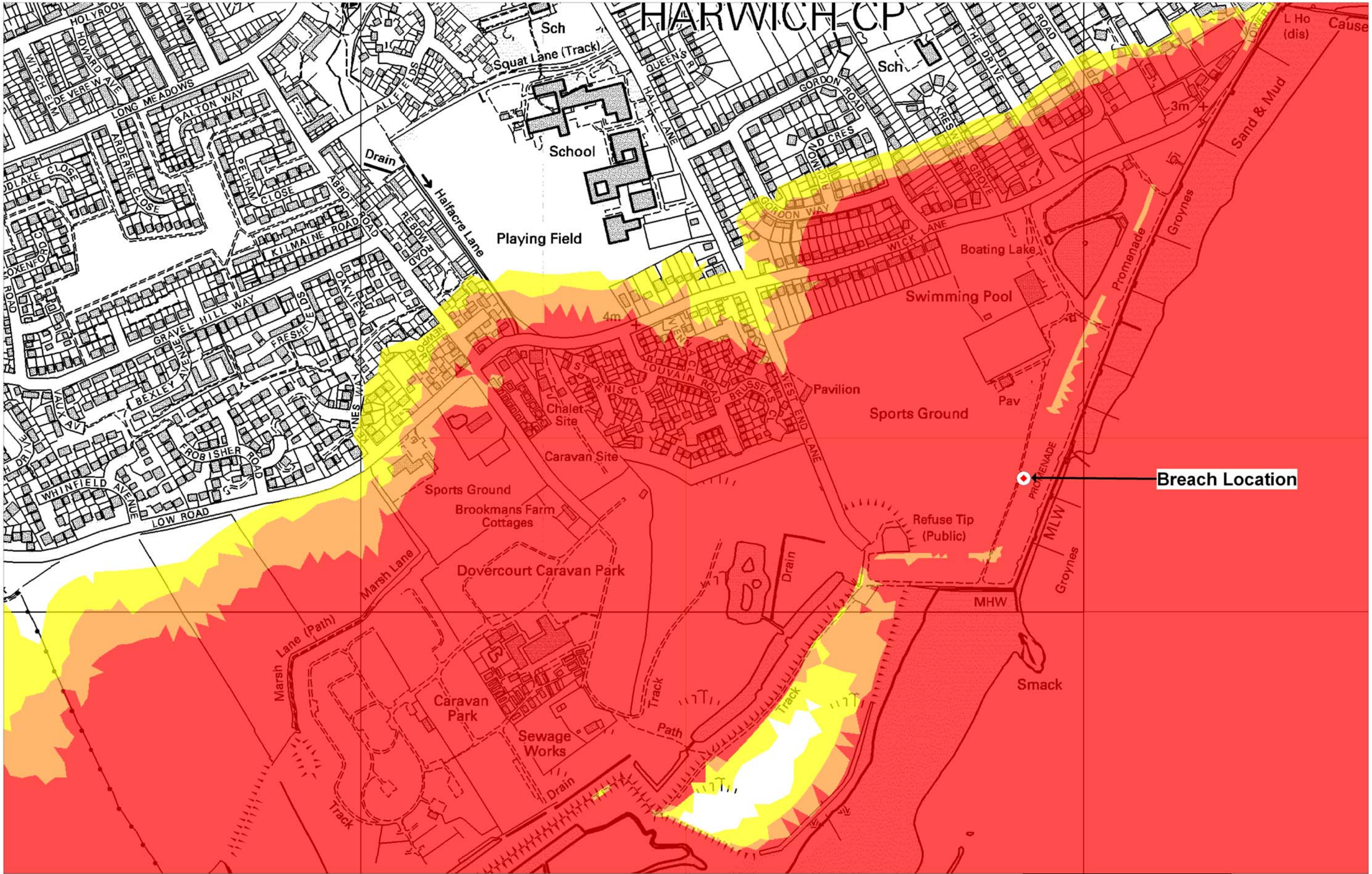
Maximum Flood Depth [m]:
0.05 0.50 1.00 1.50 2.00 3.00

FIGURE D40

Scale: 1:5000 @ A3

Drw NM Date 10/04/08 Rev 2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR03 - Dovercourt - Near Breach
1 in 1000 Year - 2108
Flood Hazard

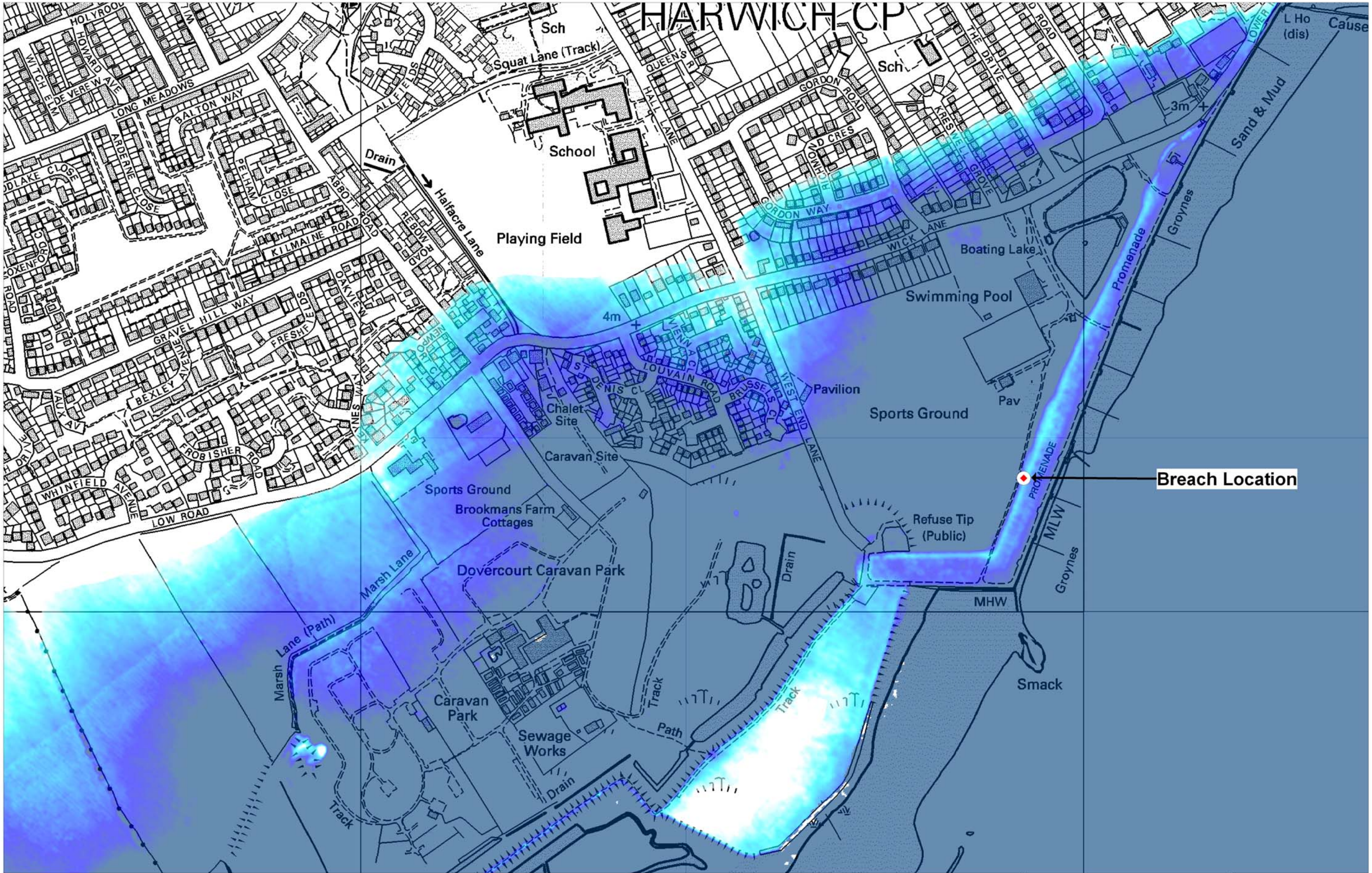
High Hazard | Medium Hazard | Low Hazard

FIGURE D41

Scale: 1:5000 @ A3

Drw NM | Date 10/04/08 | Rev 2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR03 - Dovercourt - Near Breach
1 in 1000 Year - 2108
Flood Depth

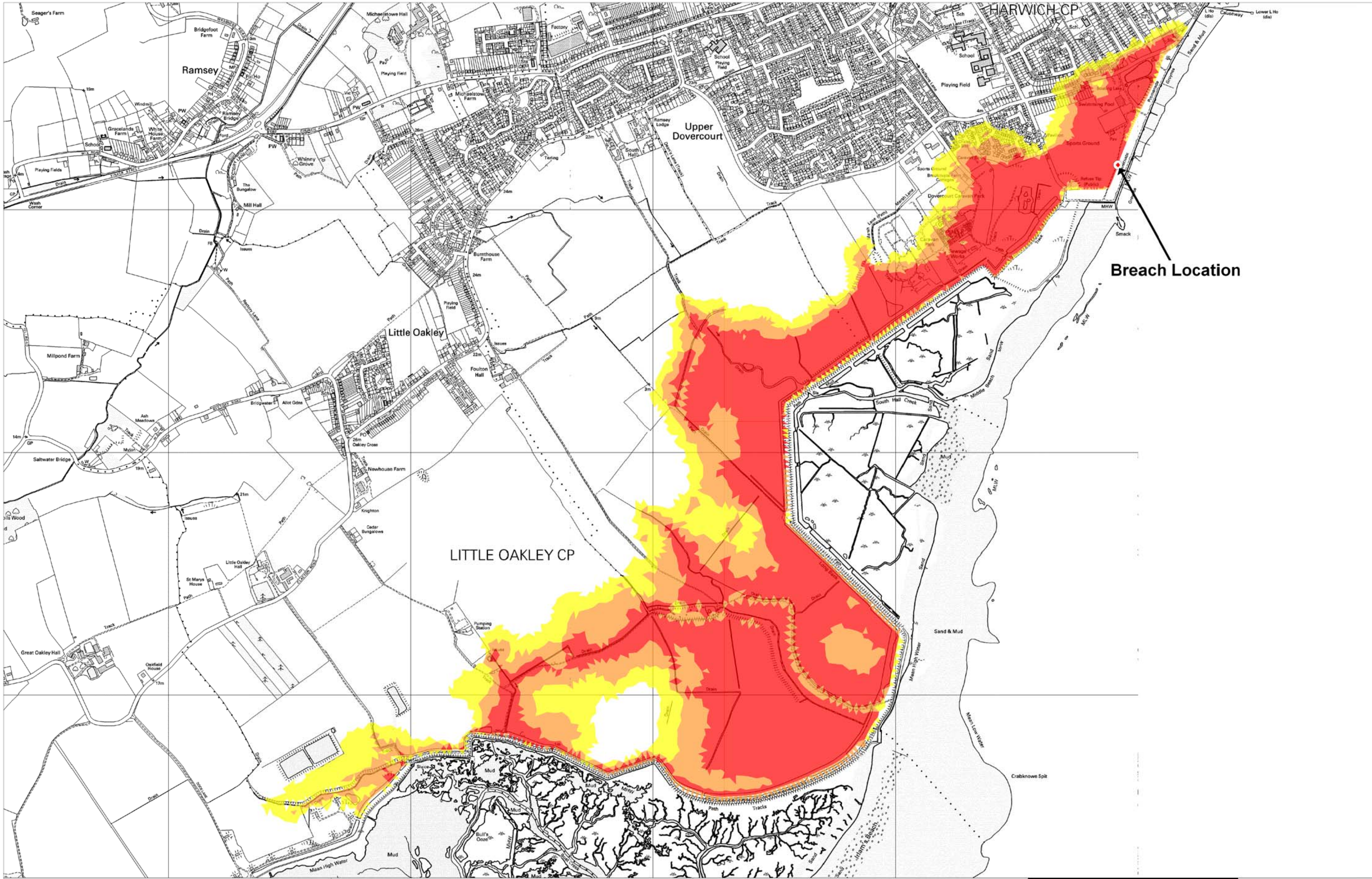
Maximum Flood Depth [m]:
0.05 0.50 1.00 1.50 2.00 3.00

FIGURE D42

Scale: 1:5000 @ A3

Drw NM | Date 10/04/08 | Rev 2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

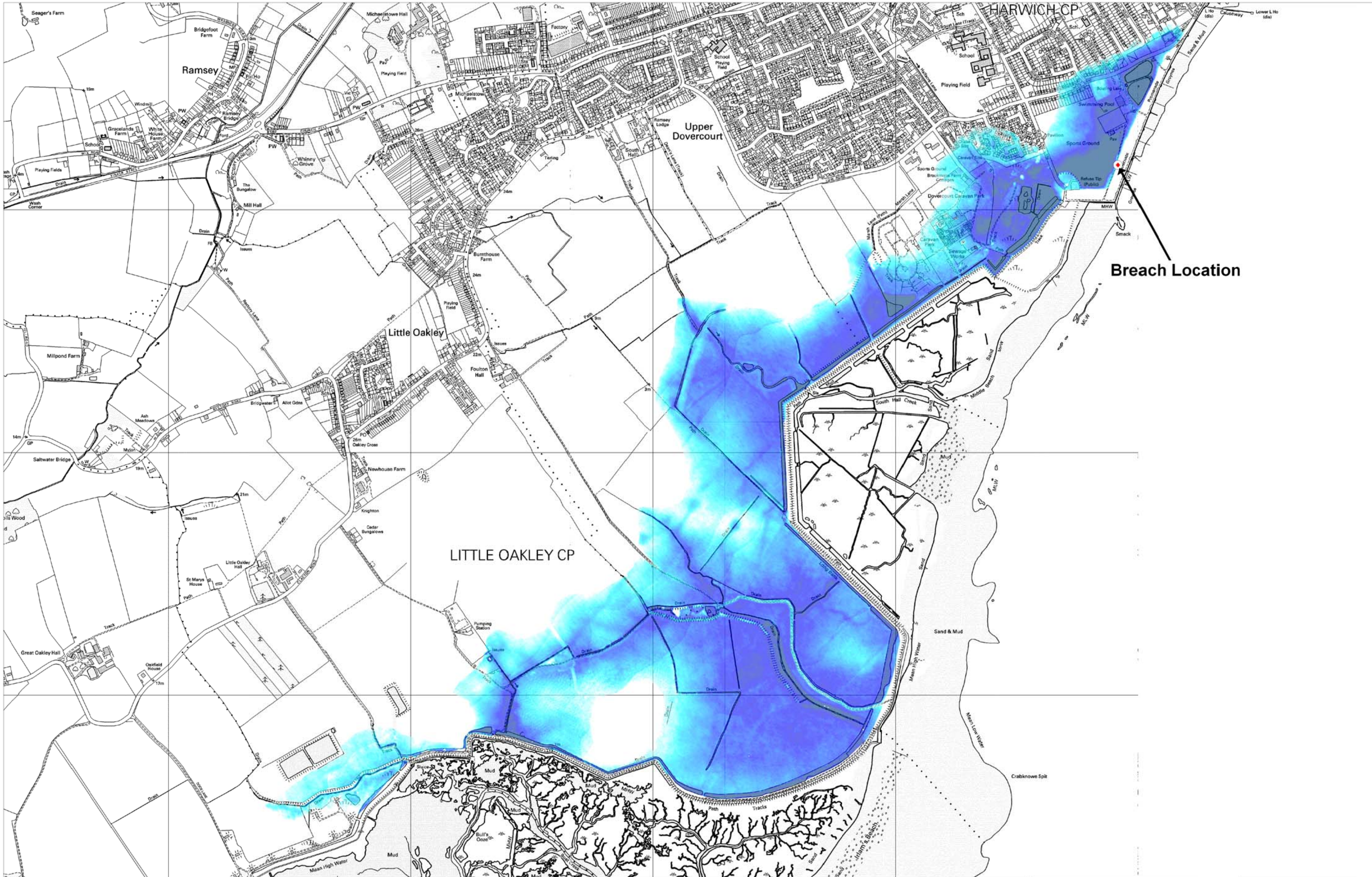
Title:
HAR03 - Dovercourt - Full Extent
1 in 200 Year - 2008
Flood Hazard

FIGURE D43

Scale: 1:15000 @ A3

Drw	NM	Date	10/04/08	Rev	2

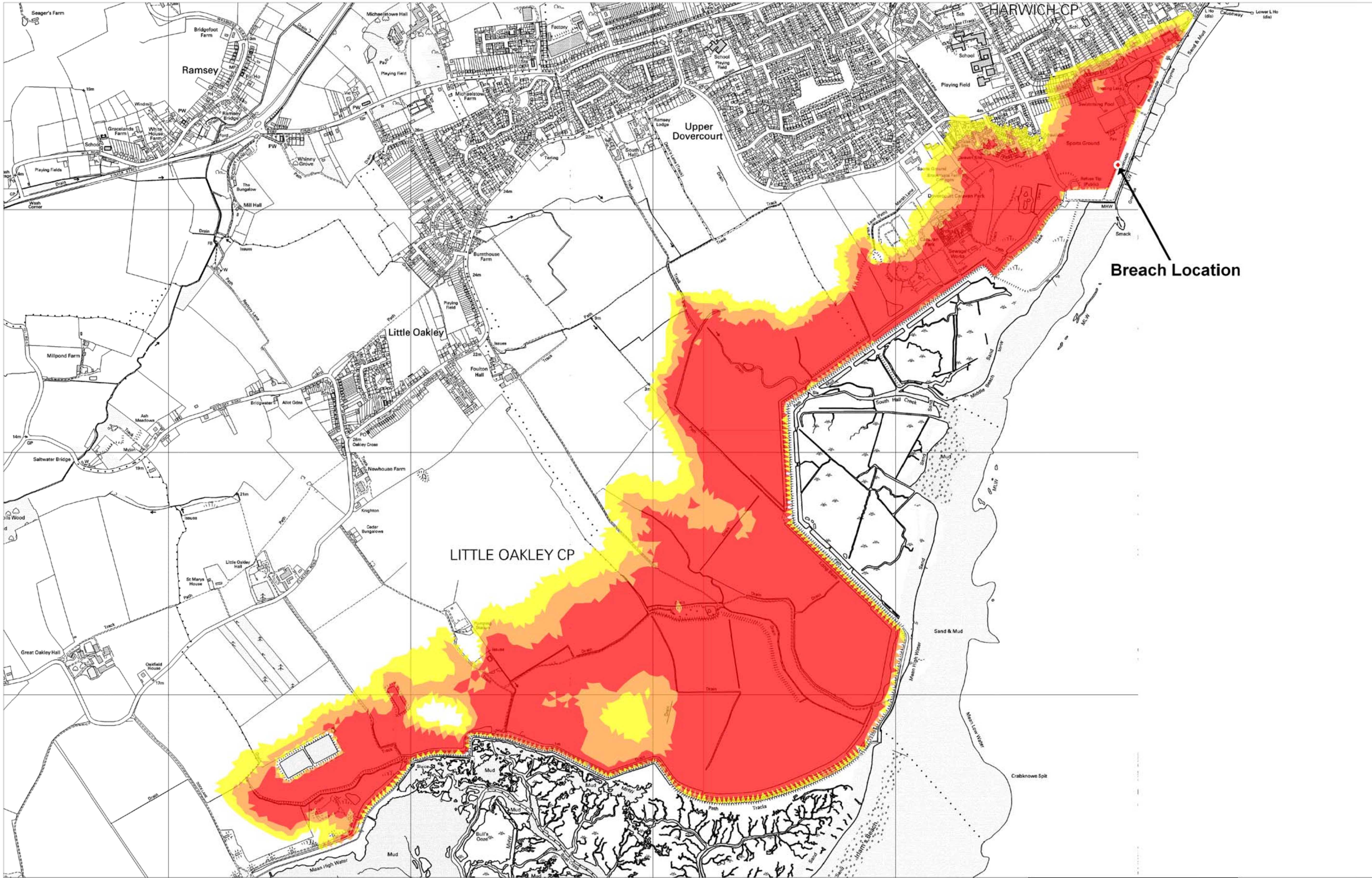
Scott Wilson
www.scottwilson.com



Project:	Title:	Maximum Flood Depth [m]:	FIGURE D44
Harwich SFRA **Tendring District Council**	**HAR03 - Dovercourt - Full Extent** **1 in 200 Year - 2008** **Flood Depth**	0.05 0.50 1.00 1.50 2.00 3.00	Scale: 1:15000 @ A3 Drw NM Date 10/04/08 Rev 2

Scott Wilson

www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR03 - Dovercourt - Full Extent
1 in 1000 Year - 2008
Flood Hazard

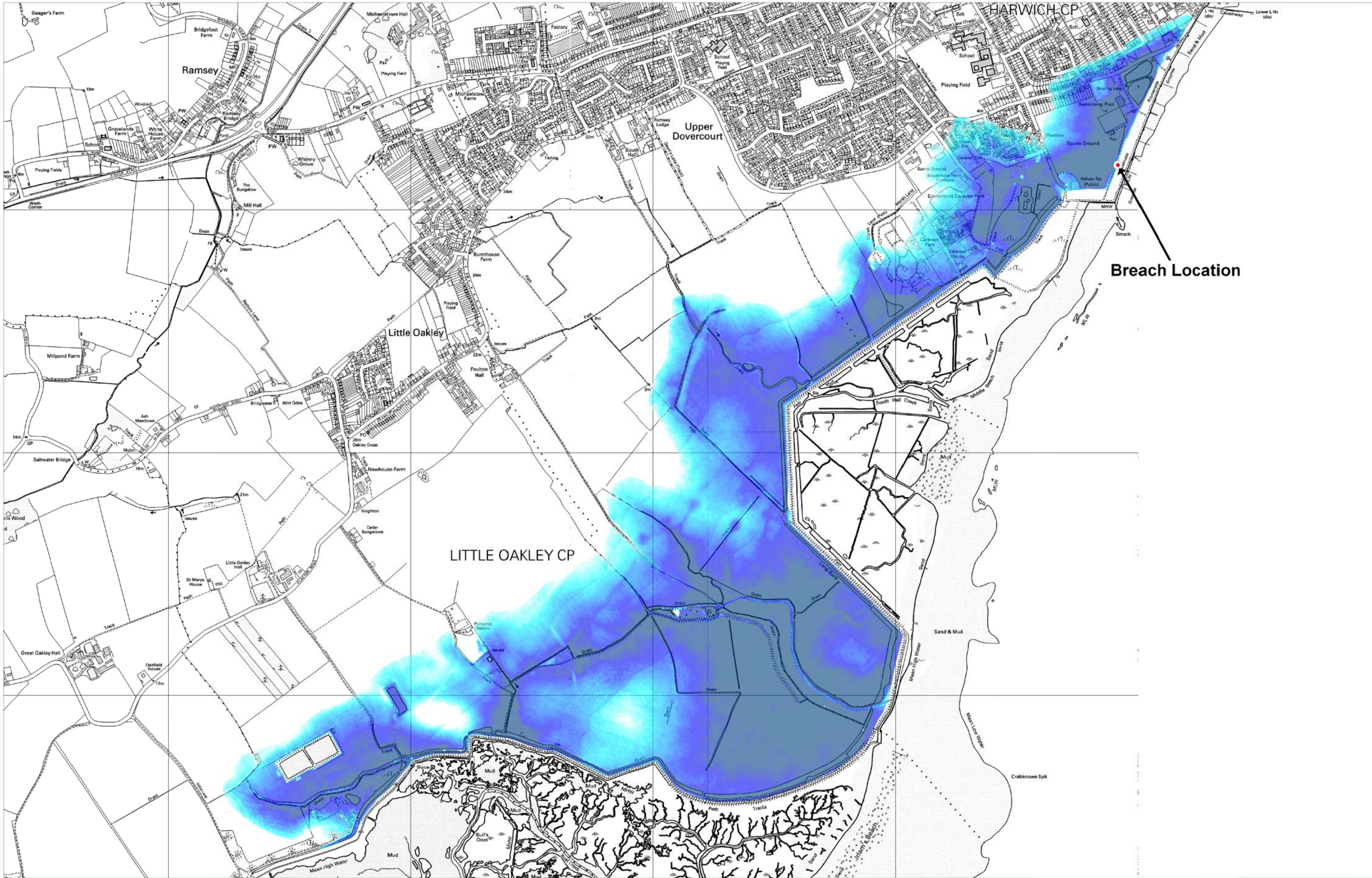
High Hazard
Medium Hazard
Low Hazard

FIGURE D45

Scale: 1:15000 @ A3

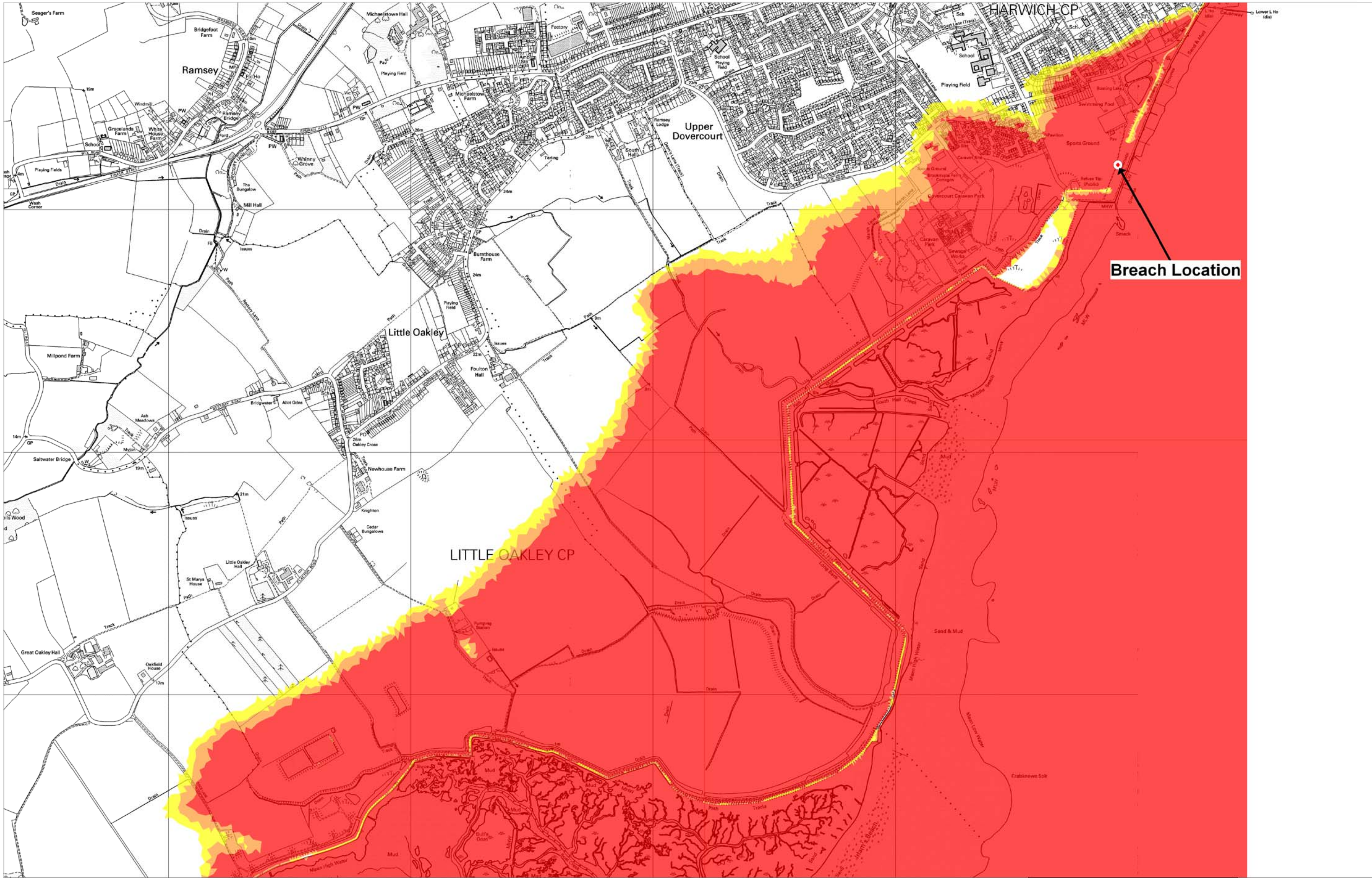
Drw NM Date 10/04/08 Rev 2

www.scottwilson.com



Project:	Title:	Maximum Flood Depth [m]:	FIGURE D46
Harwich SFRA Tendring District Council	**HAR03 - Dovercourt - Full Extent 1 in 1000 Year - 2008 Flood Depth**	0.05 0.50 1.00 1.50 2.00 3.00	Scale: 1:15000 @ A3
			Drw NM Date 10/04/08 Rev 2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR03 - Dovercourt - Full Extent
1 in 200 Year - 2108
Flood Hazard

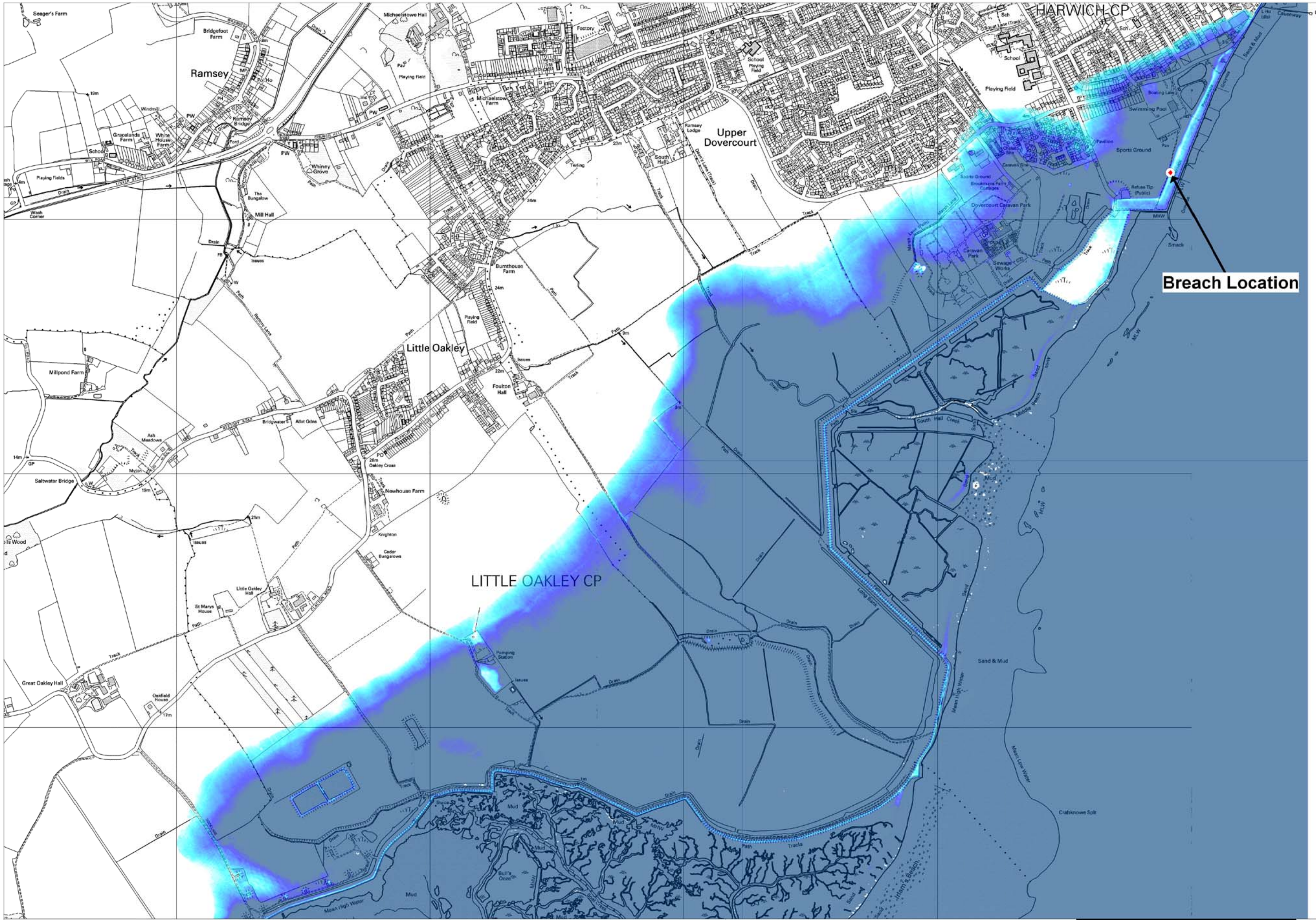
High Hazard
Medium Hazard
Low Hazard

FIGURE D47

Scale: 1:15000 @ A3

Drw NM | Date 10/04/08 | Rev 2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

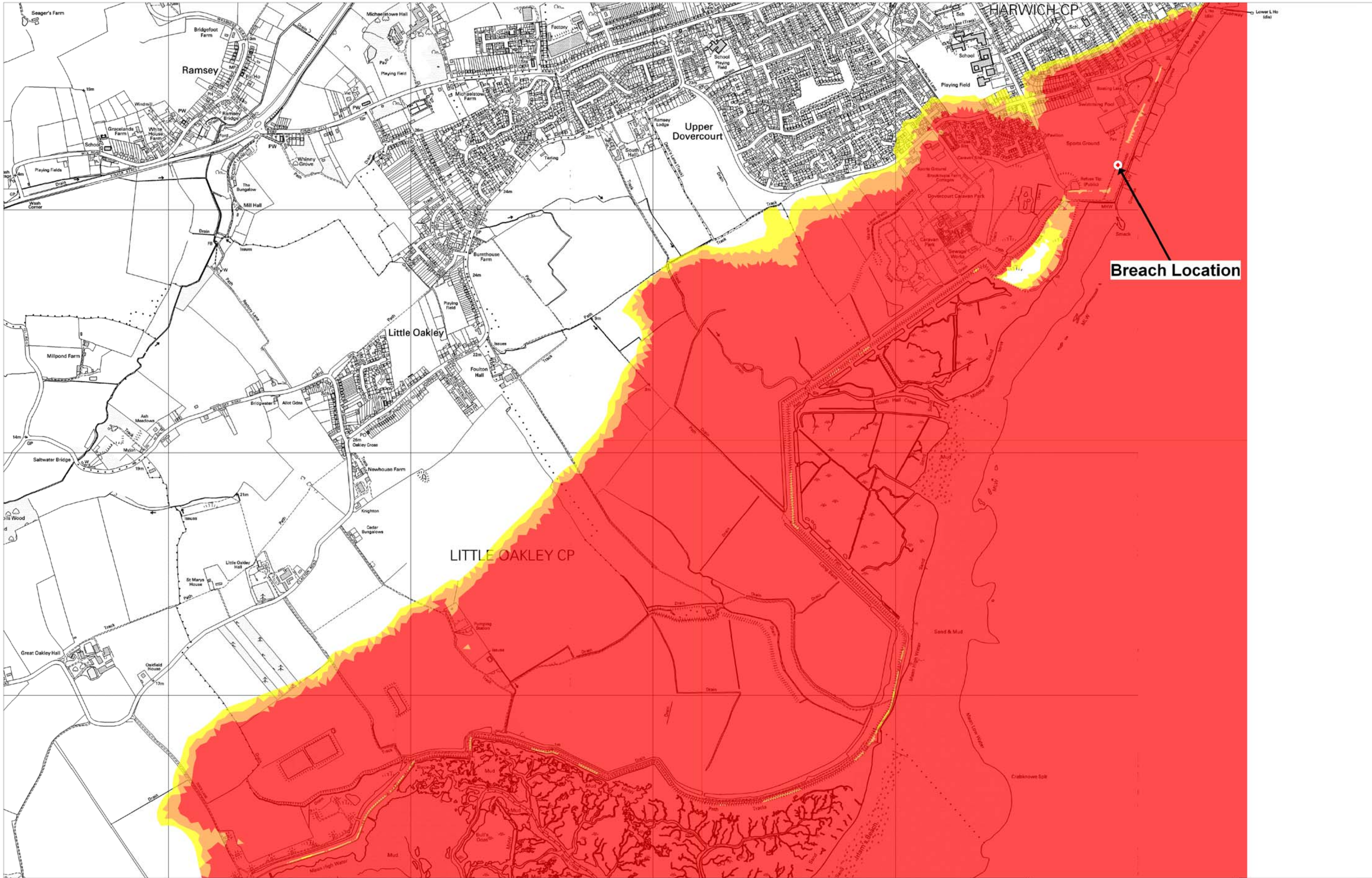
Title:
HAR03 - Dovercourt - Full Extent
1 in 200 Year - 2108
Flood Depth

FIGURE D48

Scale: 1:15000 @ A3

Drw NM Date 10/04/08 Rev 2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR03 - Dovercourt - Full Extent
1 in 1000 Year - 2108
Flood Hazard

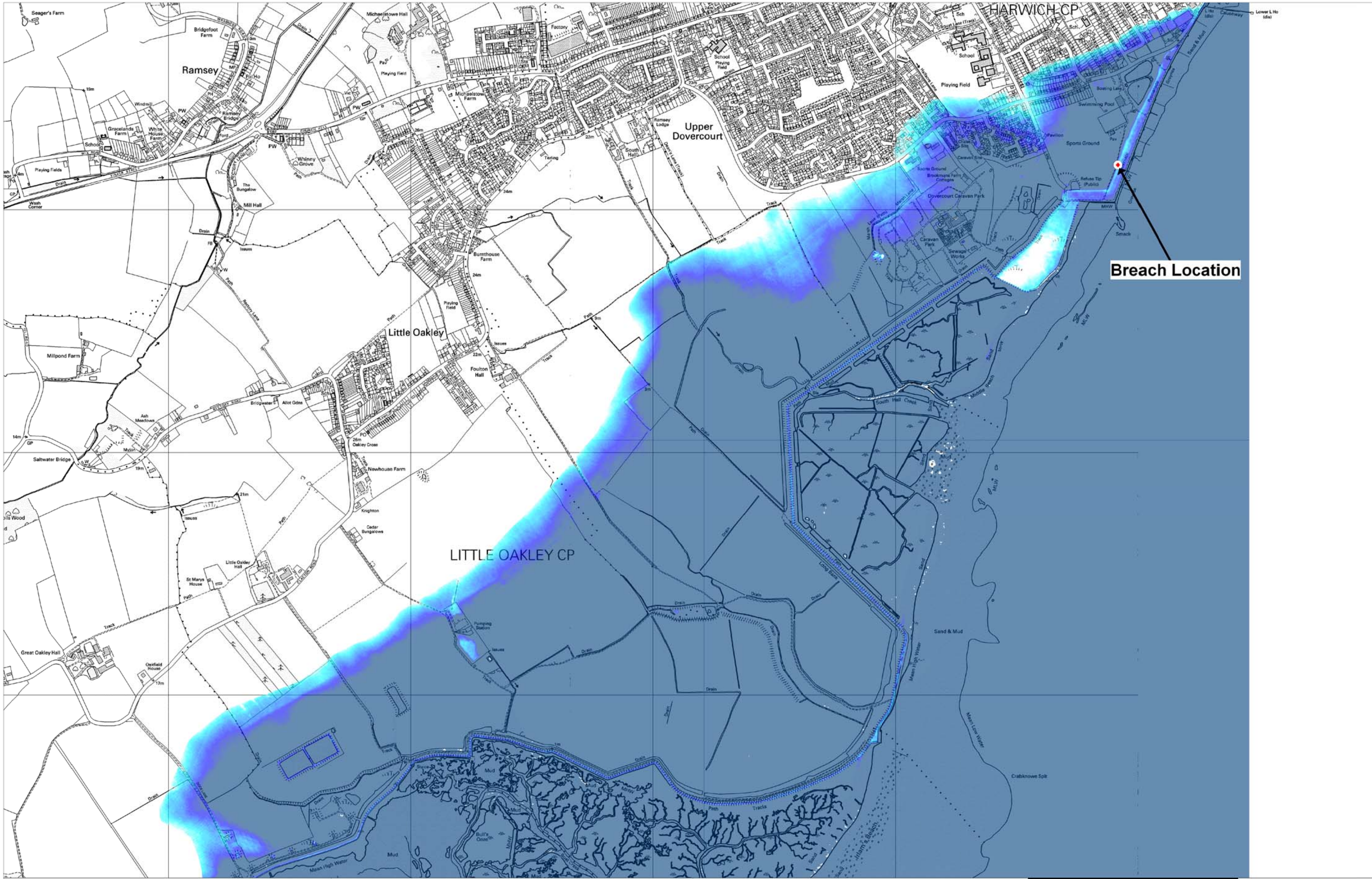
High Hazard
Medium Hazard
Low Hazard

FIGURE D49

Scale: 1:15000 @ A3

Drw NM | Date 10/04/08 | Rev 2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

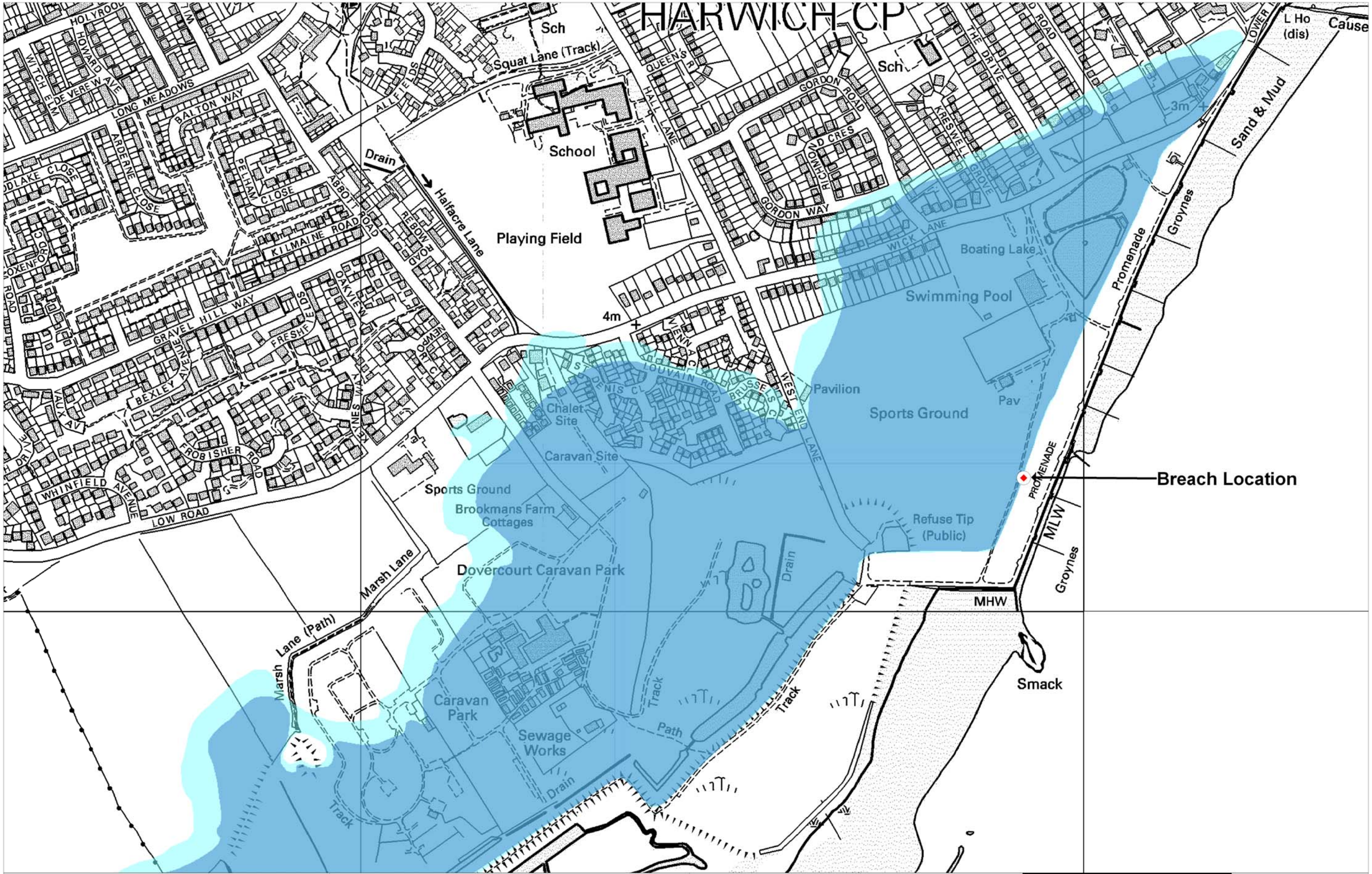
Title:
HAR03 - Dovercourt - Full Extent
1 in 1000 Year - 2108
Flood Depth

FIGURE D50

Scale: 1:15000 @ A3

Drw NM | Date 10/04/08 | Rev 2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR03 - Dovercourt - Full Breach Flood Outlines - 2008

1 in 200 Year
1 in 1000 Year

FIGURE D51

Scale: 1:5000 @ A3

Drw NM Date 10/04/08 Rev 2

Scott Wilson
www.scottwilson.com

Project:
Harwich SFRA
Tendring District Council

Title:
HAR03 - Dovercourt - Full Breach Flood Outlines - 2108

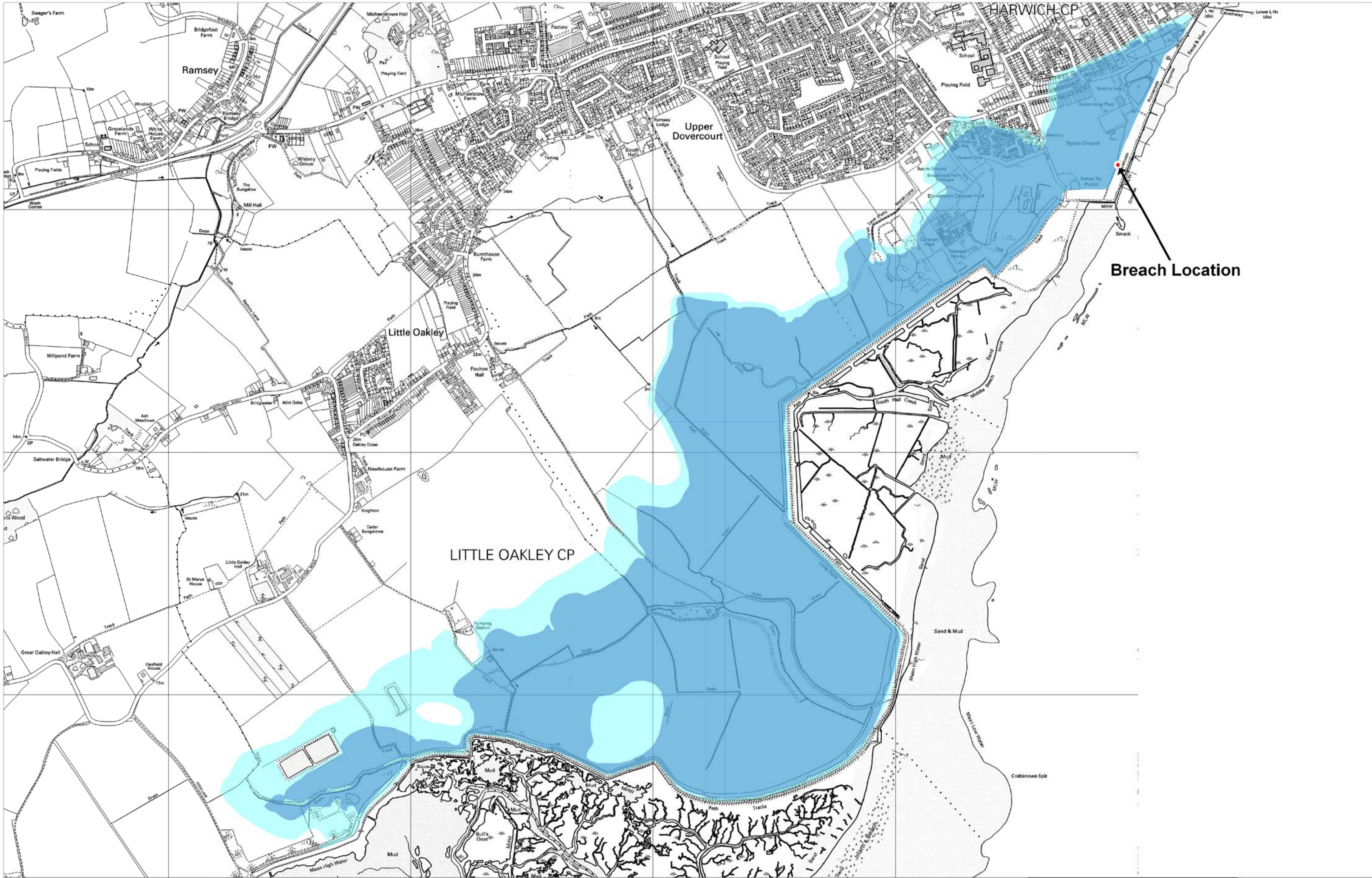
1 in 200 Year
1 in 1000 Year

FIGURE D52

Scale: 1:5000 @ A3

Drw NM Date 10/04/08 Rev 2

Scott Wilson
www.scottwilson.com



Project:
Harwich SFRA
Tendring District Council

Title:
HAR03 - Dovercourt - Full Extent Flood Outlines - 2008

FIGURE D53

Scale: 1:15000 @ A3

Drw NM Date 10/04/08 Rev 2

Scott Wilson
www.scottwilson.com

Project:
Harwich SFRA
Tendring District Council

Title:
HAR03 - Dovercourt - Full Extent
Flood Outlines - 2108

FIGURE D54

Scale: 1:15000 @ A3

Drw NM Date 10/04/08 Rev 2

www.scottwilson.com

Appendix E – Sequential Test Tables

Table E1: Sequential Test Table for Tendring District Council

Site ID	Location Name	Grid Reference	Fluvial Flood Zone				Tidal Flood Zone				Groundwater	Drainage	Surface Water	Development Type and Vulnerability	Exception Test Candidate (Y/N)
			1	2	3a	3b	1	2	3a	3b	(Y/N)	(Y/N)	(Y/N)	Essential Infrastructure / Water Compatible / Highly / More / Less	Compare Flood Zone with Vulnerability Classification
1	Harwich	TQ 123 456	✓	✓	✓		✓	✓	✓		N	N	N	Residential - More Vulnerable	Y

Table E2: Sites that require application of Exception Test in Level 2 SFRA

SITE	FLOOD ZONE	DEVELOPMENT VULNERABILITY	EXCEPTION TEST		
			PART A	PART B	PART C
		Essential Infrastructure / Water Compatible / Highly / More / Less	Wider Sustainability Drivers	Brownfield Land (Y/N)	To be addressed in the Level 2 SFRA
Example	Flood Zone 3a	More Vulnerable	• Close proximity to transport infrastructure • Gentrification • Intensification to reduce pressure for Green belt review	Development of previously developed developable land, Site assists LPA to satisfy government targets for redevelopment of previously developed land	

Table E3: Sequential Test Key - A Guide to using the GIS Layers

Category	GIS Layer	Example Question
Development Vulnerability	Not applicable refer to Table D2 in PPS25	Question 1 – Is the proposed development defined as 'highly vulnerable' according to Table D2 in Planning Policy Statement 25?
		Question 2- Is the proposed development defined as 'more vulnerable' according to Table D2 in Planning Policy Statement 25?
		Question 3 - Is the proposed development defined as 'less vulnerable' according to Table D2 in Planning Policy Statement 25?
		Question 4 - Is the proposed development defined as 'essential infrastructure according to Table D2 in Planning Policy Statement 25?
		Question 5 - Is the proposed development defined as 'water compatible development' according to Table D2 in Planning Policy Statement 25?
Flood Zone Classification	Fluvial/Tidal Flood Zone 2 Fluvial/Tidal Flood Zone 3 Functional Floodplain 3b Historic Flood Database	Question 6 – Through consultation of the Environment Agency's Flood Zone maps, is the development site located in Flood Zone 1?
		Question 7 - Through consultation of the Environment Agency's Flood Zone maps, is the development site located in Flood Zone 2?
		Question 8 - Through consultation of the Environment Agency's Flood Zone maps, is the development site located in Flood Zone 3a?
		Question 9 - Through consultation of the Environment Agency's Flood Zone maps, is the development site located in Flood Zone 3b?
	NA	Question 10 - Can the development be located in Flood Zone 1?
		Question 11 - Can the development be located in Flood Zone 2?
		Question 12 - Can the development be located in Flood Zone 3a?
	Fluvial/ Watercourses	Question 13 - Is the site located within 8m of a watercourse?
Other Flood Sources	NA	Question 14 – Is the site impacted by the effects of climate change
	Sewers/ Historical Records	Question 15 - Is the site in an area potentially at risk from sewer flooding?
	Overland Flow/Areas at risk of overland flow	Question 16 - Is the site in an area potentially at risk from overland flow flooding?
	Groundwater/ Groundwater Sites	Question 17 - Is the site located in an area of rising groundwater levels?
		Question 18 - Does the site have a history of flooding from any other source?
Flood Risk Management	Mitigation/ Flood Warning Areas	Question 19 - Does the site benefit from flood risk management measures?
	NA	Question 20 - Can the development be relocated to an area benefiting from flood risk management measures or of lower flood risk?

Appendix F – Sustainable Drainage Systems Tables

Table F-1: Summary of SuDS Techniques and their Suitability to meet the Three Goals of Sustainability

Management Train	Component	Description	Water Quantity	Water Quality	Amenity Biodiversity
Source, Prevention	Green roofs	Layer of vegetation or gravel on roof areas providing absorption and storage.	●	●	●
Source, Prevention	Rainwater harvesting	Capturing and reusing rainwater for domestic or irrigation uses.	●	○	○
Source, Prevention	Permeable pavements	Infiltration through the surface into underlying layer.	●	●	○
Source	Filter drains	Drain filled with permeable material with a perforated pipe along the base.	●	●	
Source	Infiltration trenches	Similar to filter drains but allows infiltration through sides and base.	●	●	
Source	Soakaways	Underground structure used for store and infiltration.	●	●	
Source	Bio-retention areas	Vegetated areas used for treating runoff prior to discharge into receiving water or infiltration	●	●	●
Source, Site	Swales	Grassed depressions, provides temporary storage, conveyance, treatment and possibly infiltration.	●	●	○
Site	Sand filters	Provides treatment by filtering runoff through a filter media consisting of sand.	●	●	
Site, Regional	Basins	Dry depressions outside of storm periods, provides temporary attenuation, treatment and possibly infiltration.	●	●	○
Site, Regional	Ponds	Designed to accommodate water at all times, provides attenuation, treatment and enhances site amenity value.	●	●	●
Site, Regional	Wetland	Similar to ponds, but are designed to provide continuous flow through vegetation.	●	●	●

Key: ● – highly suitable, ○ - suitable depending on design

Table F-2: Specific Drift Deposits Geology within Harwich

Drift Deposit	Permeability	General Characteristics	Locations	SuDS
Alluvium	Variably Permeable	Generally clay with some gravel sand and silt	Found within Ramsey River valleys and coastal floodplains	Infiltration and combined infiltration/attenuation systems and attenuation systems e.g. permeable surfaces, sub surface infiltration, basins and ponds, swales and filter strips i.e. a combined system
Head (Undifferentiated)	Variably Permeable	Variable generally dominated by sand and gavel	Small pocket located in the vicinity of Bobbit's Hole	Infiltration and combined infiltration/attenuation systems and attenuation systems e.g. permeable surfaces, sub surface infiltration, basins and ponds, swales and filter strips i.e. a combined system
Kesgrave Formation	Permeable	Sand and gravel	Found within a central band across Harwich in elevated areas	**Infiltration** and combined infiltration/attenuation systems and attenuation systems e.g. permeable surfaces, sub surface infiltration, basins and ponds, swales and filter strips i.e. a combined system

Table F-3: Specific Solid Geology within Harwich

Solid Geology	Permeability	General Characteristics	Locations	
London Clay Formation	Impermeable	Clay, Orange brown becoming blue grey with depth, variably silty with thin sand and rare pebble beds. Some siltstone nodules and bands and Selonite Crystals, occasional shell fragments.	The dominant solid lithology across the district.	Attenuation systems e.g. basins and ponds, green roofs, tanks, rainwater harvesting etc
Thanet Sand & The Lambeth Group	Variably Permeable	Lambeth Group was formerly known as the Woolwich and Reading Formation and consists of mottled clays sands silts with some shelly beds. Thanet sands.	Present in the Harwich peninsula	Infiltration and combined infiltration/attenuation systems and attenuation systems e.g. permeable surfaces, sub surface infiltration, basins and ponds, swales and filter strips i.e. a combined system
Red Crag	Permeable	Red, iron-stained sand	Localised pockets in Harwich and Dovercourt	**Infiltration** and combined infiltration/attenuation systems and attenuation systems e.g. permeable surfaces, sub surface infiltration, basins and ponds, swales and filter strips i.e. a combined system

Table F-4: Sustainable Drainage Systems Summary for Allocation Sites

SITE	GEOLOGY	APPROPRIATE SUDS	DRAINAGE ISSUES	SITE RUNOFF LIMITATIONS